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February 15, 2007

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Alberta Energy and Utilities Board  
640 - 5 Avenue SW  
Calgary, Alberta  
T2P 3G4

Attention: Mr. Gary Perkins, Board Counsel

Dear Mr. Perkins:

**Re: EUB Application Nos. 1394112, 1409180 and 1481725  
Cold Lake Oil Sands Area - Clearwater Deposit**

Husky's Reply Submission filed with the Board on January 30, 2007, contained formatting and typographical errors. Those errors have been corrected and Husky's amended Reply Submission is enclosed. A blacklined version, illustrating the formatting and typographical changes made to the original Reply, is also enclosed. We confirm that no substantive changes were made to Husky's original Reply Submission filed on January 30<sup>th</sup>.

We ask that Husky's Reply Submission which was filed with the Board on January 30, 2007, be removed from the record in these proceedings, and be replaced with the enclosed amended Reply Submission of Husky.

Yours truly,

**BORDEN LADNER GERVAIS LLP**

**RANDALL W. BLOCK**

/encl.

cc: Mr. Ernie Smith, Alberta Energy and Utilities Board  
Mr. Don Davies, McCarthy Tetrault  
Mr. Patrick J. McGovern, Thackray Burgess  
Ms. Cheryl Trudell, Imperial Oil Resources  
Ms. Susan Anderson, Husky Oil Operations Ltd.

CALGARY • MONTREAL • OTTAWA • TORONTO • VANCOUVER • WATERLOO REGION

**ALBERTA ENERGY AND UTILITIES BOARD**

**IN THE MATTER OF** the *Alberta Energy and Utilities Board Act*, R.S.A. 2000, c. A-17, the *Energy Resources Conservation Act*, R.S.A. 2000, c. E-10, the *Oil and Gas Conservation Act*, R.S.A. 2000, c. O-6 and regulations thereunder, the *Oil Sands Conservation Act*, R.S.A. 2000, c. O-7, and section 3 of the *Oil Sands Conservation Regulation*, AR/76/88, all as amended;

**IN THE MATTER OF** Alberta Energy and Utilities Board (“EUB” or “Board”) Interim Directive ID99-1, as amended (“ID99-1”);

**IN THE MATTER OF** Application No. 1394112 by Canadian Natural Resources Limited requesting the Board shut in gas production in the Clearwater Formation in the Cold Lake Oil Sands Area;

**IN THE MATTER OF** Application No. 1409180 by EnCana Corporation to the Board for approval to produce gas in the Clearwater Formation in the Fisher field of the Cold Lake Oil Sands Area;

**AND IN THE MATTER OF** Application No. 1481725 by Husky Oil Operations Limited requesting the Board shut in gas production in the Clearwater Formation in the Cold Lake Oil Sands Area; and

**AND IN THE MATTER OF** EUB Notice of Rescheduling of Hearing dated October 13, 2007.

**REPLY SUBMISSION OF  
HUSKY OIL OPERATIONS LIMITED**

**January 30, 2007**

**TABLE OF CONTENTS**

**1. Introduction and Executive Summary..... 2**

**2. EnCana Fails to Properly Model the Geology of the Clearwater Formation and Gas and Water Zones..... 8**

**3. The Caribou Area Contains a Valuable Bitumen Resource in the Clearwater Formation ..... 12**

**4. The Pressure Data Confirm that Pressure Depletion caused by Ongoing Gas Production by EnCana is Communicated Rapidly and Broadly ..... 12**

**5. Impact of Pressure Depletion on Bitumen Recovery..... 14**

**6. Husky’s Response to EnCana’s Additional Simulations (EnCana IR to Husky January 24, 2007)..... 23**

**7. Conclusion ..... 25**

**References..... 27**

**List of Figures..... 28**

## **1. Introduction and Executive Summary**

It is common ground that Husky Oil Operations Limited (“Husky”) holds 56 sections of bitumen leases (the “Caribou Area”) contiguous to EnCana Corporation’s (“EnCana”) leases with gas production from the Clearwater Formation. Bitumen and gas in the Caribou Area are both reservoiried in the Clearwater and extensive gas production has occurred and is continuing. Furthermore, EnCana has applied to the Board for authorization to produce additional gas from the Clearwater. Husky has applied to the Board for an order requiring EnCana to shut in certain gas wells on the basis that EnCana’s continued production from these wells will adversely impact Husky’s recovery of bitumen resources that it intends to produce using an experimental Hybrid Steam Assisted Gravity Drainage (“HSAGD”) process.

In its filed submissions in this proceeding, EnCana has claimed that its continued and proposed production of gas will not adversely affect the economic development of Husky’s bitumen resources. EnCana attempts to support this claim by postulating that there is a continuous and correlatable barrier between the gas and bitumen zones for which there is no evidence. EnCana has failed to provide supporting geological evidence for its assertion of a shale barrier. EnCana has neglected to model the HSAGD process that Husky is proposing to use. Further, EnCana’s simulation is inappropriate for thermal processes such as HSAGD, and the underlying history match is unacceptable.

Husky has demonstrated that production of the adjacent gas caps will be detrimental to the recovery of Husky’s bitumen resource. Husky’s detailed geological study of the area, contrary to EnCana’s unsupported claim, shows there are no laterally continuous and correlatable barriers between the gas and bitumen. Husky has provided a realistic simulation model that matches the history. Furthermore, Husky has modelled the HSAGD process that it intends to use in the Caribou Area.

The pressures in the gas caps have been depleted significantly from the initial pressures and continue to be depleted. Extensive piezometer data located in the bitumen zone in Husky’s Caribou Area show pressure drops in excess of 50% in places and the pressure depletion is ongoing. The pressure depletion in the gas cap is communicated vertically and laterally into the bitumen zone through the top water where present or through the initially mobile water phase in the bitumen zone where top water is absent.

Husky has a significant resource over the entire lease: 1.1 billions barrels of this resource reside in Husky’s 15 section lease (Lease Number 7188110343) area. Continued depletion of pressure resulting from EnCana’s continued production from its adjacent wells will significantly harm the ultimate bitumen recovery by either HSAGD or Cyclic Steam Simulation (“CSS”) processes. These observations are fully consistent with Husky’s simulations of the HSAGD and CSS processes and also established experience and learnings of the CSS process. Significant amounts of solution gas are evolving from the bitumen due to pressure depletion. This gas is migrating to the gas pools. In addition to confirming that no pressure barriers exist, this loss of solution gas will have a significant detrimental effect on bitumen recovery.

Shutting in the gas production is required to stop the continued pressure depletion and the resulting loss of solution gas. Specifically, in this Reply Submission, Husky addresses the following EnCana claims:

**1.1 EnCana's claim that pressure depletion in the gas pools does not adversely affect the bitumen recovery is unsupported**

Husky has presented pressure data confirming pressure depletion. Husky's piezometer readings are consistent and provide ample continuous pressure data over time. The evidence is clear and overwhelming that pressure depletion resulting from EnCana's gas production is communicated to Husky's leases. Husky has been able to demonstrate, through detailed geological studies and rigorous reservoir simulation, that there is a significant risk to the bitumen resource as a result of continued gas cap production.

**1.2 EnCana's conclusion that continued gas production will result in "no harm to bitumen" is based on modelling that is fundamentally flawed for the following key reasons:**

**(a) The geological foundation for EnCana's numerical reservoir model is incorrect: EnCana has failed to incorporate a realistic geological model of the Caribou Area into its numerical reservoir simulation model**

EnCana provides no discussion of the depositional setting. The absence of a basic understanding of the distribution of facies severely limits the ability to predict the distribution of reservoir properties.

In its reservoir model, EnCana introduced a phantom vertical transmissibility barrier between the gas and water, extending over almost the entire gas cap area. There is absolutely no geological justification for such a barrier.

EnCana has not presented a comprehensive geological distribution of shales. Husky has provided detailed distributions of shales. EnCana has failed to differentiate shales between the clay-rich barriers and baffles.

EnCana provides no discussion of the hydrocarbon emplacement, despite the fact that it uses hydrocarbon emplacement as a justification for the phantom transmissibility barrier, previously discussed.

Rather than acknowledging that significant volumes of gas are exsolving from the bitumen into the gas cap, thus providing pressure support and replenishing gas volumes, EnCana arbitrarily increased the size of the gas caps.

**(b) EnCana has failed to simulate the HSAGD recovery process that Husky intends to employ at Caribou**

EnCana made no attempt to model the HSAGD process that Husky intends to use.

HSAGD is a hybrid of SAGD and Horizontal Well CSS (“HWCSS”). HSAGD must be modelled and analyzed as a separate and distinct hybrid process. Through its simulation of the HSAGD process, Husky has established that there is significant harm to the recovery of bitumen caused by loss of solution gas in the bitumen zone resulting from the lowering the reservoir pressure due to gas pool depletion.

**(c) EnCana fails to assess the effects of producing gas to abandonment pressures (~200 kPa) prior to thermal recovery**

Gas production has been significant and is ongoing. Current gas pressures are approximately 1000 kPa, in stark contrast to the initial pressures of ~2800 kPa. EnCana’s simulations use current gas cap pressures, not the long-term abandonment pressures. The result is to significantly understate the impact of the continued production of the EnCana gas on ultimate bitumen recovery.

EnCana fails to account for the fact that gas depletion to abandonment pressure will occur prior to any thermal recovery by Husky.

Gas can be produced after the bitumen recovery with no adverse effects. In contrast, bitumen cannot be produced after gas depletion without an adverse effect because of gas exsolution concomitant with production of the gas caps. This has significant implications for resource conservation as the industry considers the development of bitumen resources, whose recovery economics are dependent upon the use of newer reservoir pressure-sensitive technologies.

**(d) EnCana uses an unrealistically low net to gross ratio of 10% in simulation layers under the gas cap**

By using a low net to gross ratio of 10% under the gas cap, EnCana has not only reduced the volume of bitumen in this layer, but has also reduced the horizontal cross-sectional area open to flow, and thus the horizontal flow conductivity by 90%. There is no geological reason for this. The result is to artificially and improperly to reduce the effect of gas pressure decline on pressures within the bitumen, thereby reducing the effect that continued gas production has on the bitumen reserves.

**(e) EnCana uses grossly oversized grid blocks for thermal recovery processes**

In attempting to model both the gas production and the bitumen production in one global reservoir model, EnCana utilizes an extremely coarse grid for the reservoir volume affected by the thermal recovery processes. These grid block dimensions are far too large to allow the numerical model to capture the steam chamber growth and gravity drainage effects.

**(f) EnCana uses inappropriate well spacing for its reservoir simulation**

EnCana’s horizontal spacing of its horizontal wells is far too large. Placing the wells 280 m apart prevents or severely inhibits the steam chambers from interacting and eventually coalescing, as would occur with SAGD, CSS, and HSAGD.

**(g) EnCana's "horizontal" wells are slanted from heel to toe**

EnCana's well trajectories are not truly horizontal. This has the effect of drowning the production wells, and possibly the toes of the injection wells, thereby impairing the production capacity of the process.

**(h) EnCana's wells have erratic partial completions**

EnCana's wells are not completed in all grid blocks penetrated.<sup>1</sup> As such, the wells cannot accept flow from all grid blocks and therefore do not realistically model the processes.

**(i) EnCana's permeability data is not representative of the Clearwater Formation**

EnCana's permeability plots do not include correct permeability data and underestimate the average maximum permeability. As such, the EnCana's simulations are incorrect.

**(j) EnCana does not include reservoir heterogeneity**

EnCana does not consider reservoir heterogeneity, other than to construct a deterministic model of the reservoir, i.e. "layer cake". The heterogeneity of the reservoir is a key factor affecting process performance and dynamics that must be included in models.

**(k) EnCana uses an unrealistically low live oil viscosity of 17,000 cp**

EnCana's live oil viscosity of 17,000 cp is far too low and not realistic for the Clearwater reservoir as supported by published data.

**(l) EnCana's reservoir simulation model utilizes incorrect relative permeabilities**

EnCana's oil relative permeability curve is concave downward and is not representative of the Caribou Area, as is supported by Husky's special core analysis.

**(m) EnCana did not use temperature-dependent relative permeability curves**

EnCana failed to incorporate any temperature dependency of their relative permeability curves in their thermal simulations. EnCana states that temperature dependency would make no difference to their conclusions. This statement is not substantiated, and in Husky's opinion, is incorrect.

**(n) EnCana failed to use dilation during CSS**

The CSS process in bituminous oil sands requires fracture injection pressures and dilation to fully model the relevant physics. EnCana failed to inject at a sufficiently high steam pressure to invoke dilation. Furthermore, without dilation there is no compaction drive during the production phase of each CSS cycle.

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<sup>1</sup> KADE Technologies Inc., *Gas-Over-Bitumen Reservoir Simulation Study*, January 8, 2007, submitted by EnCana ("EnCana January 8<sup>th</sup> KADE Simulation").

**(o) EnCana's history match of pressures and production is flawed**

The description of EnCana's history match procedure reveals that EnCana made numerous attempts to arbitrarily adjust the input data to obtain the history match of the pressures and production data. Despite these attempts, the history match plots given by EnCana demonstrate clearly that the history match of pressures and production is still of very poor quality:

- most piezometer pressures are not matched,
- pressure trends were not matched, and
- total water production is not matched.

The failure of the history match raises serious questions in respect of the totality of EnCana's reservoir simulation model and consequently the results that are being used to justify EnCana's overall conclusion that continued gas production will have no effect on bitumen recovery.

EnCana acknowledges that pressure matches in the north were lower and to the south were higher and then asserts that "on average" the pressures were matched. Typically in history matching, the absolute deviations between simulation and field data are minimized and not averaged. Therefore, any prediction based on such a model is questionable and unreliable. Again, the failure of the history match makes the reservoir simulation model, its results, and any conclusions drawn from its results meaningless.

**(p) EnCana's CSS results contradict the accepted principle that solution gas is an important drive mechanism in the CSS process**

EnCana's model acknowledges significant solution gas evolution, but fails to acknowledge any effect on the CSS recovery processes. Solution gas is a known drive mechanism of heavy oil recovery using CSS. One cannot inhibit or eliminate this drive mechanism without an adverse affect on bitumen recovery.

**(q) Husky's response to EnCana's additional simulations (January 24, 2007 response to EnCana information requests)**

In duplicating EnCana's runs, Husky determined that the runs with the original operating strategy and new liquid constraint led to high gas production rates and water accumulation in the steam chambers which impaired oil production. Obviously, operating with a strategy where gas and potentially steam production is high and forming a zone largely saturated with water due to excessive steam injection is inefficient. Therefore, the operating conditions of the original model were not optimized and EnCana's results do not reflect the true deliverability of the reservoir.

Husky's current 2D simulations with a liquid constraint and a modified operating strategy using the same input parameters as before have more realistic production rates. Note that further optimization of the operating strategy is possible. With limited optimization, these last simulations confirm the harmful effects of gas cap depletion on bitumen recovery as shown by the original runs.

For all of the above reasons, Husky continues to submit that existing gas production must be halted and no new gas production should be permitted in the Caribou Area. Husky's detailed submissions are set forth in the following sections.

## **2. EnCana Fails to Properly Model the Geology of the Clearwater Formation and Gas and Water Zones**

EnCana fails to properly model the geology of the Clearwater Formation, and the associated gas and water zones.

### **2.1 EnCana does not provide a discussion of the depositional setting**

EnCana has not provided a geological interpretation of the depositional setting of the Clearwater Formation in the Caribou Area. Failure to understand the lateral and vertical distribution of the facies essentially undermines any understanding of vertical or horizontal permeability barriers. An understanding of the depositional setting is the necessary first step to assessing the impacts of continued, and indeed increased, gas production on bitumen recovery.

### **2.2 EnCana models phantom permeability barriers**

EnCana's application of phantom permeability barriers in simulation work, accomplished with a transmissibility reduction, is indefensible. EnCana's simulation work encompassing an impermeable layer under the water zone<sup>2</sup> is neither supported by core nor wireline log data, and is contrary to a reasonable interpretation of the geology of the Caribou Area. The assertion, as reflected in EnCana's simulation models, that some form of barrier exists is contrary to any realistic and reliable geologic model.

EnCana introduces a vertical permeability barrier under the water zones by arguing that:

- (i) the density difference between bitumen and water would have caused gravity segregation, had there been no barrier,<sup>3</sup> and
- (ii) bitumen failed to displace water thus there is a barrier.

Husky dealt with this matter in its response to the Board's September 5, 2006 information request to Husky, Question 2:

- (i) invading oil displaced the original mobile formation water,
- (ii) oil degraded to bitumen, releasing methane as a byproduct,
- (iii) this methane accumulated as a gas cap,
- (iv) subsequent removal of overburden resulted in leakage of gas,
- (v) gas migration was followed by an influx of water to replace the voidage, and
- (vi) water preferentially filled the base of the gas cap because bitumen was too viscous and too similar in density to be displaced.

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<sup>2</sup> EnCana's response to Husky information requests of January 12, 2007, question 6.

<sup>3</sup> EnCana's response to Husky information requests of January 12, 2007.

EnCana has provided no reliable justification for its postulated permeability barrier. The existence of water over bitumen is not indicative of a barrier because the density difference between the two liquids is very small; combined with the high oil viscosity, the differential densities would result in too small of a driving force to overcome capillary pressures. Lastly, no impermeable physical barrier has been observed in the core data.<sup>4</sup>

Husky has performed a comprehensive review of available geologic data for the Caribou Area. There is no geologic evidence of a laterally continuous and competent physical barrier to vertical flow under the water zone and therefore no barrier for pressure transmission from the gas cap to the underlying bitumen. There are no laterally continuous observable barriers, and none can be inferred. The presence of gas over water over bitumen is well understood as a result of the hydrocarbon emplacement model in Northern Alberta.

The suggestion that there is a barrier because of the existence of the water zone is expressly contrary to the many findings of the Board that the pressure communication will be transmitted through the gas and the water to the underlying bitumen, in the absence of laterally continuous and competent barriers.

### **2.3 Shales are not laterally continuous in the Caribou Area**

EnCana failed to present a comprehensive geological description of the depositional setting, and therefore presents no evidence as to the types and distribution of shales across the area of concern.

Husky provided an interpretation of the depositional setting for the Clearwater Formation in the Caribou Area.<sup>5</sup> Husky's core and log review has resulted in a detailed interpretation that consistently explains Husky's piezometer observations by establishing the lateral and vertical pathways for pressure communication.

The Husky regional facies distribution (**Figure 2.1**) reflects an interpretation of the reservoir as an incised valley system opening towards the north-northwest. The valley system is two-sided such that it has incised into a regional highstand, deltaic, muddy shoreface that is preserved on both the east and west side of the incised valley complex (**Figure 2.2**). Husky refers to the bordering muddy shoreface units as the "Western Regional Shale" and the "Eastern Regional Shale." These two shale units in core and well logs appear to be regionally correlative, clay-rich units that probably constitute permeability barriers (**Figure 2.3**), but the shale on the east side is of limited extent. These possible impermeable barriers in the east are found outside Husky's lease.

Eroded into the regional shales is the incised valley fill, which constitutes the main target reservoir in the Husky Caribou Area. The incised valley fill can be broadly differentiated into a central sand-rich axis, flanked on the east and west by marginal valley deposits. The central sand-rich axis appears to merge into the marginal valley deposits without sharp lateral facies boundaries. Both facies are characterised by interbedded mud stringers, but the marginal valley

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<sup>4</sup> Husky's response to EnCana information requests of October 17, 2006.

<sup>5</sup> Husky's response to Board information requests of November 10, 2006, question 1a.

deposits on the east flank of the complex are much more mud-rich with a strong brackish marine signature reflected in the trace fossil assemblages.

The mud-rich marginal valley is distinctly different from the adjacent Eastern Regional Shale, and does not constitute laterally continuous shale barriers. Rather, the marginal valley facies consists of interbedded, discontinuous mud stringers and mud clasts (**Figure 2.4**), similar to that seen in the sandy axis facies, but in greater concentration. It is also observed that all of the interbedded sands are bitumen-saturated, indicating that they are interconnected and that they did not constitute a barrier during hydrocarbon migration and emplacement. This is indicative of potential pressure connectivity across these facies.

There are places where there is gas over water over bitumen with no mud in between, and there are places where there is gas over water over interbedded sandy mud layers. Therefore, EnCana's geological model as reflected in its simulation work, where there is an impermeable shale layer within the water zone, is not supported by, and is in fact contrary to, the core data.

In summary, Husky's bitumen leases lie directly in an incised valley, where older sediments have been cut and re-worked, resulting in no laterally continuous and competent barriers. There are two adjacent mud-rich facies on the eastern side of the system. The muddy interbedded valley margin shales combined with the immediately adjacent eastern regional shale constitute the two components of what Husky informally refers to as the "Eastern Shale Complex" and CNRL refers to as the "C&D muds".

Husky, in distinction to EnCana, has provided a reasonable and comprehensive interpretation of the shales, their properties, and their distribution. Any realistic simulation work must reflect the absence of any continuous and competent barriers between the overlying gas and the bitumen.

#### **2.4 EnCana has failed to differentiate shales**

EnCana has failed to differentiate the two discrete shale units that make up the Eastern Shale Complex,<sup>6</sup> and appears to have assigned permeability properties seen in the eastern regional shale to the entire complex without recognizing that the valley margin shale (western subunit, **Figure 2.1**) has a measurable and significant permeability (30 to 500 mD).<sup>7</sup>

Husky differentiates the shales in the East Regional Complex: an eastern subunit which is a solid mud (barrier shale) and a western subunit, which is interbedded sandy, mud with finite permeability (baffle shale) and would not act as barrier.

On the Husky Leases shales are not continuous and, in addition Husky simulation work honours lab-derived data in relation to the shales themselves. The valley margin shale component will act as a baffle shale and could not be a regional barrier. EnCana's submission demonstrates a lack of the geological input that is absolutely necessary for proper reservoir modeling and simulation work.

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<sup>6</sup> EnCana's response to Husky information requests of January 12, 2007; Drawing 5, Isopach of C to D Mudstone.

<sup>7</sup> Husky's response to Board information requests of January 12, 2007, question 2a.

## **2.5 EnCana does not provide an explanation for hydrocarbon emplacement**

EnCana failed to provide an explanation for emplacement of the hydrocarbons in the Clearwater Formation reservoir. However, EnCana does allude to the bitumen displacing the water.<sup>8</sup> Husky disputes that this is possible. An understanding of hydrocarbon emplacement does not have to invoke the presence of significant lateral and vertical permeability barriers, again, refuting the application of such barriers in their simulation.

Husky supports the conventional hydrocarbon emplacement model (Aitken et al., 2004<sup>9</sup>; Larter et al., 2003<sup>10</sup>), which readily explains the presence of gas over water over bitumen. In such a model, no barriers are needed between the gas, water, and bitumen. This model is also consistent with the existence of multiple pressure communication pathways between the bitumen and the gas cap.

## **2.6 EnCana's speculation that water over bitumen suggests barriers to flow is flawed**

EnCana's contention that the presence of water over bitumen suggests barriers to flow is unsubstantiated.<sup>11</sup> Husky outlined the commonly accepted theory for development of the gas over water over bitumen situation in its response to the Board's September 19, 2006 information request, question 2. Mobile hydrocarbons migrate through porous and permeable sediments into a trap. Biodegradation of the oil phase occurs, creating bitumen and gas as by-products. Subsequent natural migration of the gas allows water to displace some of the gas resulting in gas over water over bitumen. All facets of this hydrocarbon emplacement require a porous and permeable reservoir, with no lateral or vertical permeability barriers. This, once again, is contrary to the application of artificial permeability barriers to facilitate history matching, as done by EnCana in their simulation work.

## **2.7 EnCana's calculated OGIP is unjustified**

Husky notes that EnCana's volumetrically calculated OGIP's are much smaller than its "history matched" final simulated volumes (D Pool increased by 30% and B Pool by 18%).<sup>12</sup> No geological evidence has been presented for these larger volumes.

Husky's detailed geological study and previous submissions<sup>13</sup> disagree with EnCana's "history matched" volumes. Furthermore, the additional gas that had to be introduced to EnCana's numerical simulation model is most likely the solution gas that evolves from the bitumen as a result of pressure depletion and migrates into the gas pools. Clearly there are no barriers to solution gas migration into the gas pools. These pools must be shut in to prevent pressure depletion and resulting loss of solution gas in the bitumen zone.

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<sup>8</sup> EnCana Response to Husky information requests of January 12, 2007.

<sup>9</sup> Aitken, C.M., Jones, D.M., Larter, S.R., "Anaerobic Hydrocarbon Biodegradation in Deep Subsurface Oil Reservoirs", (2004) *Nature* 431, 291-294.

<sup>10</sup> Larter, S. R., Wilhelms A., Head I., Koopmans M., Aplin A., Di Primio R., Zwach C., Erdmann M., Telnaes, N., "The Controls on the Composition, of Biodegraded Oils in the Deep Subsurface: (Part 1) Biodegradation Rates in Petroleum Reservoirs", (2003), *Org. Geochem.* 34:601-613.

<sup>11</sup> EnCana's responses to Husky information requests of January 12, 2007, question 7a.

<sup>12</sup> EnCana January 8<sup>th</sup> KADE Simulation.

<sup>13</sup> P/Z plots as shown in Husky's response to Board information requests of November 10, 2006, Appendix A.

### **3. The Caribou Area Contains a Valuable Bitumen Resource in the Clearwater Formation**

Notwithstanding EnCana's unsupported assertions to the contrary, the fact is that the Caribou Area contains a valuable bitumen resource in the Clearwater Formation. Commercially viable thermal recovery operations exist in CNRL's Primrose field, in an extension to Husky's Clearwater reservoir, immediately to the south of Husky's lease.

Husky currently estimates that there are 1.1 billion barrels of bitumen in place in Husky's 15 section lease in the Clearwater Formation, all adversely affected by EnCana's gas production from the Clearwater Formation. The estimate of volume of bitumen in place may well increase with further delineation drilling.

Husky estimates ultimate bitumen recovery factors between 27% and 50% (300 to 550 million barrels). The remaining gas in the associated gas pools amounts to approximately 5 million boe. Consequently, the value of the bitumen resource vastly exceeds that of the remaining gas and the bitumen resource must be conserved.

EnCana provided an estimate of 2.7 billion barrels OBIP<sup>14</sup> for a 99-section area that encompasses Husky's 15 section lease. This significantly underestimates the total resource in jeopardy as a result of EnCana's exclusive use of core data, but nonetheless, EnCana's estimate indicates a significant resource worthy of protection.

Furthermore, the entire extent of the bitumen resource is yet to be fully evaluated. Limited drilling has occurred in the northern and western regions of Husky's two leases, and additional resource-bearing incised valleys could be identified by further delineation work.

Additional geological work and delineation drilling is underway. Husky is currently in a 44-well delineation drilling program. An additional 40 cores through the Clearwater bitumen reservoir will be cut, providing further valuable information to evaluate the extent and distribution of the resource. Consequently, the harmful effects of gas cap depletion to the bitumen resource are potentially applicable to much larger bitumen volumes than those that have already been identified.

The geologic evidence is clear that there is a valuable bitumen resource in the Clearwater Formation in the Caribou Area. Exploitation and recovery of this major bitumen resource is at significant risk due to continued gas production and concurrent pressure depletion of the bitumen.

### **4. The Pressure Data Confirm that Pressure Depletion caused by Ongoing Gas Production by EnCana is Communicated Rapidly and Broadly**

Husky has 31 piezometers installed in seven wells in the Caribou Area. 25 of 31 (81%) were recording monotonically declining pressures of up to 56% on November 14, 2006. Even if the two highest decline rates are excluded, the mean decline on November 14, 2006 from an assumed "initial" pressure of 2808 kPa was 5.8%. The declines have increased by 12.5% during

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<sup>14</sup> EnCana January 8<sup>th</sup> KADE Simulation.

this 2.5 month period alone. That is, the rates of decline are increasing by 5% per month.<sup>15</sup> The remainder of the Husky piezometer data (six piezometers) are exhibiting anomalous behaviour. They are being more strongly affected by operations not related to the gas cap depletion, i.e. possibly due to nearby water disposal or response to gas cap operations.

Husky's piezometer data proves that rapid pressure decline is occurring throughout the bitumen zone due to adjacent gas production. It appears that the overall pressure decline levels and the pressure trends in the bitumen zone are not being disputed by EnCana as its claims to match the Husky piezometer data to precondition its simulation runs for the gas cap depletion sensitivity study.<sup>16</sup>

The pressure communication from the adjacent gas cap to the bitumen zone is unimpeded because there are no continuous vertical or horizontal permeability barriers as explained in the geology section. Husky's geological mapping indicates that the top water zone is areally more extensive than both the overlying gas zone in the east and south and the underlying shale zone in the east.<sup>17</sup> The pressure is communicated from the adjacent gas production to the bitumen through two means:

- (i) pressure transients travel from the gas zone to the top water zone and from there to the bitumen zone laterally and vertically, and
- (ii) where there is no top water zone, pressure is transmitted directly from the gas cap to the bitumen vertically and laterally.

Husky's reservoir simulation results demonstrate that the depletion of the offset gas cap reduces the pressure in the reservoir throughout the width of the simulation model (several hundred meters). **Figures 4.1 and 4.2** show that the pressure falls throughout the reservoir. In support of these simulation results, field data show that this distance is greater than 3 km. This is due to water mobility in the reservoir at original conditions, as has been established from relative permeability measurements.<sup>18</sup> Mobility of water at initial conditions must be included in reservoir simulation models of the Caribou Area.

As the pressure falls in the gas pool, the gas-water contact rises and adds to the volume and areal extent of the top water. **Figure 4.2** shows that after pressure depletion starts, the water saturation in the gas pool rises. Physically this is because of mobile water in the reservoir.

The piezometer pressure decline rate data is reasonably matched in Husky's reservoir simulation models.<sup>19</sup> For evolution of solution gas into bubbles in the pore space, the pressure decline rate is a key factor that controls the rate of solution gas bubble formation, which ultimately impacts the critical gas saturation at which the gas phase becomes mobile. The absolute value of the pressure controls the amount of solution gas dissolved in the oil phase. No unusual flow barriers or adjustments to the net-to-gross ratio or modifications to the oil phase viscosity were done to achieve the history match. Rather, given that the model was a generic unit model of the field, the

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<sup>15</sup> Husky's response to Board information requests of November 10, 2006.

<sup>16</sup> EnCana January 8<sup>th</sup>, KADE Simulation.

<sup>17</sup> Husky's response to Board information requests of October 13, 2006.

<sup>18</sup> Husky's response to EnCana information requests of November 10, 2006.

<sup>19</sup> Husky's response to EnCana information requests of January 12, 2007.

initial gas in place per unit model size was altered (i.e. total gas in the model was altered) until the pressure decline rate was matched. This is a simple and non-radical method to match the gas pool performance that does not alter the underlying geological model obtained from core and log data. It must be borne in mind that the metric used to obtain the gas pool pressure match conducted by Husky was the absolute deviation between the simulation-calculated and field-derived pressure decline rates. Consequently, Husky maintains that its model results are reliable because of the quality of the history match in its model.

## **5. Impact of Pressure Depletion on Bitumen Recovery**

EnCana's ongoing production of gas from the gas cap continuously drops the pressure in the gas cap. This pressure drop propagates laterally throughout the gas cap and the subjacent bottom water zone, which underlies gas pools. This decline of the pressure is then transmitted down to the adjacent bitumen reservoir, as proven by Husky's piezometer data.

The decline of the pressure within the bitumen zone causes gas exsolution from the bitumen. The problem is that this loss of gas results in an increase in bitumen viscosity, and in a loss of solution gas drive. The increase in viscosity impedes any bitumen recovery process, and the loss of solution gas removes an important drive mechanism for CSS and HSAGD. As such, the declining pressure in the bitumen will adversely affect the subsequent HSAGD or CSS processes.

The pressure drop in the bitumen referred to above, is directly due to the production of gas from the gas caps. Shutting in the gas production will stop the pressure decline in the gas cap, which will stop the pressure drop in the bitumen reservoir. This will prevent further gas exsolution and its associated negative effects on the thermal recovery processes being proposed.

### **5.1 EnCana has failed to incorporate realistic geology into its reservoir model**

EnCana has failed to incorporate a realistic geological model of the Caribou Area into its numerical reservoir simulation model.

#### **(a) Artificial transmissibility barrier between the water and the bitumen**

In its reservoir simulation, EnCana arbitrarily and severely reduces the vertical transmissibility between the water and the bitumen zone below the gas cap by a factor of about 1,000,000.<sup>20</sup> The result is to artificially create a barrier to vertical flow that extends for almost for the entire areal extent of the gas cap (**Figure 5.1**).

Husky does not incorporate any impermeable transmissibility barriers within its reservoir model. Based on core data, geophysical log data, and Husky's understanding of the depositional environments, there is absolutely no justification for introducing this barrier to vertical flow. In fact, Husky's core analysis data and core work suggests that this shale should have permeability in the 30 to 500 mD range. Husky assigned this sandy shale layer a permeability of 50 mD and a

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<sup>20</sup> EnCana Simulation models on CDs; EnCana response to Husky information requests of January 12, 2007.

porosity of 10%, based on the core analysis.<sup>21</sup> In addition to there being no laterally continuous barriers, the shale itself is permeable.

EnCana's arbitrary and unsupported transmissibility reduction essentially insulates the gas cap from the underlying bitumen, thereby severely limiting the pressure transmission that Husky has demonstrated to be occurring. The result of EnCana's creating an artificial barrier is that pressure drops in the gas cap do not appear to affect the pressures in the bitumen to the full extent. This results in EnCana's model predicting higher bitumen pressures and less gas exsolution. This understates the effect of gas cap depletion on bitumen recovery according to EnCana's model.

It is fundamentally incorrect for EnCana to introduce a "phantom" barrier to vertical flow in the Caribou Area.

**(b) EnCana uses an unrealistically low net to gross ratio of 10% under the gas cap**

By using a low net to gross ratio of 10% under the gas cap,<sup>22</sup> EnCana has not only reduced the volume of bitumen in these layers, but has also reduced the horizontal transmissibility by 90%. **(Figure 5.2)**. This, together with the vertical transmissibility barrier described above **(Figure 5.1)**, nearly seals off the gas cap from the bitumen zone below. This reduces the affect of gas cap depletion on the pressures within the bitumen, thereby reducing the effect of continued gas production on the bitumen reserves. The use of a low net to gross ratio of 10% is unjustifiable.

Husky has used porosities, saturation and thicknesses populated from the geostatistical model based on actual well data. Husky's incorporation of actual data realistically demonstrates the existence of pressure transmissibility between the gas cap and the bitumen.

**(c) The east shale (C-D mud) was assigned an unrealistically low permeability that was not supported by laboratory data**

An examination of EnCana's reservoir simulation input files<sup>23</sup> reveals that the East shale (C-D mud) was assigned an unrealistically low permeability that was not supported by laboratory data. In fact, laboratory data confirms that it should have been in the 30 to 500 mD range<sup>24</sup> instead of the 0.001 mD used in EnCana's simulation. By incorrectly postulating the existence of a low permeability layer, EnCana effectively creates a barrier between the gas cap and the lower bitumen zone. This in essence separates the reservoir into two units, which precipitates the conclusions of EnCana's simulation study. Such a low permeability effectively forms a barrier between the gas cap and the lower bitumen zone.

Husky has used conservative shale permeability for the East shale (C-D mudstone) in its simulations, based on the laboratory data given below (provided in Husky's responses to EnCana information requests of October 17, 2006, question 4).

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<sup>21</sup> Husky's response to Board information requests of January 12, 2007.

<sup>22</sup> EnCana Simulation models on CDs; EnCana response to Husky information requests of January 12, 2007.

<sup>23</sup> EnCana January 8<sup>th</sup> KADE Simulation.

<sup>24</sup> Husky Oil Operations Limited, *Impact of Gas Cap Depletion on Bitumen Recovery in Cold Lake Clearwater Formation*, January 8, 2007.

Table 1: Laboratory and Simulation Shale Permeabilities and Porosities

	496.3m - 496.4m	499.9m - 500m	Reservoir Simulation
Maximum Permeability, $k_{max}$	526 mD	29 mD	50 mD
Porosity, $\phi$	34.0%	29.8%	10%

By assuming a shale permeability that is 30,000 to 300,000 times smaller than that supported by laboratory data, EnCana has again artificially insulated the underlying bitumen reservoir from pressure changes caused by gas cap depletion. This would severely inhibit the pressure transmission across this shale and into the underlying formations, including the bitumen reservoir. As such, in EnCana’s simulation work, this would minimize gas exsolution within the time frame of the simulation, thereby minimizing the effects of gas cap production on the bitumen reserve.

**(d) Permeability data is not representative of the Clearwater Formation**

EnCana’s permeability plots exclude all Husky 2005 data and underestimate the average permeability based on commercial data base values that replaced horizontal permeability with vertical permeability, and excluded horizontal permeability entirely.

Husky’s reservoir simulation model used permeability data that are representative of the Clearwater reservoir in the Caribou Area, as determined using Husky’s core analysis.<sup>25</sup> Husky contends that a correct numerical simulation should be based on the best data available.

EnCana claims that its model can still “match” the piezometer data, despite the fact that EnCana uses the wrong permeabilities. One cannot match the pressure data with a flawed model.

**(e) EnCana does not include reservoir heterogeneity**

EnCana does not consider reservoir heterogeneity, other than to construct a deterministic model of the reservoir. This is an overly simplistic approach to the reservoir’s heterogeneity.

The heterogeneity of the reservoir is a key factor that must be included in models (Deutsch, 2002<sup>26</sup>). To accomplish this, Husky used geostatistical methods to include an unbiased representation of heterogeneity in the reservoir simulation model, using data from four wells located in the central portion of the incised valley. These four wells provide a reasonable representation of the area that is a candidate for thermal recovery, and which is likely to be impacted negatively by depletion of the adjacent gas zone.

Deterministic methods can be used to generate heterogeneity. However, the heterogeneity has to be introduced subjectively with such methods and the result will not be unbiased. The general procedure used by Husky is described in the IR dated January 8, 2007. Even though a single

<sup>25</sup> Husky’s response to EnCana information requests of January 12, 2007.

<sup>26</sup> Deutsch, Clayton V., “Geostatistical Reservoir Modeling”, (2002), Oxford University Press.

realization was used to build the reservoir model, all realizations generated by geostatistics are considered equiprobable and will demonstrate the same effect. Since the size of the model is significantly larger than the scale of the heterogeneities, it is reasonable to use a single realization. In this context, the model used in this study is representative of uncertainties associated with characterizing the Clearwater Formation.

Husky's geostatistical analysis demonstrates that a reservoir simulation model has been constructed that honours the heterogeneities observed at the four wells, i.e. calcite layers and mud rich bitumen zones are represented in Husky's model. This is superior to a layer cake model where heterogeneity is not included and no well data is honoured as in the EnCana simulation model.

As can be seen from the discussion above, the physics of the process and the geology of the reservoir are represented in Husky's simulation model. Consequently, the results of the reservoir simulation model are a fair representation of the analysis of the risk to the bitumen resource due to gas cap depletion.

**(f) Summary**

EnCana's reservoir simulation model requires the creation of various barriers or restrictions to flow between the gas cap and the underlying bitumen. These features are geologically unjustifiable. Gas cap volumes have to be arbitrarily increased in order to match the observed pressure declines.

Husky's reservoir simulation models are consistent with the geology, rock-fluid, and fluid properties of the Clearwater reservoir. The models have no unusual features added to achieve the history match and capture all of the major physics of the thermal processes under evaluation. The models are detailed, with sufficient grid resolution. Husky's models demonstrate that gas cap depletion can impair production of adjacent bitumen resources and that these resources should be conserved.

**5.2 EnCana's reservoir simulations are fundamentally flawed.**

EnCana's simulation study submitted January 8, 2007, asserts that gas depletion does not cause adverse effects to bitumen production during SAGD and HWCSS operations. However, this model is deficient with respect to geology and ignores a number of physical phenomena that take place during the mentioned thermal processes. Therefore, the conclusions derived from EnCana's study cannot be supported by its numerical simulation model. Husky is of the opinion that its simulation model reflects the reality in the reservoir more closely and, therefore, its results realistically and correctly assess the risks to the bitumen resource.

**(a) EnCana has failed to simulate the HSAGD recovery process that Husky intends to employ at the Caribou Area**

EnCana does not address Husky's proposed thermal recovery process, HSAGD which is a combination of the CSS and the SAGD processes where the steam chamber created by each process will interact and eventually form one larger steam chamber. It is not possible to draw conclusions on the HSAGD process based simplistically on the individual results of each of the CSS and the SAGD processes separately.

Husky's simulations directly address the HSAGD and HWCSS processes, which Husky is proposing for the Caribou resource. Husky is in the process of applying to the EUB to implement the novel HSAGD process in the Caribou Area. If HSAGD does not work, Husky will convert the operation to HWCSS. CNRL operates a commercially successful HWCSS in an extension to our reservoir in the Primrose field, immediately to the south of Husky's lease.

Husky has provided results of numerical reservoir models, which demonstrate that continued gas cap production will adversely affect both the HSAGD process and the HWCSS process.

**(b) EnCana simulations incorrectly use current gas cap pressures, not the realistic long-term abandonment pressures**

EnCana's simulations consider the effect of gas cap depletion on thermal recovery under current conditions. Therefore, the pressure depletion level in the model does not capture what would happen to the resource in the long term. In EnCana's simulation, gas cap pressures are much higher than they will be upon abandonment. Husky is unable to begin exploiting its Caribou bitumen resource today, and will most certainly not be finished exploiting its resources in the near future. As such, assuming current gas cap pressures for the reservoir simulation is incorrect, as it will minimize the pressure drop in the bitumen due to gas production. This will minimize gas exsolution in the simulation, and therefore the deleterious effect of continued gas cap production on the bitumen recovery processes.

Husky has examined the effect of unabated gas cap production on bitumen recovery. Given the rapid pressure drawdown in the gas cap, it is highly probable that the gas cap will be at abandonment pressure at approximately the same time that Husky would be able to begin its steam injection process. As such, it is far more realistic to use the abandonment pressure of 200 kPa for the gas cap. Husky has done this, and found that gas cap production adversely affects the recovery of bitumen. Further, in Husky's view, ultimate recovery of bitumen has already been harmed with the significant pressure depletion that has occurred.

**(c) EnCana uses unsuitable grid block dimensions**

The portion of EnCana's grid that includes the thermal process is completely unsuitable for modelling thermal processes. Grid block widths of 10 m and thicknesses of 3 m are inappropriate for modeling gravity dominated thermal processes. The length scale for conductive heating in oil sands is in the 2 m to 3 m range so this means that grid blocks smaller than these dimensions are required to capture the temperature profile at the edges of the steam chamber.

Husky's approach to modelling the thermal processes is the industry standard. The grid dimensions in the 2D and 3D models prepared by Husky use small grid block sizes to accurately simulate the thermal profile at the edges of the steam chamber and its advance. The 2D grid blocks are 1 m × 1 m near the wells (width and height). In the 3D model, those dimensions are the same, and the grid block lengths are 20 m in the downwell orientation. The 1 m × 1 m dimensions are the industry-accepted standards in the cross-well plane for thermal gravity drainage processes. The 20-m length of the 3D grid blocks is smaller than what is commonly used, e.g.: lengths between 50 m and 100 m. Physically, the thermal length scale in thermal gravity drainage processes is of the order of 2 to 3 m. Thus, to resolve the conductive heating zone around a steam chamber, it is absolutely essential that the grid blocks are smaller than this length scale if the physics of the process are to be accurately represented.

The grid blocks are far too large to allow the numerical model to capture the physics of the process. A grid block's average temperature determines its thermally dependent grid block properties. Larger grid blocks take proportionally longer times to heat up in response to steam injection. As such, the bitumen in large grid blocks remains until entire grid block heats up. This is incorrect as it has the effect of causing the large grid block to retain bitumen for extended durations, followed by sudden flushing of bitumen once it finally becomes mobile. A gravity dominated thermal process, such as SAGD and HSAGD as well as later stages of CSS, cannot be modelled correctly in this way.

**(d) EnCana uses an unrealistically low live oil viscosity of 17,000 cP**

EnCana's live oil viscosity of 17,000 cP is far too low and not realistic for the Clearwater reservoir as supported by published data (Mehrotra and Svrcek, 1988<sup>27</sup>; Boberg et al., 1992<sup>28</sup>; Erno et. al., 1991<sup>29</sup>). A well-known property such as the oil viscosity should not need to be a variable for history matching.

Husky uses realistic and representative fluid properties and PVT (solubility) data. The oil viscosity is typical for Cold Lake Clearwater reservoir (80,000 cP). These data are considered as relatively certain and therefore would never be considered as a variable history match parameter. The gas solubility and methane viscosity data, projected to equivalent liquid values, are typical of those used for Cold Lake Clearwater reservoir (Mehrotra and Svrcek, 1988<sup>30</sup>).

EnCana's use of a low bitumen viscosity is unrepresentative of the Cold Lake reservoir in the Caribou Area. Therefore, simulations conducted with this viscosity will provide unrealistic results.

EnCana's use of an incorrect live oil viscosity results in unrealistically high initial bitumen mobility in the numerical simulation thereby suppressing the effects of gas cap depletion on the bitumen recovery.

**(e) EnCana's reservoir simulation model uses relative permeability data that are not representative of the Clearwater**

EnCana's relative permeability data is not representative of the Clearwater reservoir in the Caribou Area as indicated by Husky's special core analysis, which was provided to EnCana.<sup>31</sup> The concave downwards shape of EnCana's oil relative permeability curve is questionable. If the oil relative permeability was independent of multiphase effects (e.g. miscible fluids) one would have a relative permeability curve that is a diagonal straight line. That is, oil would have an equivalent flow capacity proportional to the pore space it occupied. Assigning the oil phase a relative permeability that is higher than its saturation is unrealistic and wrong. Again, EnCana's use of an incorrect oil relative permeability curve results in unrealistically high initial bitumen

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<sup>27</sup> Mehrotra, A.K., and Svrcek, W.Y., "Properties of Cold Lake Bitumen Saturated with Pure Gases and Gas Mixtures", (1988), Can. J. Chem. Eng., 66:656.

<sup>28</sup> Boberg, T.C., Rotter, M.B., and Stark, S.D., "History Match of Multiwell Simulation Models of the Cyclic Steam Stimulation Process at Cold Lake", SPE Reservoir Engineering, August 1992: 321.

<sup>29</sup> Erno, B.P., Christ, J.R., Wilson, R.C., "Depth Related Oil Viscosity Variation in Canadian Heavy Oil Reservoirs", JCPT, May-June 1991.

<sup>30</sup> *Ibid*, note 27.

<sup>31</sup> Husky's response to EnCana information requests of January 12, 2007.

effective permeability (and mobility) in the numerical simulation thereby suppressing the effects of gas cap depletion on the bitumen recovery.

Husky's reservoir simulation model used laboratory relative permeability curves that have conventional concave-upward shapes.<sup>32</sup> These are representative of the Clearwater reservoir in the Caribou Area and were estimated using Husky's special core analysis.<sup>33</sup>

**(f) EnCana failed to use temperature-dependent relative permeability curves**

An examination of EnCana's reservoir simulation input files<sup>34</sup> reveals that EnCana did not use temperature-dependent relative permeability curves to simulate the thermal processes. Any simulation should contain as much known physics of the problem being solved as possible. Furthermore, EnCana states that temperature dependency would make no difference to its conclusions. This statement is not substantiated.

Experimental data clearly show that relative permeability changes with temperature and that this dependency has an impact on the behaviour of the system (Prats, 1982<sup>35</sup>). Husky used experimentally determined temperature dependency in its numerical simulation model.<sup>36</sup> This more realistically honours the underlying physics of thermal recovery processes. EnCana did not include this dependence.

Husky maintains that EnCana's model, by failing to utilize the temperature dependency of the relative permeability curves, has resulted in unrealistic relative permeabilities at elevated temperatures which introduced yet another error into their simulation.

The end result will likely be understated gas cap depletion effects.

**(g) EnCana failed to use dilation during CSS**

EnCana is not correctly simulating the CSS process in bituminous oil sands, which requires fracture injection pressures and dilation to fully model the relevant physics. EnCana has allowed for some limited dilation in its input file<sup>37</sup> for the reservoir simulator. However, EnCana fails to inject at a sufficiently high steam pressure, or threshold pressure, to invoke that dilation. CSS injection volumes are low, and injection pressures at 1000 m<sup>3</sup>/d very low compared to field observations.

Without steam injection above fracturing pressure, and permitting dilation and enhanced permeability at that pressure, EnCana cannot realistically model HSAGD or CSS steam injection. Furthermore, without dilation there is no compaction drive during the production phase of each CSS cycle. EnCana has not realistically modelled CSS production.

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<sup>32</sup>Husky's response to EnCana information requests of January 12, 2007.

<sup>33</sup>Husky's response to EnCana information requests of January 12, 2007.

<sup>34</sup> EnCana Simulation Models on CD; EnCana's response to Husky information requests of January 12, 2007.

<sup>35</sup> Prats, Michael, "Thermal Recovery", Monograph Volume 7, SPE Henry L. Doherty Series, Dallas, 1982. ISBN: 0-89520-314-6.

<sup>36</sup> Husky's response to EnCana information requests of January 12, 2007.

<sup>37</sup> EnCana Simulation Models on CDs; EnCana's response to Husky information requests of January 12, 2007.

In reservoirs having significant initial injectivity, the CSS process can succeed with steam injection below the fracture pressure, as is done in California and Venezuela (Butler, 1991<sup>38</sup>). However, in reservoirs with heavier oil or bitumen such as Cold Lake, there is limited initial injectivity. For commercially viable injection and production rates, steam must be injected above the fracture pressure in order to fracture the oil sand formation, as is now being done in the CNRL Primrose CSS project to the south of Husky's lease (CNRL, 2005<sup>39</sup>). Fracturing the formation exposes a much larger area of oil sand to steam, and results in an extensive zone of hyper-permeability along which fluids can flow to and from each well. The steam injection in the Cold Lake reservoir creates fractures that propagate horizontally, therefore the overburden gradient is the fracture gradient.

In STARS, this dilation in the CSS process is modeled using the "quad" model, which permits both elastic deformation and irreversible dilation. In the quad model, the dependences of porosity on pressure, and permeability on porosity, are modeled. Once the injection pressure exceeds a threshold pressure representing the fracture pressure, a permeability multiplier progressively enhances the permeability. While this has been incorporated into the models of Husky and EnCana, the steam injection pressure used by EnCana is below its threshold pressure. As such, dilatancy is never invoked.

Furthermore, outside of the initial fracture plane, dilatancy should occur in the oil sand matrix, but to a lesser degree. This is modeled by Husky, in which a permeability multiplier of 5 is achievable, but which is absent from the EnCana model. As such, the EnCana model has little to no dilatancy.

Consequently, EnCana's results are irrelevant to CSS process and to its hybrid, HSAGD in Alberta's oil sands.

**(h) EnCana's "horizontal" wells are slanted from heel to toe**

EnCana's wells dip from heel to toe (**Figure 5.3**).<sup>40</sup> The gravity drainage aspects of SAGD, HWCSS, and HSAGD require the producers to be horizontal for optimal performance. With such a dip, the producer wells will be drowned, i.e. maintain a liquid level far above the completion screens. This is inefficient and ineffective in draining the reservoir.

This well trajectory suggests that EnCana's reservoir simulation well placement does not reflect commonly accepted horizontal well trajectories typically used in reservoir simulation. That is, it does not reflect what is practiced in reality. It is not known what actual impact this unusual well configuration has on EnCana's simulation study results. However, wells that have up to 7 m differential elevation in a reservoir that is only 30 m thick at most do bring into question EnCana's simulation results.

Husky's wells have a normal trajectory, being truly horizontal in the simulation model. They are modeled as simple horizontal source and sinks using commonly accepted well placement practices at the centre of the grid blocks. Although simpler in specification, the Husky wells are

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<sup>38</sup> Butler, Roger M., "Thermal Recovery of Oil and Bitumen", (1991), Prentice Hall Inc., N.J., U.S.A., 528.

<sup>39</sup> CNRL, "Canadian Natural Resources Limited's Primrose, Wolf Lake and Burnt Lake Annual Presentation to the EUB", January 7, 2005, (power point file).

<sup>40</sup> EnCana Simulation Models on CDs; EnCana's response to information requests of January 12, 2007.

modelled better. The Husky simulation will be more representative of field operations than the EnCana simulation using slanted wells.

**(i) EnCana's wells have erratic partial completions**

EnCana's wells are not completed in all grid blocks penetrated (**Figure 5.3**).<sup>41</sup> As such, the wells cannot accept flow from all grid blocks and therefore do not realistically model the processes.

Husky's wells are at the centre of the grid blocks. The Peaceman R-factor (or well index) was determined by the simulator, as is common practice. The wells were completed in every block penetrated by the well. This is far more representative of field practice and therefore the Husky model is superior in this regard.

**(j) EnCana uses inappropriate well spacing for its reservoir simulation**

An examination of EnCana's reservoir simulation input files<sup>42</sup> reveals that the well spacing used in the simulation model is unrealistically large and does not reflect the current practice in SAGD or CSS. As such, EnCana's results are not relevant to Husky's proposed process for this resource. Placing wells pairs at such large distances makes it impossible for the well pairs to interact.

It should be noted that interaction between the SAGD well pair and the CSS well is one of the main features of the HSAGD process. Consequently, EnCana's reservoir simulation well placement does not reflect what is practiced in reality and, therefore, its results are irrelevant to the HWCSS process, where typical interwell distances of 80 to 180 m are employed, i.e. the Primrose reservoir immediately south of Husky's lease.

In contrast, the well spacing used in Husky's reservoir model is 100 m. This is typical of SAGD inter-wellpair spacing and falls in the range of HWCSS spacing used commercially by CNRL and Imperial Oil.

**(k) Poor quality history match of pressures and production**

The description of EnCana's history match procedure in the EnCana January 8<sup>th</sup> KADE Simulation reveals that EnCana made numerous attempts to arbitrarily adjust the input data to obtain the history match of the pressures and production data. Some of these adjustments are discussed above (for example, artificial viscosity reduction, phantom transmissibility barriers, gas volume adjustments). Despite these attempts, the history match plots given by EnCana demonstrate clearly that the history match of pressures and production is still of very poor quality:

- most piezometer pressures are not matched,
- pressure trends were not matched, and

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<sup>41</sup> EnCana's response to information requests of January 12, 2007.

<sup>42</sup> EnCana January 8<sup>th</sup> KADE Simulation.

- total water production is not matched.

The failure of the history match brings into question the totality of the reservoir simulation model and subsequent results that are being used to justify EnCana's overall conclusion that continued gas production will have no effect on bitumen recovery.

EnCana acknowledges that pressure matches in the north were lower and to the south were higher and then asserts "on average" the pressures were matched.<sup>43</sup> Typically in history matching, the absolute deviations between simulation and field data are minimized and not averaged. This means that the errors are additive. The "history match" and the alterations made to the input data to achieve the "tuned" model are of dubious quality. Therefore, any prediction based such a model is questionable and unreliable. Again, the failure of the history match makes the reservoir simulation model, its results, and any conclusions drawn from its results, meaningless.

### **(I) Summary**

The quality of EnCana's history match, coupled with the other issues discussed above, leads Husky to the conclusion that the EnCana model and simulation results are unreliable and incorrect. Therefore, EnCana's conclusion from the EnCana January 8<sup>th</sup> KADE Simulation, namely that gas cap depletion has no impact on the bitumen recovery, is likewise questionable and unreliable.

In contrast, Husky used a more rigorous geological model and modeled the correct physics of the process using realistic scenarios. Husky found that gas production adversely affected the bitumen recovery process due to pressure depletion in the reservoir, which caused gas exsolution. Husky's results should be accepted over EnCana's.

### **6. Husky's Response to EnCana's Additional Simulations (EnCana IR to Husky January 24, 2007)**

Additional simulations were run by EnCana with Husky's 2D data decks where a total liquid constraint (750 m<sup>3</sup>/day) was placed on the HWCSS production wells. EnCana's results from these additional simulations for the depleted and nondepleted cases were very similar.

In Husky's original runs, without the total liquid constraint, a large fraction of the oil was produced in the first few days of the production interval of the cycle. In EnCana's runs, the total liquid constraint limited the high oil rate that previously occurred in the first few days of each production cycle, so total production was impaired. In duplicating EnCana's runs, Husky determined that the runs with the original operating strategy new liquid constraint led to high gas production rates and water accumulation in the steam chambers which impaired oil production. Obviously, operating with a strategy where gas and potentially steam production is high and forming a zone largely saturated with water due to excessive steam injection is inefficient. Therefore, the operating conditions of the original model were not optimized and the results do not reflect the true deliverability of the reservoir.

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<sup>43</sup> EnCana January 8<sup>th</sup> KADE Simulation.

After cap gas depletion and solution gas exsolution, the viscosity of the oil phase is higher. Thus, the mobility of the oil is lower and as a result, it would be expected that less oil would be produced from the depleted case.

Husky's current 2D simulations with a liquid constraint and a modified operating strategy using the same input parameters as before have more realistic production rates (**Figure 6.1**). Note that further optimization of the operating strategy is possible. With limited optimization, these last simulations confirm the harmful effects of gas cap depletion on bitumen recovery as shown by the original runs. The differences in the cumulative volumes are large in the early cycles, which suggest that the economics of the process would be severely impacted by depletion of the gas pools. Most of the effort went into optimizing the HWCSS performance; further optimization of the HSAGD could be achieved. Therefore, the results shown in **Figure 6.1** are only a start and the marked difference between the depleted and undepleted case would only widen with further optimization of the process.

## 7. Conclusion

As detailed in this Reply Submission and Husky's previous submissions, Husky submits that resource conservation requires that EnCana's gas production in the Caribou Area must be shut-in and no further gas production allowed. Ongoing gas production in the Caribou Area has a significant impact on ultimate bitumen recovery. Therefore, Husky requests the Board order:

- a. all of the following wells be immediately shut-in:

Number	Well ID	Perforation	Top Depth	Base Depth	Pool
1	00/03-11-070-06W402	2	437.0	438.0	CLWR Undef
2	00/05-10-069-04W402	4	500.3	501.3	CLWR D
3	00/05-13-069-06W400	3	476.0	480.0	CLWR EE
		4	468.0	470.0	CLWR EE
4	00/05-16-070-05W400	3	425.0	425.5	CLWR S
5	00/05-22-070-05W400	2	422.5	423.5	CLWR S
6	00/06-20-069-05W400	1	445.2	446.5	CLWR G
7	00/06-21-070-05W400	1	417.0	422.0	CLWR S
8	00/06-28-069-04W402	1	427.0	430.0	CLWR B
		2	423.0	425.0	
9	00/11-33-068-05W400	1	450.5	452.0	CLWR CC
		2	462.0	463.0	CLWR DD
10	00/12-04-070-04W400	1	427.8	428.3	CLWR
11	02/16-28-068-05W400	1	453.5	454.5	CLWR CC
		2	464.5	465.5	CLWR DD
12	03/08-03-069-04W402	2	495.5	497.5	CLWR D
13	00/10-33-068-04W402	2	485.0	486.0	CLWR D
14	00/08-26-069-05W400	1	435.5	436.5	CLWR Undef
15	00/11-13-070-05W400	1	442.5	445.0	CLWR Undef
16	00/08-36-069-05W400	2	441.0	444.0	CLWR B
17	00/06-32-069-04W402	7	430.0	434.0	CLWR B
18	00/06-19-069-04W402	2	440.8	441.8	CLWR B
19	00/05-29-069-04W400	3	435.4	438.0	CLWR B
20	02/10-35-069-05W400	1	435.0	436.5	CLWR B
21	00/05-21-069-04W400	1	443.5	449.0	CLWR B
22	00/06-17-069-04W400	1	445.0	447.0	CLWR B
23	00/06-12-070-05W400	1	434.0	440.0	CLWR B
24	00/10-06-070-04W400	3	428.5	433.5	CLWR B
		4	436.0	438.0	

and

b. the following well be denied approval to produce:

Upper Clearwater B Undefined 100/14 -31-068-04W4/0.

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and is submitted on behalf of Husky Oil Operations Limited this 30<sup>th</sup> day of January, 2007.

**HUSKY OIL OPERATIONS LIMITED**

Per: \_\_\_\_\_  
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**List of Figures**

- Figure 2.1 Regional Facies Distribution and Interpretation
- Figure 2.2 Husky Caribou East-West Stratigraphic Cross Section
- Figure 2.3 East Regional Shale Core Photograph
- Figure 2.4 Valley Margin Shale Core Photograph
- Figure 4.1 Pressured Depletion in Husky 2D Reservoir Simulation Model
- Figure 4.2 Pressure Depletion in Husky 3D Reservoir Model
- Figure 5.1 Map of Vertical Transmissibility Factory (TRANSK) from Encana Model
- Figure 5.2 View of Net to Gross Distribution in EnCana Model
- Figure 5.3 View of Wells in EnCana Model
- Figure 6.1 Results of Husky Simulation Cases

**ALBERTA ENERGY AND UTILITIES BOARD**

**IN THE MATTER OF** the *Alberta Energy and Utilities Board Act*, R.S.A. 2000, c. A-17, the *Energy Resources Conservation Act*, R.S.A. 2000, c. E-10, the *Oil and Gas Conservation Act*, R.S.A. 2000, c. O-6 and regulations thereunder, the *Oil Sands Conservation Act*, R.S.A. 2000, c. O-7, and section 3 of the *Oil Sands Conservation Regulation*, AR/76/88, all as amended;

**IN THE MATTER OF** Alberta Energy and Utilities Board (“EUB” or “Board”) Interim Directive ID99-1, as amended (“ID99-1”);

**IN THE MATTER OF** Application No. 1394112 by Canadian Natural Resources Limited requesting the Board shut in gas production in the Clearwater Formation in the Cold Lake Oil Sands Area;

**IN THE MATTER OF** Application No. 1409180 by EnCana Corporation to the Board for approval to produce gas in the Clearwater Formation in the Fisher field of the Cold Lake Oil Sands Area;

**AND IN THE MATTER OF** Application No. 1481725 by Husky Oil Operations Limited requesting the Board shut in gas production in the Clearwater Formation in the Cold Lake Oil Sands Area; and

**AND IN THE MATTER OF** EUB Notice of Rescheduling of Hearing dated October 13, 2007.

**REPLY SUBMISSION OF  
HUSKY OIL OPERATIONS LIMITED**

**January 30, 2007**

## TABLE OF CONTENTS

1. Introduction and Executive Summary.....	2
2. EnCana Fails to Properly Model the Geology of the Clearwater Formation and Gas and Water Zones .....	8
3. The Caribou Area Contains a Valuable Bitumen Resource in the Clearwater Formation .....	12
<del>4. The Pressure Data Confirm that Pressure Depletion caused by Ongoing Gas Production by EnCana is Communicated Rapidly and Broadly .....</del>	<del>134.</del>
<u>4. The Pressure Data Confirm that Pressure Depletion caused by Ongoing Gas Production by EnCana is Communicated Rapidly and Broadly .....</u>	<u>12</u>
5. Impact of Pressure Depletion on Bitumen Recovery .....	14
<del>6. Husky's Response To Encana's Additional Simulations (Encana IR To Husky January 24, 2007) .....</del>	<del>23</del>
<u>6. Husky's Response to EnCana's Additional Simulations (EnCana IR to Husky January 24, 2007).....</u>	<u>23</u>
<del>7. Conclusion .....</del>	<del>247.</del>
<u>7. Conclusion .....</u>	<u>25</u>
<del>8. References.....</del>	<del>26</del>
<u>8. References.....</u>	<u>26</u>
<del>9. List Of Figures.....</del>	<del>27</del>
<u>9. List Of Figures.....</u>	<u>27</u>
<del>10. List of Figures.....</del>	<del>28</del>
<u>10. List of Figures.....</u>	<u>28</u>

#### **1-1. Introduction and Executive Summary**

It is common ground that Husky Oil Operations Limited (“Husky”) holds 56 sections of bitumen leases (the “Caribou Area”) contiguous to EnCana Corporation’s (“EnCana”) leases with gas production from the Clearwater Formation. Bitumen and gas in the Caribou Area are both reservoired in the Clearwater and ~~Extensive~~**extensive** gas production has occurred and is continuing. Furthermore, EnCana has applied to the Board for authorization to produce additional gas from the Clearwater. Husky has applied to the Board for an order requiring EnCana to shut in certain gas wells on the basis that EnCana’s continued production from these wells will adversely impact Husky’s recovery of bitumen resources **that** it intends to produce using an experimental Hybrid Steam Assisted Gravity Drainage (“HSAGD”) process.

In its filed submissions in this proceeding, EnCana has claimed that its continued and proposed production of gas will not adversely affect the economic development of Husky’s bitumen ~~resource~~**resources**. EnCana attempts to support this claim by postulating that there is a continuous and correlatable barrier between the gas and bitumen zones for which there is no evidence. EnCana has failed to provide supporting geological evidence for its assertion of a shale barrier. EnCana has neglected to model the HSAGD process that Husky is proposing to use. Further, EnCana’s simulation is inappropriate for thermal processes such as HSAGD, and the underlying history match is unacceptable.

Husky has demonstrated that production of the adjacent gas caps will be detrimental to the recovery of Husky’s bitumen resource. Husky’s detailed geological study of the area, contrary to EnCana’s unsupported claim, shows there are no laterally continuous and correlatable barriers between the gas and bitumen. Husky has provided a realistic simulation model that matches the history. Furthermore, Husky has modelled the HSAGD process that it intends to use **at in the Caribou Area**.

The pressures in the gas caps have been depleted significantly from the initial pressures and continue to be depleted. Extensive piezometer data ~~in Husky’s Caribou leases~~ located in the bitumen zone **in Husky’s Caribou Area** show pressure drops in excess of 50% in places and the pressure depletion is ongoing. The pressure depletion in the gas cap is communicated vertically and laterally into the bitumen zone through the top water where present or **through** the initially mobile water phase in the bitumen zone where top water is absent.

Husky has a significant resource over the entire lease: 1.1 billions barrels of this resource reside in Husky’s 15 section lease (Lease Number 7188110343) area. Continued depletion of pressure resulting from EnCana’s continued production from its adjacent wells will significantly harm the ultimate bitumen recovery by either HSAGD or Cyclic Steam Simulation (“CSS”) processes. These observations are fully consistent with Husky’s simulations of the HSAGD and CSS processes and also established experience and learnings of the CSS process. Significant amounts of solution gas are evolving from the bitumen due to pressure depletion. This gas is migrating to the gas pools. In addition to confirming that no pressure barriers exist, this loss of solution gas will have a significant detrimental effect on bitumen recovery.

Shutting in the gas production is required to stop the continued pressure depletion and the resulting loss of solution gas. Specifically, in this Reply Submission, Husky addresses the following EnCana claims:

~~1.1~~ **1.1 EnCana's claim that pressure depletion in the gas pools does not adversely affect the bitumen recovery is unsupported.**

Husky has presented pressure data confirming pressure depletion. Husky's piezometer readings are consistent and provide ample continuous pressure data over time. The evidence is clear and overwhelming that pressure depletion resulting from EnCana's gas production is communicated to Husky's leases. Husky has been able to demonstrate, through detailed geological studies and rigorous reservoir simulation, that there is a significant risk to the bitumen resource as a result of continued gas cap production.

~~1.2~~ **1.2 EnCana's conclusion that continued gas production will result in "no harm to bitumen" is based on modelling that is fundamentally flawed for the following key reasons:**

~~(a)~~ **(a) The geological foundation for EnCana's numerical reservoir model is incorrect: EnCana has failed to incorporate a realistic geological model of the Caribou Area into its numerical reservoir simulation model.**

EnCana provides no discussion of the depositional setting. The absence of a basic understanding of the distribution of facies, severely limits the ability to predict the distribution of reservoir properties.

In its reservoir model, EnCana introduced a phantom vertical transmissibility barrier between the gas and water, extending over almost the entire gas cap area. There is absolutely no geological justification for such a barrier.

EnCana has not presented a comprehensive geological distribution of shales. Husky has provided detailed distributions of shales. EnCana has failed to differentiate shales between the clay-rich barriers and baffles.

EnCana provides no discussion of the hydrocarbon emplacement, despite the fact that it uses hydrocarbon emplacement as a justification for the phantom transmissibility barrier, previously discussed.

Rather than acknowledging that significant volumes of gas are exsolving from the bitumen into the gas cap, thus providing pressure support and replenishing gas volumes, EnCana arbitrarily increased the size of the gas caps.

~~(b)~~ **(b) EnCana has failed to simulate the HSAGD recovery process that Husky intends to employ at Caribou**

EnCana made no attempt to model the HSAGD process that Husky intends to use.

HSAGD is a hybrid of SAGD and **Horizontal Well CSS (“HWCSS”)**. HSAGD must be modelled and analyzed as a separate and distinct hybrid process. Through its simulation of the HSAGD process, Husky has established that there is significant harm to the recovery of bitumen caused by loss of solution gas in the bitumen zone resulting from the lowering the reservoir pressure due to gas pool depletion.

~~(c)~~ **(c) EnCana fails to assess the effects of producing gas to abandonment pressures (~200 kPa) prior to thermal recovery.**

Gas production has been significant and is ongoing. Current gas pressures are approximately 1000 kPa, in stark contrast to the initial pressures of ~2800 kPa. EnCana’s simulations use current gas cap pressures, not the long-term abandonment pressures. The result is to significantly understate the impact of the continued production of the EnCana gas on ultimate bitumen recovery.

EnCana fails to account for the fact that gas depletion to abandonment pressure will occur prior to any thermal recovery by Husky.

Gas can be produced after the bitumen recovery with no adverse effects. In contrast, bitumen cannot be produced after gas depletion without an adverse effect because of gas exsolution concomitant with production of the gas caps. This has significant implications for resource conservation as the industry considers the development of bitumen resources, whose recovery economics are dependent upon the use of newer reservoir pressure-sensitive technologies.

~~(d)~~ **(d) EnCana uses an unrealistically low net to gross ratio of 10% in simulation layers under the gas cap**

By using a low net to gross ratio of 10% under the gas cap, EnCana has not only reduced the volume of bitumen in this layer, but has also reduced the horizontal cross-sectional area open to flow, and thus the horizontal flow conductivity by 90%. There is no geological reason for this. The result is to artificially and improperly to reduce the effect of gas pressure decline on pressures within the bitumen, thereby reducing the effect that continued gas production has on the bitumen reserves.

~~(e)~~ **(e) EnCana uses grossly oversized grid blocks for thermal recovery processes**

In attempting to model both the gas production and the bitumen production in one global reservoir model, EnCana utilizes an extremely coarse grid for the reservoir volume affected by the thermal recovery processes. These grid block dimensions are far too large to allow the numerical model to capture the steam chamber growth and gravity drainage effects.

~~(f)~~ **(f) EnCana uses inappropriate well spacing for its reservoir simulation**

EnCana’s horizontal spacing of its horizontal wells is far too large. Placing the wells 280 m apart prevents or severely inhibits the steam chambers from interacting and eventually coalescing, as would occur with SAGD, CSS, and HSAGD.

~~(g)~~

**(g) EnCana's "horizontal" wells are slanted from heel to toe**

EnCana's well trajectories are not truly horizontal. This has the effect of drowning the production wells, and possibly the toes of the injection wells, thereby impairing the production capacity of the process.

**~~(h)~~ (h) EnCana's wells have erratic partial completions**

EnCana's wells are not completed in all grid blocks penetrated.<sup>1</sup> As such, the wells cannot accept flow from all grid blocks and therefore do not realistically model the processes.

**~~(i)~~ (i) EnCana's permeability data is not representative of the Clearwater Formation**

EnCana's permeability plots do not include correct permeability data and underestimate the average maximum permeability. As such, the EnCana's simulations are incorrect.

**~~(j)~~ (j) EnCana does not include reservoir heterogeneity**

EnCana does not consider reservoir heterogeneity, other than to construct a deterministic model of the reservoir, i.e. "layer cake". The heterogeneity of the reservoir is a key factor affecting process performance and dynamics that must be included in models.

**~~(k)~~ (k) EnCana uses an unrealistically low live oil viscosity of 17,000 ~~cp~~ cp**

EnCana's live oil viscosity of 17,000 cp is far too low and not realistic for the Clearwater reservoir as supported by published data.

**~~(l)~~ (l) EnCana's reservoir simulation model utilizes incorrect relative permeabilities**

EnCana's oil relative permeability curve is concave downward and is not representative of the Caribou ~~area~~ Area, as is supported by Husky's special core analysis.

**~~(m)~~ (m) EnCana did not use temperature-dependent relative permeability curves**

EnCana failed to incorporate any temperature dependency of their relative permeability curves in ~~its~~ their thermal simulations. EnCana states that temperature dependency would make no difference to their conclusions. This statement is not substantiated, and in Husky's opinion, is incorrect.

**~~(n)~~ (n) EnCana failed to use dilation during CSS**

The CSS process in bituminous oil sands requires fracture injection pressures and dilation to fully model the relevant physics. EnCana failed to inject at a sufficiently high steam pressure to

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<sup>1</sup> KADE Technologies Inc., *Gas-Over-Bitumen Reservoir Simulation Study*, January 8, 2007 ("2007, submitted by EnCana ("EnCana January 8<sup>th</sup> KADE Simulation")),

invoke dilation. Furthermore, without dilation there is no compaction drive during the production phase of each CSS cycle.

**~~(o)~~ (o) EnCana's history match of pressures and production is flawed**

The description of EnCana's history match procedure reveals that EnCana made numerous attempts to arbitrarily adjust the input data to obtain the history match of the pressures and production data. Despite these attempts, the history match plots given by EnCana demonstrate clearly that the history match of pressures and production is still of very poor quality:

- most piezometer pressures are not matched,
- pressure trends were not matched, and
- total water production is not matched.

The failure of the history match raises serious questions in respect of the totality of EnCana's reservoir simulation model and consequently the results that are being used to justify EnCana's overall conclusion that continued gas production will have no effect on bitumen recovery.

EnCana acknowledges that pressure matches in the north were lower and to the south were higher and then asserts that "on average" the pressures were matched. Typically in history matching, the absolute deviations between simulation and field data are minimized and not averaged. Therefore, any prediction based on such a model is questionable and unreliable. Again, the failure of the history match makes the reservoir simulation model, its results, and any conclusions drawn from its results meaningless.

**~~(p)~~ (p) EnCana's CSS results contradict the accepted principle that solution gas is an important drive mechanism in the CSS process**

EnCana's model acknowledges significant solution gas evolution, but fails to acknowledge any effect on the CSS recovery processes. Solution gas is a known drive mechanism of heavy oil recovery using CSS. One cannot inhibit or eliminate this drive mechanism without an adverse ~~effect~~**affect** on bitumen recovery.

**~~(q)~~ (q) Husky's response to EnCana's additional simulations (*EnCana IR to Husky January 24, 2007 response to EnCana information requests*)**

In duplicating EnCana's runs, Husky determined that the runs with the original operating strategy and new liquid constraint led to high gas production rates and water accumulation in the steam chambers which impaired oil production. Obviously, operating with a strategy where gas and potentially steam production is high and forming a zone largely saturated with water due to excessive steam injection is inefficient. Therefore, the operating conditions of the original model were not optimized and EnCana's results do not reflect the true deliverability of the reservoir.

Husky's current 2D simulations with a liquid constraint and a modified operating strategy using the same input parameters as before have more realistic production rates. Note that further optimization of the operating strategy is possible. With limited optimization, these last

simulations confirm the harmful effects of gas cap depletion on bitumen recovery as shown by the original runs.

For all of the above reasons, Husky continues to submit that existing gas production must be halted and no new gas production should be permitted in the Caribou Area. Husky's detailed submissions are set forth in the following sections.

## **2-2. EnCana Fails to Properly Model the Geology of the Clearwater Formation and Gas and Water Zones**

EnCana fails to properly model the geology of the Clearwater Formation, and the associated gas and water zones.

### **(a) 2.1 EnCana does not provide a discussion of the depositional setting**

EnCana has not provided a geological interpretation of the depositional setting of the Clearwater Formation in the Caribou Area. Failure to understand the lateral and vertical distribution of the facies essentially undermines any understanding of vertical or horizontal permeability barriers. An understanding of the depositional setting is the necessary first step to assessing the impacts of continued, and indeed increased, gas production on bitumen recovery.

### **(b) 2.2 EnCana ~~Models Phantom~~ models phantom permeability barriers**

EnCana's application of phantom permeability barriers in simulation work, accomplished with a transmissibility reduction, is indefensible. EnCana's simulation work encompassing an impermeable layer under the water zone<sup>2</sup> is neither supported by core nor wireline log data, and is contrary to a reasonable interpretation of the geology of the Caribou Area. The assertion, as reflected in EnCana's simulation models, that some form of barrier exists is contrary to any realistic and reliable geologic model.

EnCana introduces a vertical permeability barrier under the water zones by arguing that:

- (i) ~~The~~ (i) the density difference between bitumen and water would have caused gravity segregation, had there been no barrier<sup>3</sup>; and
- (ii) ~~(ii)~~ (ii) bitumen failed to displace water thus there is a barrier.

Husky dealt with this matter in its response to the Board's September 5, 2006 information request to Husky, Question 2:

- (i) ~~(i)~~ (i) invading oil displaced the original mobile formation water,
- (ii) ~~(ii)~~ (ii) oil degraded to bitumen, releasing methane as a byproduct,
- (iii) ~~(iii)~~ (iii) this methane accumulated as a gas cap,
- (iv) ~~(iv)~~ (iv) subsequent removal of overburden resulted in leakage of gas,
- (v) ~~(v)~~ (v) gas migration was followed by an influx of water to replace the voidage, and

<sup>2</sup> EnCana's response to Husky ~~January 12, 2007~~ information request requests of January 12, 2007, question 6.

<sup>3</sup> EnCana's response to Husky ~~January 12, 2007~~ information requests: of January 12, 2007.

(vi) (vi) water preferentially filled the base of the gas cap because bitumen was too viscous and too similar in density to be displaced.

EnCana has provided no reliable justification for its postulated permeability barrier. The existence of water over bitumen is not indicative of a barrier because the density difference between the two liquids is very small; combined with the high oil viscosity, the differential densities would result in too small of a driving force to overcome capillary pressures. Lastly, no impermeable physical barrier has been observed in the core data<sup>4</sup>.

Husky has performed a comprehensive review of available geologic data for the Caribou Area. There is no geologic evidence of a laterally continuous and competent physical barrier to vertical flow under the water zone and therefore no barrier for pressure transmission from the gas cap to the underlying bitumen. There are no laterally continuous observable barriers, and none can be inferred. The presence of gas over water over bitumen is well understood as a result of the hydrocarbon emplacement model in Northern Alberta.

The suggestion that there is a barrier because of the existence of the water zone is expressly contrary to the many findings of the Board that the pressure communication will be transmitted through the gas and the water to the underlying bitumen, in the absence of laterally continuous and competent barriers.

**(e) 2.3 Shales are not ~~Laterally Continuous~~ laterally continuous in the Caribou Area**

EnCana failed to present a comprehensive geological description of the depositional setting, and therefore presents no evidence as to the types and distribution of shales across the area of concern.

Husky provided an interpretation of the depositional setting for the Clearwater Formation in the Caribou Area.<sup>5</sup> Husky's core and log review has resulted in a detailed interpretation that consistently explains Husky's piezometer observations by establishing the lateral and vertical pathways for pressure communication.

The Husky regional facies distribution (**Figure 2.1**) reflects an interpretation of the reservoir as an ~~Incised Valley System~~ **incised valley system** opening towards the north-northwest. The valley system is two-sided such that it has incised into a regional highstand, deltaic, muddy shoreface that is preserved on both the east and west side of the incised valley complex (**Figure 2.2**). Husky refers to the bordering muddy shoreface units as the "Western Regional Shale" and the "Eastern Regional Shale." These two shale units in core and well logs appear to be regionally correlative, clay-rich units that probably constitute permeability barriers (**Figure 2.3**), but the shale on the east side is of limited extent. These possible impermeable barriers in the east are found outside Husky's ~~Lease~~ **lease**.

Eroded into the regional shales is the incised valley fill, which constitutes the main target reservoir ~~on~~ **in** the Husky Caribou ~~lease~~ **Area**. The incised valley fill can be broadly differentiated into a central sand-rich axis, flanked on the east and west by marginal valley deposits. The

<sup>4</sup> Husky's response to ~~EnCana's October 17, 2006~~ **EnCana** information requests ~~of October 17, 2006~~.

<sup>5</sup> Husky's response to ~~EUB~~ **Board information requests of** November 10, 2006 ~~information request~~, **2006, question 1a**.

central sand-rich axis appears to merge into the marginal valley deposits without sharp lateral facies boundaries. Both facies are characterised by interbedded mud stringers, but the marginal valley deposits on the east flank of the complex are much more mud-rich with a strong brackish marine signature reflected in the trace fossil assemblages.

The mud-rich marginal valley is distinctly different from the adjacent Eastern Regional Shale, and does not constitute laterally continuous shale barriers. Rather, the marginal valley facies consists of interbedded, discontinuous mud stringers and mud clasts (**Figure 2.4**), similar to that seen in the sandy axis facies, but in greater concentration. It is also observed that all of the interbedded sands are bitumen-saturated, indicating that they are interconnected and that they did not constitute a barrier during hydrocarbon migration and emplacement. This is indicative of potential pressure connectivity across these facies.

There are places where there is gas over water over bitumen with no mud in between, and there are places where there is gas over water over interbedded sandy mud layers. Therefore, EnCana's geological model as reflected in its simulation work, where there is an impermeable shale layer within the water zone, is not supported by, and is in fact contrary to, the core data.

In summary, Husky's bitumen leases lie directly in an incised valley, where older sediments have been cut and re-worked, resulting in no laterally continuous and competent barriers. There are two adjacent mud-rich facies on the eastern side of the system. The muddy interbedded valley margin shales combined with the immediately adjacent eastern regional shale constitute the two components of what Husky informally refers to as the "Eastern Shale Complex" and CNRL refers to as the "C&D muds".

Husky, in distinction to EnCana, has provided a reasonable and comprehensive interpretation of the shales, their properties, and their distribution. Any realistic simulation work must reflect the absence of any continuous and competent barriers between the overlying gas and the bitumen.

**(d) 2.4 EnCana has failed to differentiate shales**

EnCana has failed to differentiate the two discrete shale units that make up the Eastern Shale Complex,<sup>6</sup> and appears to have assigned permeability properties seen in the eastern regional shale to the entire complex without recognizing that the valley margin shale (western subunit, **Figure 2.1**) has a measurable and significant permeability (30 to 500 mD).<sup>7</sup>

Husky differentiates the shales in the East Regional Complex: an eastern subunit which is a solid mud (barrier shale) and a western subunit,<sup>2</sup> which is interbedded sandy<sub>2</sub> mud with finite permeability (baffle shale) and would not act as barrier.

On the Husky Leases shales are not continuous and, in addition Husky simulation work honours lab-derived data in relation to the shales themselves. The valley margin shale component will act as a baffle shale and could not be a regional barrier. EnCana's submission demonstrates a lack of the geological input that is absolutely necessary for proper reservoir modeling and simulation work.

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<sup>6</sup> EnCana's response to Husky information request 07-01-12, requests of January 12, 2007; Drawing 5, Isopach of C to D Mudstone.

<sup>7</sup> Husky's response to EUB Board information request 07-01-12, requests of January 12, 2007, question 2a.

**(e) 2.5 EnCana does not provide an explanation for hydrocarbon emplacement**

EnCana failed to provide an explanation for emplacement of the hydrocarbons in the Clearwater Formation reservoir. However, EnCana does allude to the bitumen displacing the water.<sup>8</sup> Husky disputes that this is possible. An understanding of hydrocarbon emplacement does not have to invoke the presence of significant lateral and vertical permeability barriers, again, refuting the application of such barriers in their simulation.

Husky supports the conventional hydrocarbon emplacement model (Aitken et al., 2004<sup>9</sup>; Larter et al., 2003<sup>10</sup>), which readily explains the presence of gas over water over bitumen. In such a model, no barriers are needed between the gas, water, and bitumen. This model is also consistent with the existence of multiple pressure communication pathways between the bitumen and the gas cap.

**(f) 2.6 EnCana's speculation that water over bitumen suggests barriers to flow is flawed.**

EnCana's contention that the presence of water over bitumen suggests barriers to flow is unsubstantiated.<sup>9-11</sup> Husky outlined the commonly accepted theory for development of the gas over water over bitumen situation in ~~our~~ its response to the Board's **September 19, 2006** information request ~~06-09-05~~, **question 2**. Mobile hydrocarbons migrate through porous and permeable sediments into a trap. Biodegradation of the oil phase occurs, creating bitumen and gas as by-products. Subsequent natural migration of the gas allows water to displace some of the gas resulting in gas over water over bitumen. All facets of this hydrocarbon emplacement require a porous and permeable reservoir, with no lateral or vertical permeability barriers. This, once again, is contrary to the application of artificial permeability barriers to facilitate history matching, as done by EnCana in their simulation work.

**(g) 2.7 EnCana's calculated OGIP is unjustified**

Husky notes that EnCana's volumetrically calculated OGIP's are much smaller than its "history matched" final simulated volumes (D Pool increased by 30% and B Pool by 18%).<sup>10-12</sup> No geological evidence has been presented for these larger volumes.

Husky's detailed geological study and previous submissions<sup>11-13</sup> disagree with EnCana's "history matched" volumes. Furthermore, the additional gas that had to be introduced to EnCana's numerical simulation model is most likely the solution gas that evolves from the bitumen as a

<sup>8</sup> EnCana Response to Husky information request ~~2007-01-12~~ requests of January 12, 2007.

<sup>9</sup> Aitken, C.M., Jones, D.M., Larter, S.R., "Anaerobic Hydrocarbon Biodegradation in Deep Subsurface Oil Reservoirs", (2004) Nature 431, 291-294.

<sup>10</sup> Larter, S. R., Wilhelms A., Head I., Koopmans M., Aplin A., Di Primio R., Zwach C., Erdmann M., Telnæs, N., "The Controls on the Composition, of Biodegraded Oils in the Deep Subsurface: (Part 1) Biodegradation Rates in Petroleum Reservoirs", (2003), Org. Geochem. 34:601-613.

<sup>9-11</sup> EnCana's responses to Husky information request ~~07-01-12~~ requests of January 12, 2007, question 7a.

<sup>10-12</sup> EnCana January 8<sup>th</sup> KADE Simulation.

<sup>11-13</sup> P/Z plots as shown in Husky-Response's response to Board Information Request, ~~06-11-10~~ information requests of November 10, 2006, Appendix A.

result of pressure depletion and migrates into the gas pools. Clearly there are no barriers to solution gas migration into the gas pools. These pools must be shut in to prevent pressure depletion and resulting loss of solution gas in the bitumen zone.

### **3. 3. The Caribou Area Contains a Valuable Bitumen Resource in the Clearwater Formation**

Notwithstanding EnCana's unsupported assertions to the contrary, the fact is that the Caribou Area contains a valuable bitumen resource in the Clearwater Formation. Commercially viable thermal recovery operations exist in CNRL's Primrose field, in an extension to Husky's Clearwater reservoir, immediately to the south of Husky's lease.

Husky currently estimates that there are 1.1 billion barrels of bitumen in place in Husky's 15-section lease in the Clearwater Formation, all adversely affected by EnCana's gas production from the Clearwater Formation. The estimate of volume of bitumen in place may well increase with further delineation drilling.

Husky estimates ultimate bitumen recovery factors between 27% and 50% (300 to 550 million barrels). The remaining gas in the associated gas pools amounts to approximately 5 million boe. Consequently, the value of the bitumen resource vastly exceeds that of the remaining gas and the bitumen resource must be conserved.

EnCana provided an estimate of 2.7 billion barrels OBIP<sup>+214</sup> for a 99-section area that encompasses Husky's 15 section lease. This significantly underestimates the total resource in jeopardy as a result of EnCana's exclusive use of core data, but nonetheless, EnCana's estimate indicates a significant resource worthy of protection.

Furthermore, the entire extent of the bitumen resource is yet to be fully evaluated. Limited drilling has occurred in the northern and western regions of Husky's two leases, and additional resource-bearing incised valleys could be identified by further delineation work.

Additional geological work and delineation drilling is underway. Husky is currently in a 44-well delineation drilling program. An additional 40 cores through the Clearwater bitumen reservoir will be cut, providing further valuable information to evaluate the extent and distribution of the resource. Consequently, the harmful effects of gas cap depletion to the bitumen resource are potentially applicable to much larger bitumen volumes than those that have already been identified.

The geologic evidence is clear that there is a valuable bitumen resource in the Clearwater Formation in the Caribou Area. Exploitation and recovery of this major bitumen resource is at significant risk due to continued gas production and concurrent pressure depletion of the bitumen.

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<sup>+214</sup> EnCana January 8<sup>th</sup> KADE Simulation<sub>2</sub>

#### **4. ~~4.~~ The Pressure Data Confirm that Pressure Depletion caused by Ongoing Gas Production by EnCana is Communicated Rapidly and Broadly**

Husky has 31 piezometers installed in seven wells in the Caribou ~~area~~ **Area**. ~~Twenty-five~~ **25** of 31 (81%) ~~are~~ **were** recording monotonically declining pressures of up to 56% on November 14, 2006. Even if the two highest decline rates are excluded, the mean decline on ~~Nov.~~ **November** 14, 2006 from an assumed “initial” pressure of 2808 kPa ~~is~~ **was** 5.8%. The declines have increased by 12.5% during this 2.5 month period alone. That is, the rates of decline are increasing by 5% per month.<sup>1315</sup> The remainder of the Husky piezometer data (~~6~~ **six** piezometers) are exhibiting anomalous behaviour. They are being more strongly affected by operations not related to the gas cap depletion, i.e.g. possibly due to nearby water disposal or response to gas cap operations.

Husky’s piezometer data proves that rapid pressure decline is occurring throughout the bitumen zone due to adjacent gas production. It appears that the overall pressure decline levels and the pressure trends in the bitumen zone are not being disputed by EnCana as its claims to match the Husky piezometer data to precondition its simulation runs for the gas cap depletion sensitivity study.<sup>1416</sup>

The pressure communication from the adjacent gas cap to the bitumen zone is unimpeded because there are no continuous vertical or horizontal permeability barriers as explained in the geology section. Husky’s geological mapping indicates that the top water zone is ~~areally~~ **areally** more extensive than both the overlying gas zone in the east and south and the underlying shale zone in the east.<sup>1517</sup> The pressure is communicated from the adjacent gas production to the bitumen through two means:

- (i) ~~(i)~~ **(i)** pressure transients ~~travel~~ **travel** from the gas zone to the top water zone and from there to the bitumen zone laterally and vertically, and
- (ii) ~~(ii)~~ **(ii)** where there is no top water zone, pressure is transmitted directly from the gas cap to the bitumen vertically and laterally.

Husky’s reservoir simulation results demonstrate that the depletion of the offset gas cap reduces the pressure in the reservoir throughout the width of the simulation model (several hundred meters). **Figures 4.1 and 4.2** show that the pressure falls throughout the reservoir. In support of these simulation results, field data show that this distance is greater than 3 km. This is due to water mobility in the reservoir at original conditions, as has been established from relative permeability measurements.<sup>1618</sup> Mobility of water at initial conditions must be included in reservoir simulation models of the Caribou Area.

As the pressure falls in the gas pool, the gas-water contact rises and adds to the volume and areal extent of the top water. **Figure 4.2** shows that after pressure depletion starts, the water saturation in the gas pool rises. Physically this is because of mobile water in the reservoir.

<sup>1315</sup> Husky’s response to Board information ~~request 2006-11-10~~ **requests of November 10, 2006.**

<sup>1416</sup> **EnCana** January 8<sup>th</sup>, KADE Simulation~~7~~.

<sup>1517</sup> Husky’s response to **EUB Board** information ~~request 2006-10-26~~ **requests of October 13, 2006.**

<sup>1618</sup> Husky’s response to EnCana information ~~request 2006-11-10~~ **requests of November 10, 2006.**

The piezometer pressure decline rate data is reasonably matched in Husky's reservoir simulation models.<sup>+719</sup> For evolution of solution gas into bubbles in the pore space, the pressure decline rate is a key factor that controls the rate of solution gas bubble formation, which ultimately impacts the critical gas saturation at which the gas phase becomes mobile. The absolute value of the pressure controls the amount of solution gas dissolved in the oil phase. No unusual flow barriers or adjustments to the net-to-gross ratio or modifications to the oil phase viscosity were done to achieve the history match. Rather, given that the model was a generic unit model of the field, the initial gas in place per unit model size was altered (i.e. total gas in the model was altered) until the pressure decline rate was matched. This is a simple and non-radical method to match the gas pool performance that does not alter the underlying geological model obtained from core and log data. It must be borne in mind that the metric used to obtain the gas pool pressure match conducted by Husky was the absolute deviation between the simulation-calculated and field-derived pressure decline rates. Consequently, Husky maintains that its model results are reliable because of the quality of the history match in its model.

### ~~5-~~ **5. Impact of Pressure Depletion on Bitumen Recovery**

EnCana's ongoing production of gas from the gas cap continuously drops the pressure in the gas cap. This pressure drop propagates laterally throughout the gas cap and the subjacent bottom water zone, which underlies gas pools. This decline of the pressure is then transmitted down to the adjacent bitumen reservoir, as proven by Husky's piezometer data.

The decline of the pressure within the bitumen zone causes gas exsolution from the bitumen. The problem is that this loss of gas results in an increase in bitumen viscosity, and in a loss of solution gas drive. The increase in viscosity impedes any bitumen recovery process, and the loss of solution gas removes an important drive mechanism for CSS and HSAGD. As such, the declining pressure in the bitumen will adversely affect the subsequent HSAGD or CSS processes.

The pressure drop in the bitumen referred to above, is directly due to the production of gas from the gas caps. Shutting in the gas production will stop the pressure decline in the gas cap, which will stop the pressure drop in the bitumen reservoir. This will prevent further gas exsolution and its associated negative effects on the thermal recovery processes being proposed.

#### **5.1 EnCana has failed to incorporate realistic geology into ~~their~~its reservoir model.**

EnCana has failed to incorporate a realistic geological model of the Caribou Area into ~~their~~its numerical reservoir simulation model.

##### ~~(a)~~ **(a) Artificial transmissibility barrier between the water and the bitumen**

In its reservoir simulation, EnCana arbitrarily and severely reduces the vertical transmissibility between the water and the bitumen zone below the gas cap by a factor of about 1,000,000.<sup>+820</sup> The result is to artificially create a barrier to vertical flow that extends for almost for the entire areal extent of the gas cap (**Figure 5.1**).

<sup>+719</sup> Husky's response to EnCana information request 2007-01-19, requests of January 12, 2007.

<sup>+820</sup> EnCana Simulation models on CDs; EnCana response to ~~January 12, 2007~~ Husky information requests, of January 12, 2007.

Husky does not incorporate any impermeable transmissibility barriers within its reservoir model. Based on core data, geophysical log data, and Husky's understanding of the depositional environments, there is absolutely no justification for introducing this barrier to vertical flow. In fact, ~~our~~ **Husky's** core analysis data and core work suggests that this shale should have permeability in the 30 to 500 mD range. Husky assigned this sandy shale layer a permeability of 50 mD and a porosity of 10%, based on the core analysis.<sup>19,21</sup> In addition to there being no laterally continuous barriers, the shale itself is permeable.

EnCana's arbitrary and unsupported transmissibility reduction essentially insulates the gas cap from the underlying bitumen, thereby severely limiting the pressure transmission that Husky has demonstrated to be occurring. The result of EnCana's creating an artificial barrier is that pressure drops in the gas cap do not appear to affect the pressures in the bitumen to the full extent. This results in EnCana's model predicting higher bitumen pressures and less gas exsolution. This understates the effect of gas cap depletion on bitumen recovery according to EnCana's model.

It is fundamentally incorrect for EnCana to introduce a "phantom" barrier to vertical flow in the Caribou Area.

**(b) ~~(b)~~ EnCana uses an unrealistically low net to gross ratio of 10% under the gas cap**

By using a low net to gross ratio of 10% under the gas cap<sup>20, 22</sup> EnCana has not only reduced the volume of bitumen in these layers, but has also reduced the horizontal transmissibility by 90%. **(Figure 5.2)**. This, together with the vertical transmissibility barrier described above **(Figure 5.1)**, nearly seals off the gas cap from the bitumen zone below. This reduces the ~~effect~~ **affect** of gas cap depletion on the pressures within the bitumen, thereby reducing the effect of continued gas production on the bitumen reserves. The use of a low net to gross ratio of 10% is unjustifiable.

Husky has used porosities, saturation and thicknesses populated from the geostatistical model based on actual well data. Husky's incorporation of actual data realistically demonstrates the existence of pressure transmissibility between the gas cap and the bitumen.

**(e) ~~(c)~~ The east shale (C-D ~~Mudmud~~) was assigned an unrealistically low permeability that was not supported by laboratory data-**

An examination of EnCana's reservoir simulation input files<sup>21,23</sup> reveals that the East shale (C-D ~~Mudmud~~) was assigned an unrealistically low permeability that was not supported by laboratory data. In fact, laboratory data confirms that it should have been in the 30 to 500 mD range<sup>22,24</sup> instead of the 0.001 mD used in EnCana's simulation. By incorrectly postulating the existence of a low permeability layer, EnCana effectively creates a barrier between the gas cap and the

<sup>19,21</sup> Husky's response to Board information request 2007-01-08-~~requests of January 12, 2007.~~

<sup>20</sup> ~~EnCana Simulation models on CDs, EnCana response to January 12, 2007 Husky information requests.~~

<sup>22</sup> **EnCana Simulation models on CDs; EnCana response to Husky information requests of January 12, 2007.**

<sup>21, 23</sup> **EnCana** January 8<sup>th</sup> KADE Simulation.

<sup>22,24</sup> Husky Oil Operations Limited, *Impact of Gas Cap Depletion on Bitumen Recovery in Cold Lake Clearwater Formation*, January 8, 2007 (~~"January 8<sup>th</sup> Husky Simulation"~~)**2007.**

lower bitumen zone. This in essence separates the reservoir into two units, which precipitates the conclusions of EnCana’s simulation study. Such a low permeability effectively forms a barrier between the gas cap and the lower bitumen zone.

Husky has used conservative shale permeability for the East shale (C-D mudstone) in its simulations, based on the laboratory data given below (provided in ~~IR response 4, Husky’s responses to EnCana information requests of October 17, 2006~~ **2006, question 4**).

Table 1: Laboratory and Simulation Shale Permeabilities and Porosities

	496.3m - 496.4m	499.9m - 500m	Reservoir Simulation
Maximum Permeability, $k_{max}$	526 mD	29 mD	50 mD
Porosity, $\phi$	34.0%	29.8%	10%

By assuming a shale permeability that is 30,000 to 300,000 times smaller than that supported by laboratory data, EnCana has again artificially insulated the underlying bitumen reservoir from pressure changes caused by gas cap depletion. This would severely inhibit the pressure transmission across this shale and into the underlying formations, including the bitumen reservoir. As such, in EnCana’s simulation work, this would minimize gas exsolution within the time frame of the simulation, thereby minimizing the effects of gas cap production on the bitumen reserve.

**~~(d)~~ (d) Permeability data is not representative of the Clearwater Formation**

EnCana’s permeability plots exclude all Husky 2005 data and underestimate the average permeability based on commercial data base values, that replaced horizontal permeability with vertical permeability, and excluded horizontal permeability entirely.

Husky’s reservoir simulation model used permeability data that are representative of the Clearwater reservoir in the Caribou Area, as determined using Husky’s core analysis.<sup>2325</sup> Husky contends that a correct numerical simulation should be based on the best data available.

EnCana claims that its model can still “match” the piezometer data, despite the fact that EnCana uses the wrong permeabilities. One cannot match the pressure data with a flawed model.

**~~(e)~~ (e) EnCana does not include reservoir heterogeneity**

EnCana does not consider reservoir heterogeneity, other than to construct a deterministic model of the reservoir. This is an overly simplistic approach to the reservoir’s heterogeneity.

The heterogeneity of the reservoir is a key factor that must be included in models (Deutsch, 2002<sup>26</sup>). To accomplish this, Husky used geostatistical methods to include an unbiased

<sup>2325</sup> Husky’s response to EnCana January 12, 2007 information requests of January 12, 2007.

<sup>26</sup> Deutsch, Clayton V., “Geostatistical Reservoir Modeling”, (2002), Oxford University Press.

representation of heterogeneity in the reservoir simulation model, using data from four wells located in the central portion of the incised valley. These four wells provide a reasonable representation of the area that is a candidate for thermal recovery, and which is likely to be impacted negatively by depletion of the adjacent gas zone.

Deterministic methods can be used to generate heterogeneity. However, the heterogeneity has to be introduced subjectively with such methods and the result will not be unbiased. The general procedure used by Husky is described in the IR dated January 8, 2007. Even though a single realization was used to build the reservoir model, all realizations generated by geostatistics are considered equiprobable and will demonstrate the same effect. Since the size of the model is significantly larger than the scale of the heterogeneities, it is reasonable to use a single realization. In this context, the model used in this study is representative of uncertainties associated with characterizing the Clearwater Formation.

Husky's geostatistical analysis demonstrates that a reservoir simulation model has been constructed that honours the heterogeneities observed at the four wells, i.e. calcite layers and mud rich bitumen zones are represented in Husky's model. This is superior to a layer cake model where heterogeneity is not included and no well data is honoured as in the EnCana simulation model.

As can be seen from the discussion above, the physics of the process and the geology of the reservoir are represented in Husky's simulation model. Consequently, the results of the reservoir simulation model are a fair representation of the analysis of the risk to the bitumen resource due to gas cap depletion.

#### ~~(f)~~ **(f) Summary**

EnCana's reservoir simulation model requires the creation of various barriers or restrictions to flow between the gas cap and the underlying bitumen. These features are geologically unjustifiable. Gas cap volumes have to be arbitrarily increased in order to match the observed pressure declines.

Husky's reservoir simulation models are consistent with the geology, rock-fluid, and fluid properties of the Clearwater reservoir. The models have no unusual features added to achieve the history match and capture all of the major physics of the thermal processes under evaluation. The models are detailed, with sufficient grid resolution. Husky's models demonstrate that gas cap depletion can impair production of adjacent bitumen resources and that these resources should be conserved.

#### **5.2 EnCana's reservoir simulations are fundamentally flawed.**

EnCana's simulation study submitted January 8, ~~2008~~**2007**, asserts that gas depletion does not cause adverse effects to bitumen production during SAGD and HWCSS operations. However, this model is deficient with respect to geology and ignores a number of physical phenomena that take place during the mentioned thermal processes. Therefore, the conclusions derived from EnCana's study cannot be supported by its numerical simulation model. Husky is of the opinion that its simulation model reflects the reality in the reservoir more closely and, therefore, its results realistically and correctly assess the risks to the bitumen resource.

**~~(g)~~ (a) EnCana has failed to simulate the HSAGD recovery process that Husky intends to employ at the Caribou Area**

EnCana does not address Husky's proposed thermal recovery process, HSAGD which is a combination of the CSS and the SAGD processes where the steam chamber created by each process will interact and eventually form one larger steam chamber. It is not possible to draw conclusions on the HSAGD process based simplistically on the individual results of each of the CSS and the SAGD processes separately.

Husky's simulations directly address the HSAGD and HWCSS processes, which Husky is proposing for the Caribou resource. Husky is in the process of applying to the EUB to implement the novel HSAGD process in the Caribou Area. If HSAGD does not work, Husky will convert the operation to HWCSS. CNRL operates a commercially successful HWCSS in an extension to our reservoir in the Primrose field, immediately to the south of Husky's lease.

Husky has provided results of numerical reservoir models, which demonstrate that continued gas cap production will adversely affect both the HSAGD process and the HWCSS process.

**~~(h)~~ (b) EnCana simulations incorrectly use current gas cap pressures, not the realistic long-term abandonment pressures**

EnCana's simulations consider the effect of gas cap depletion on thermal recovery under current conditions. Therefore, the pressure depletion level in the model does not capture what would happen to the resource in the long term. In EnCana's simulation, gas cap pressures are much higher than they will be upon abandonment. Husky is unable to begin exploiting its Caribou bitumen resource today, and will most certainly not be finished exploiting its resources in the near future. As such, assuming current gas cap pressures for the reservoir simulation is incorrect, as it will minimize the pressure drop in the bitumen due to gas production. This will minimize gas exsolution in the simulation, and therefore the deleterious effect of continued gas cap production on the bitumen recovery processes.

Husky has examined the effect of unabated gas cap production on bitumen recovery. Given the rapid pressure drawdown in the gas cap, it is highly probable that the gas cap will be at abandonment pressure at approximately the same time that Husky would be able to begin its steam injection process. As such, it is far more realistic to use the abandonment pressure of 200 kPa for the gas cap. Husky has done this, and found that gas cap production adversely affects the recovery of bitumen. Further, in Husky's view, ultimate recovery of bitumen has already been harmed with the significant pressure depletion that has occurred.

**~~(i)~~ (c) EnCana uses unsuitable grid block dimensions**

The portion of EnCana's grid that includes the thermal process is completely unsuitable for modelling thermal processes. Grid block widths of 10 m and thicknesses of 3 m are inappropriate for modeling gravity dominated thermal processes. The length scale for conductive heating in oil sands is in the 2 m to 3 m range so this means that grid blocks smaller than these dimensions are required to capture the temperature profile at the edges of the steam chamber.

Husky's approach to modelling the thermal processes is the industry standard. The grid dimensions in the 2D and 3D models prepared by Husky use small ~~grid block~~ grid block sizes to

accurately simulate the thermal profile at the edges of the steam chamber and its advance. The 2D grid blocks are 1 m × 1 m near the wells (width and height). In the 3D model, those dimensions are the same, and the ~~gridblock~~**grid block** lengths are 20 m in the downwell orientation. The 1 m × 1 m dimensions are the industry-accepted standards in the cross-well plane for thermal gravity drainage processes. The 20-m length of the 3D grid blocks is smaller than what is commonly used, e.g.: lengths between 50 m and 100 m. Physically, the thermal length scale in thermal gravity drainage processes is of the order of 2 to 3 m. Thus, to resolve the conductive heating zone around a steam chamber, it is absolutely essential that the grid blocks are smaller than this length scale if the physics of the process are to be accurately represented.

The ~~grid block~~**blocks** are far too large to allow the numerical model to capture the physics of the process. A grid block's average temperature determines its thermally dependent grid block properties. Larger grid blocks take proportionally longer times to heat up in response to steam injection. As such, the bitumen in large grid blocks ~~remain~~**remains** until entire grid block heats up. This is incorrect as it has the effect of causing the large grid block to retain bitumen for extended durations, followed by sudden flushing of bitumen once it finally becomes mobile. A gravity dominated thermal process, such as SAGD and HSAGD as well as later stages of CSS, cannot be modelled correctly in this way.

**(j) (d) EnCana uses an unrealistically low live oil viscosity of 17,000 cP**

EnCana's live oil viscosity of 17,000 cP is far too low and not realistic for the Clearwater reservoir as supported by published data (Mehrotra and Svrcek, 1988<sup>27</sup>; Boberg et al., 1992<sup>28</sup>; Erno et al., 1991<sup>29</sup>). A well-known property such as the oil viscosity should not need to be a variable for history matching.

Husky uses realistic and representative fluid properties and PVT (solubility) data. The oil viscosity is typical for Cold Lake Clearwater reservoir (80,000 cP). These data are considered as relatively certain and therefore would never be considered as a variable history match parameter. The gas solubility and methane viscosity data, projected to equivalent liquid values, are typical of those used for Cold Lake Clearwater reservoir (Mehrotra and Svrcek, 1988<sup>30</sup>).

EnCana's use of a low bitumen viscosity is unrepresentative of the Cold Lake reservoir in the Caribou ~~area~~**Area**. Therefore, simulations conducted with this viscosity will provide unrealistic results.

EnCana's use of an incorrect live oil viscosity results in unrealistically high initial bitumen mobility in the numerical simulation thereby suppressing the effects of gas cap depletion on the bitumen recovery.

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<sup>27</sup> Mehrotra, A.K., and Svrcek, W.Y., "Properties of Cold Lake Bitumen Saturated with Pure Gases and Gas Mixtures", (1988), Can. J. Chem. Eng., 66:656.

<sup>28</sup> Boberg, T.C., Rotter, M.B., and Stark, S.D., "History Match of Multiwell Simulation Models of the Cyclic Steam Stimulation Process at Cold Lake", SPE Reservoir Engineering, August 1992: 321.

<sup>29</sup> Erno, B.P., Christ, J.R., Wilson, R.C., "Depth Related Oil Viscosity Variation in Canadian Heavy Oil Reservoirs", JCPT, May-June 1991.

<sup>30</sup> Ibid, note 27.

**~~(k)~~ (e) EnCana's reservoir simulation model uses relative permeability data that are not representative of the Clearwater**

EnCana's relative permeability data is not representative of the Clearwater reservoir in the Caribou ~~area~~ **Area** as indicated by Husky's special core analysis, which was provided to EnCana<sup>24, 31</sup>. The concave downwards shape of EnCana's oil relative permeability curve is questionable. If the oil relative permeability was independent of multiphase effects (e.g. miscible fluids) one would have a relative permeability curve that is a diagonal straight line. That is, oil would have an equivalent flow capacity proportional to the pore space it occupied. Assigning the oil phase a relative permeability that is higher than its saturation is unrealistic and wrong. Again, EnCana's use of an incorrect oil relative permeability curve results in unrealistically high initial bitumen effective permeability (and mobility) in the numerical simulation thereby suppressing the effects of gas cap depletion on the bitumen recovery.

Husky's reservoir simulation model used laboratory relative permeability curves that have conventional concave-upward shapes<sup>25, 32</sup>. These are representative of the Clearwater reservoir in the Caribou ~~area~~ **Area** and were estimated using Husky's special core analysis.<sup>26, 33</sup>

**~~(l)~~ (f) EnCana failed to use temperature-dependent relative permeability curves**

An examination of EnCana's reservoir simulation input files<sup>27, 34</sup> reveals that EnCana did not use temperature-dependent relative permeability curves to simulate the thermal processes. Any simulation should contain as much known physics of the problem being solved as possible. Furthermore, EnCana states that temperature dependency would make no difference to its conclusions. This statement is not substantiated.

Experimental data clearly show that relative permeability changes with temperature and that this dependency has an impact on the behaviour of the system (Prats, 1982) ~~Prats, Michael. Thermal Recovery. Monograph Volume 7, SPE Henry L. Doherty Series, Dallas, 1982. ISBN: 0-89520-314-6.~~<sup>35</sup> Husky used experimentally determined temperature dependency in its numerical simulation model.<sup>28, 36</sup> This more realistically honours the underlying physics of thermal recovery processes. EnCana did not include this dependence.

Husky maintains that EnCana's model, by failing to utilize the temperature dependency of the relative permeability curves, has resulted in unrealistic relative permeabilities at elevated temperatures which introduced yet another error into their simulation.

The end result will likely be understated gas cap depletion effects.

<sup>24</sup> Husky's response to EnCana January 12, 2007 information requests

<sup>31</sup> Husky's response to EnCana information requests of January 12, 2007.

<sup>25</sup> Husky's response to EnCana January 12, 2007 information requests

<sup>32</sup> Husky's response to EnCana information requests of January 12, 2007.

<sup>26, 33</sup> Husky's response to EnCana January 12, 2007 information requests of January 12, 2007.

<sup>27, 34</sup> EnCana Simulation Models on CD; EnCana's response to Husky January 12, 2007 information requests of January 12, 2007.

<sup>35</sup> Prats, Michael. "Thermal Recovery", Monograph Volume 7, SPE Henry L. Doherty Series, Dallas, 1982. ISBN: 0-89520-314-6.

<sup>28, 36</sup> Husky's response to EnCana January 12, 2007 information requests of January 12, 2007.

**~~(m)~~ (g) EnCana failed to use dilation during CSS**

EnCana is not correctly simulating the CSS process in bituminous ~~oilsands~~ **oil sands**, which requires fracture injection pressures and dilation to fully model the relevant physics. EnCana has allowed for some limited dilation in its input file<sup>2937</sup> for the reservoir simulator. However, EnCana fails to inject at a sufficiently high steam pressure, or threshold pressure, to invoke that dilation. CSS injection volumes are low, and injection pressures at 1000 m3/d very low compared to field observations.

Without steam injection above fracturing pressure, and permitting dilation and enhanced permeability at that pressure, EnCana cannot realistically model HSAGD or CSS steam injection. Furthermore, without dilation there is no compaction drive during the production phase of each CSS cycle. EnCana has not realistically modelled CSS production.

In reservoirs having significant initial injectivity, the CSS process can succeed with steam injection below the fracture pressure, as is done in California and Venezuela (Butler, 1991<sup>38</sup>). However, in reservoirs with heavier oil or bitumen such as Cold Lake, there is limited initial injectivity. For commercially viable injection and production rates, steam must be injected above the fracture pressure in order to fracture the ~~oilsand~~ **oil sand** formation, as is now being done in the CNRL Primrose CSS project to the south of Husky's lease (CNRL, 2005<sup>39</sup>). Fracturing the formation exposes a much larger area of ~~oilsand~~ **oil sand** to steam, and results in an extensive zone of hyper-permeability along which fluids can flow to and from each well. The steam injection in the Cold Lake reservoir creates fractures that propagate horizontally, therefore the overburden gradient is the fracture gradient.

In STARS, this dilation in the CSS process is modeled using the "quad" model, which permits both elastic deformation and irreversible dilation. In the quad model, the dependences of porosity on pressure, and permeability on porosity, are modeled. Once the injection pressure exceeds a threshold pressure representing the fracture pressure, a permeability multiplier progressively enhances the permeability. While this has been incorporated into the models of Husky and EnCana, the steam injection pressure used by EnCana is below its threshold pressure. As such, dilatancy is never invoked.

Furthermore, outside of the initial fracture plane, dilatancy should occur in the ~~oilsand~~ **oil sand** matrix, but to a lesser degree. This is modeled by Husky, in which a permeability multiplier of 5 is achievable, but which is absent from the EnCana model. As such, the EnCana model has little to no dilatancy.

Consequently, EnCana's results are irrelevant to CSS process and to its hybrid, HSAGD in Alberta's oil sands.

**~~(n)~~ (h) EnCana's "horizontal" wells are slanted from heel to toe**

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<sup>2937</sup> EnCana Simulation Models on CDs; EnCana's response to Husky's January 12, 2007 information requests of January 12, 2007.

<sup>38</sup> Butler, Roger M., "Thermal Recovery of Oil and Bitumen", (1991), Prentice Hall Inc., N.J., U.S.A., 528.

<sup>39</sup> CNRL, "Canadian Natural Resources Limited's Primrose, Wolf Lake and Burnt Lake Annual Presentation to the EUB", January 7, 2005, (power point file).

EnCana's wells dip from heel to toe (**Figure 5.3**)<sup>30 40</sup> The gravity drainage aspects of SAGD, HWCSS, and HSAGD require the producers to be horizontal for optimal performance. With such a dip, the producer wells will be drowned, i.e. maintain a liquid level far above the completion screens. This is inefficient and ineffective in draining the reservoir.

This well trajectory suggests that EnCana's reservoir simulation well placement does not reflect commonly accepted horizontal well trajectories typically used in reservoir simulation. That is, it does not reflect what is practiced in reality. It is not known what actual impact this unusual well configuration has on EnCana's simulation study results. However, wells that have up to 7 m differential elevation in a reservoir that is only 30 m thick at most do bring into question EnCana's simulation results.

Husky's wells have a normal trajectory, being truly horizontal in the simulation model. They are modeled as simple horizontal source and sinks using commonly accepted well placement practices at the centre of the grid blocks. Although simpler in specification, the Husky wells are modelled better. The Husky simulation will be more representative of field operations than the EnCana simulation using slanted wells.

**~~(o)~~ (i) EnCana's wells have erratic partial completions**

EnCana's wells are not completed in all grid blocks penetrated (**Figure 5.3**).<sup>31 41</sup> As such, the wells cannot accept flow from all grid blocks and therefore do not realistically model the processes.

Husky's wells are at the centre of the grid blocks. The Peaceman R-factor (or well index) was determined by the simulator, as is common practice. The wells were completed in every block penetrated by the well. This is far more representative of field practice and therefore the Husky model is superior in this regard.

**~~(p)~~ (i) EnCana uses inappropriate well spacing for its reservoir simulation**

An examination of EnCana's reservoir simulation input files<sup>32 42</sup> reveals that the well spacing used in the simulation model is unrealistically large and does not reflect the current practice in SAGD or CSS. As such, EnCana's results are not relevant to Husky's proposed process for this resource. Placing wells pairs at such large distances makes it impossible for the well pairs to interact.

It should be noted that interaction between the SAGD well pair and the CSS well is one of the main features of the HSAGD process. Consequently, EnCana's reservoir simulation well placement does not reflect what is practiced in reality and, therefore, its results are irrelevant to the HWCSS process, where typical interwell distances of 80 to 180 m are employed, ei.gg. the Primrose reservoir immediately south of Husky's lease.

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<sup>30 40</sup> EnCana Simulation Models on CDs; EnCana's response to January 8, 2007 information requests of January 12, 2007.

<sup>31 41</sup> EnCana's response to January 8, 2007 information requests of January 12, 2007.

<sup>32 42</sup> EnCana January 8<sup>th</sup> KADE Simulation,

In contrast, the well spacing used in Husky's reservoir model is 100 m. This is typical of SAGD inter-wellpair spacing and falls in the range of HWCSS spacing used commercially by CNRL and Imperial Oil.

**(e)- (k) Poor quality history match of pressures and production**

The description of EnCana's history match procedure in the EnCana January 8<sup>th</sup> KADE Simulation reveals that EnCana made numerous attempts to arbitrarily adjust the input data to obtain the history match of the pressures and production data. Some of these adjustments are discussed above (for example, artificial viscosity reduction, phantom transmissibility barriers, gas volume adjustments). Despite these attempts, the history match plots given by EnCana demonstrate clearly that the history match of pressures and production is still of very poor quality:

- most piezometer pressures are not matched,
- pressure trends were not matched, and
- total water production is not matched.

The failure of the history match brings into question the totality of the reservoir simulation model and subsequent results that are being used to justify EnCana's overall conclusion that continued gas production will have no effect on bitumen recovery.

EnCana acknowledges that pressure matches in the north were lower and to the south were higher and then asserts "on average" the pressures were matched<sup>33, 43</sup>. Typically in history matching, the absolute deviations between simulation and field data are minimized and not averaged. This means that the errors are additive. The "history match" and the alterations made to the input data to achieve the "tuned" model are of dubious quality. Therefore, any prediction based such a model is questionable and unreliable. Again, the failure of the history match makes the reservoir simulation model, its results, and any conclusions drawn from its results, meaningless.

**(r)- (l) Summary**

The quality of EnCana's history match, coupled with the other issues discussed above, leads Husky to the conclusion that the EnCana model and simulation results are unreliable and incorrect. Therefore, EnCana's conclusion from ~~its simulation study~~ the EnCana January 8<sup>th</sup> KADE Simulation, namely that gas cap depletion has no impact on the bitumen recovery, is likewise questionable and unreliable.

In contrast, Husky used a more rigorous geological model and modeled the correct physics of the process using realistic scenarios. Husky found that gas production adversely affected the bitumen recovery process due to pressure depletion in the reservoir, which caused gas exsolution. Husky's results should be accepted over EnCana's.

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<sup>33</sup> January 8<sup>th</sup> KADE Simulation

<sup>43</sup> EnCana January 8<sup>th</sup> KADE Simulation.

**~~6-6. Husky's Response To Eneana~~ EnCana's Additional Simulations (Eneana EnCana IR  
To Husky January 24, 2007)**

Additional simulations were run by EnCana with Husky's 2D data decks where a total liquid constraint (750 m<sup>3</sup>/day) was placed on the HWCSS production wells. EnCana's results from these additional simulations for the depleted and nondepleted cases ~~was~~were very similar.

In Husky's original runs, without the total liquid constraint, a large fraction of the oil was produced in the first few days of the production interval of the cycle. In EnCana's runs, the total liquid constraint limited the high oil rate that previously occurred in the first few days of each production cycle, so total production was impaired. In duplicating EnCana's runs, Husky determined that the runs with the original operating strategy new liquid constraint led to high gas production rates and water accumulation in the steam chambers which impaired oil production. Obviously, operating with a strategy where gas and potentially steam production is high and forming a zone largely saturated with water due to excessive steam injection is inefficient. Therefore, the operating conditions of the original model were not optimized and the results do not reflect the true deliverability of the reservoir.

After cap gas depletion and solution gas exsolution, the viscosity of the oil phase is higher. Thus, the mobility of the oil is lower and as a result, it would be expected that less oil would be produced from the depleted case.

Husky's current 2D simulations with a liquid constraint and a modified operating strategy using the same input parameters as before have more realistic production rates (**Figure 6.1**). Note that further optimization of the operating strategy is possible. With limited optimization, these last simulations confirm the harmful effects of gas cap depletion on bitumen recovery as shown by the original runs. The differences in the cumulative volumes are large in the early cycles, which ~~suggests~~suggest that the economics of the process would be severely impacted by depletion of the gas pools. Most of the effort went into optimizing the HWCSS performance; further optimization of the HSAGD could be achieved. Therefore, the results shown in **Figure 6.1** are only a start and the marked difference between the depleted and undepleted case would only widen with further optimization of the process.

~~7.~~

**7. Conclusion**

As detailed in this Reply Submission and Husky's previous submissions, Husky submits that resource conservation requires that EnCana's gas production in the Caribou ~~area~~ **Area** must be shut-in and no further gas production allowed. Ongoing gas production in the Caribou Area has a significant impact on ultimate bitumen recovery. Therefore, Husky ~~seeks~~ **requests the Board order:**

- a. ~~The~~ **all of the** following wells ~~all~~ be immediately shut-in:

Number	Well ID	Perforation	Top Depth	Base Depth	Pool
1	00/03-11-070-06W402	2	437.0	438.0	CLWR Undef
2	00/05-10-069-04W402	4	500.3	501.3	CLWR D
3	00/05-13-069-06W400	3	476.0	480.0	CLWR EE
		4	468.0	470.0	CLWR EE
4	00/05-16-070-05W400	3	425.0	425.5	CLWR S
5	00/05-22-070-05W400	2	422.5	423.5	CLWR S
6	00/06-20-069-05W400	1	445.2	446.5	CLWR G
7	00/06-21-070-05W400	1	417.0	422.0	CLWR S
8	00/06-28-069-04W402	1	427.0	430.0	CLWR B
		2	423.0	425.0	
9	00/11-33-068-05W400	1	450.5	452.0	CLWR CC
		2	462.0	463.0	CLWR DD
10	00/12-04-070-04W400	1	427.8	428.3	CLWR
11	02/16-28-068-05W400	1	453.5	454.5	CLWR CC
		2	464.5	465.5	CLWR DD
12	03/08-03-069-04W402	2	495.5	497.5	CLWR D
13	00/10-33-068-04W402	2	485.0	486.0	CLWR D
14	00/08-26-069-05W400	1	435.5	436.5	CLWR Undef
15	00/11-13-070-05W400	1	442.5	445.0	CLWR Undef
16	00/08-36-069-05W400	2	441.0	444.0	CLWR B
17	00/06-32-069-04W402	7	430.0	434.0	CLWR B
18	00/06-19-069-04W402	2	440.8	441.8	CLWR B
19	00/05-29-069-04W400	3	435.4	438.0	CLWR B
20	02/10-35-069-05W400	1	435.0	436.5	CLWR B
21	00/05-21-069-04W400	1	443.5	449.0	CLWR B
22	00/06-17-069-04W400	1	445.0	447.0	CLWR B
23	00/06-12-070-05W400	1	434.0	440.0	CLWR B
24	00/10-06-070-04W400	3	428.5	433.5	CLWR B

		4	436.0	438.0	
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**9.** \_\_\_\_\_

**List ~~Of~~ of Figures**

- Figure 2.1 Regional Facies Distribution and Interpretation
- Figure 2.2 Husky Caribou East-West Stratigraphic Cross Section
- Figure 2.3 East Regional Shale Core Photograph
- Figure 2.4 Valley Margin Shale Core Photograph
- Figure 4.1 Pressured Depletion in Husky 2D Reservoir Simulation Model
- Figure 4.2 Pressure Depletion in Husky 3D Reservoir Model
- Figure 5.1 Map of Vertical Transmissibility Factory (TRANSK) from Encana Model
- Figure 5.2 View of Net to Gross Distribution in ~~Encana~~ EnCana Model
- Figure 5.3 View of Wells in ~~Enacna~~ EnCana Model
- Figure 6.1 Results of Husky Simulation Cases