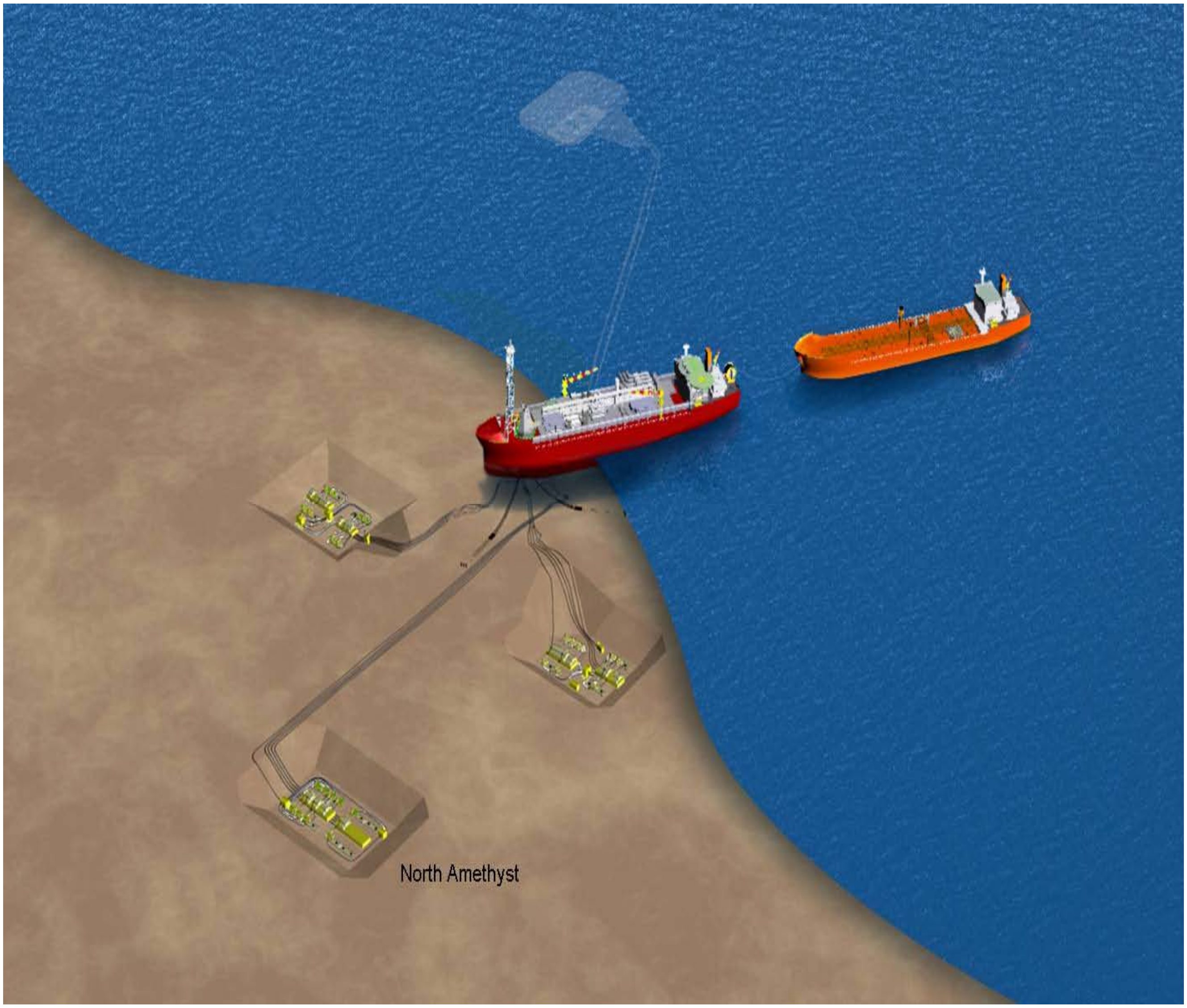
Husky Energy

# Development Plan

## North Amethyst Satellite Tie-back to *SeaRose FPSO*




**Cover graphic: Tie-back Option A**

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# Executive Summary

Husky Oil Operations Limited (Husky) and its partner Petro-Canada propose to undertake development of the North Amethyst field in the Jeanne d'Arc Basin on the Grand Banks within the Significant Discovery Licences (SDL) 1024 and 1044, Production Licence (PL) 1006 and Exploration Licence (EL) 1045.

Husky identified two alternatives for development of the North Amethyst field: a subsea tie-back system to the existing *SeaRose FPSO* facility or a subsea development to a new steel ship-shaped FPSO facility. The investigation of the alternative production systems concluded that the preferred option for the North Amethyst field development should be based on a subsea tie-back system to the *SeaRose*. The base production profile for the White Rose Development predicts that the *SeaRose* will reach the end of plateau in 2008. As spare production capacity becomes available on the *SeaRose,* a subsea tie-back will make use of this future capacity, thereby maximizing utilization of the existing infrastructure and lowering the threshold for small field developments. This option is the more viable economic alternative for North Amethyst.

The North Amethyst Satellite Tie-back will consist of construction of a new glory hole with a capacity of up to sixteen wells. The tie-back is expected to require from seven to ten wells consisting of four production and three to six water injection wells. Further field optimization and planning will determine the final well count.

The flow line routing for the tie-back is subject to FEED engineering, flow assurance studies and further economic evaluation. The results of these studies will determine the exact routing from the North Amethyst glory hole to the *SeaRose*. The field will, therefore, either be tied back from the glory hole directly via new flow lines and new dedicated riser systems (Option A) or via new flow lines to the existing subsea infrastructure (Option B).

North Amethyst will be produced from the Ben Nevis Formation at approximately 600 m shallower then the South Avalon Pool. The North Amethyst field is separated from the Terrace by the West Terrace Fault which occurred after the deposition of the Ben Nevis sands. The difference in the overall stratigraphic thickness between the Terrace and North Amethyst is almost entirely seen within the Nautilus shales as the Ben Nevis reservoir is similar in thickness to South Avalon Pool wells. The oil column is overlain by a gas cap for which the properties are very similar to that of South Avalon Pool. The higher porosity and permeability values of North Amethyst are largely attributed to less compaction. Secondary recovery is planned through water injection support.

The glory hole construction and subsea installation activities associated with developing the tie-back will be similar to those employed for the existing White Rose Development.

The total predicted recoverable oil from North Amethyst is 70 mm bbls on a P50 basis (estimated as of August 2007). The cost of the North Amethyst Satellite Tie-back is estimated to be approximately $1.3 billion (CDN) for either option discussed in this Plan.

Required modifications to the *SeaRose* in support the North Amethyst Satellite Tie-Back are detailed in *White Rose Development Plan Amendment SeaRose FPSO Modifications* (Husky Document No. SR-SRT-RP-0003), submitted concurrently with this document. A Benefits Plan (Husky Document No. SR-SRT-RP-0006).and a Concept Safety Analysis (Husky Document No. SR-HSE-RP-0003) have been submitted to the C-NLOPB as separate reports.

As further information becomes available, plans will be modified and refined. Submission of this document does not commit Husky to proceed with the tie-back. It should also be noted that this potential tie-back is currently in the preliminary front end engineering (FEED) phase and has not yet been sanctioned by the White Rose partners.

# 1.0 Project Overview

## 1.1 Purpose and Scope of the Project

Husky Oil Operations Limited (Husky), as the Operator and in joint-venture with Petro-Canada (PetroCan), submitted a Development Application (DA) for the White Rose Development to the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) in January 2001. This DA was prepared pursuant to the Canada-Newfoundland Atlantic Accord Implementation Act and the Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act. The C-NLOPB approved the White Rose DA in December 2001. The Production License PL 1006 applies to the existing White Rose Development.

Oil production from the *SeaRose* Floating, Production, Storage and Offloading (*FPSO*) is predicted to begin to decline in 2008. As spare production capacity becomes available in *SeaRose,* a subsea tie-back will make use of this future capacity, thereby maximizing utilization of the existing infrastructure and lowering the threshold for small field developments. To this end, in September 2006 an Amendment to the White Rose Development Plan was submitted to the C-NLOPB. The Amendment outlined plans for development of the South White Rose Extension (SWRX) area located approximately four km south of the current Southern Drill Centre (SDC). This application is still under review by the C-NLOPB. Development of the North Amethyst Satellite Tie-back will also provide additional production to fill available capacity on the *SeaRose*.

This document is being submitted to outline a proposed tie-back of a satellite field to the *SeaRose*. Husky and its co-venturer Petro-Canada propose to undertake development of the North Amethyst field in the Jeanne d'Arc Basin on the Grand Banks within the Significant Discovery Licences (SDL) 1024 and 1044, Production Licence (PL) 1006 and Exploration Licence (EL) 1045. The tie-back will consist of construction of a new glory hole with a capacity of up to sixteen wells. The North Amethyst Satellite Tie-back is expected to require from seven to ten wells consisting of four production and three to six water injection wells. Further field optimization and planning will determine the final well count.

Husky identified two options for development of the North Amethyst field: a subsea tie-back system to the existing *SeaRose* FPSO facility or a subsea system to a new steel ship-shaped FPSO facility. Husky investigated options for a new build FPSO versus a tanker conversion and compared key risks, schedule impacts and development costs for each alternative. The investigation concluded that the North Amethyst field should be developed by subsea tie-back to the *SeaRose*. The base production profile for the White Rose Development predicts that the *SeaRose* will reach the end of plateau in 2008. As spare production capacity becomes available on the *SeaRose*, a subsea tie-back will make use of this future capacity, thereby maximizing utilization of the existing infrastructure and lowering the threshold for small field developments. This option is the more viable economic alternative for North Amethyst.

The flow line routing for the tie-back is subject to FEED engineering, flow assurance studies, and further economic evaluation. The results of these studies will determine the exact routing from the North Amethyst glory hole to the *SeaRose*. The field will, therefore, either be tied back from the glory hole directly via new flow lines and new dedicated riser systems (Option A) or via new flow lines to the existing subsea infrastructure (Option B).

Should Option A tie-back be selected, modifications to the *SeaRose* turret, buoy and topsides to accommodate the new flowlines and umbilical from the North Amethyst Drill Centre (NADC) will be required. The details of the *SeaRose* modifications are provided in the White Rose Development Plan Amendment (Husky Document No. SR-SRT-RP-0003) submitted concurrently with this document.

As further information becomes available, plans will be modified and refined. Submission of this document does not commit Husky to proceed with the tie-back. It should also be noted that this potential tie-back is currently in the preliminary FEED phase and has not yet been sanctioned by the White Rose partners.

The White Rose oil field is located on the Grand Banks, approximately 350 km east of the Island of Newfoundland on the eastern edge of the Jeanne d'Arc Basin (Figure 1-1).


**Figure 1-1 White Rose Oil Field**

The White Rose SDL consists of both oil and gas fields or pools, including the South Avalon Pool, the North Avalon Pool, and the West Avalon Pool. The main oil reservoir at White Rose is the Ben Nevis - Avalon Formation sandstone.

The White Rose Development utilizes the *SeaRose FPSO*, an FPSO facility with ice avoidance capacity (disconnectable turret) and subsea wells. Crude oil is transported to market by shuttle tankers. Oil production from the White Rose field commenced in November 2005.

Subsea installations for the initial development scope (South Avalon) consisted of a potential of 21 subsea wells. As of July 2007, 17 wells have been drilled and completed (nine water injection, one gas injection, and seven oil producers). The base plan is for 18 wells including another gas injection well. The wells are manifolded and connected to flowlines and flexible risers which terminate at the FPSO.

The location of the North Amethyst field is shown in Figure 1-2.

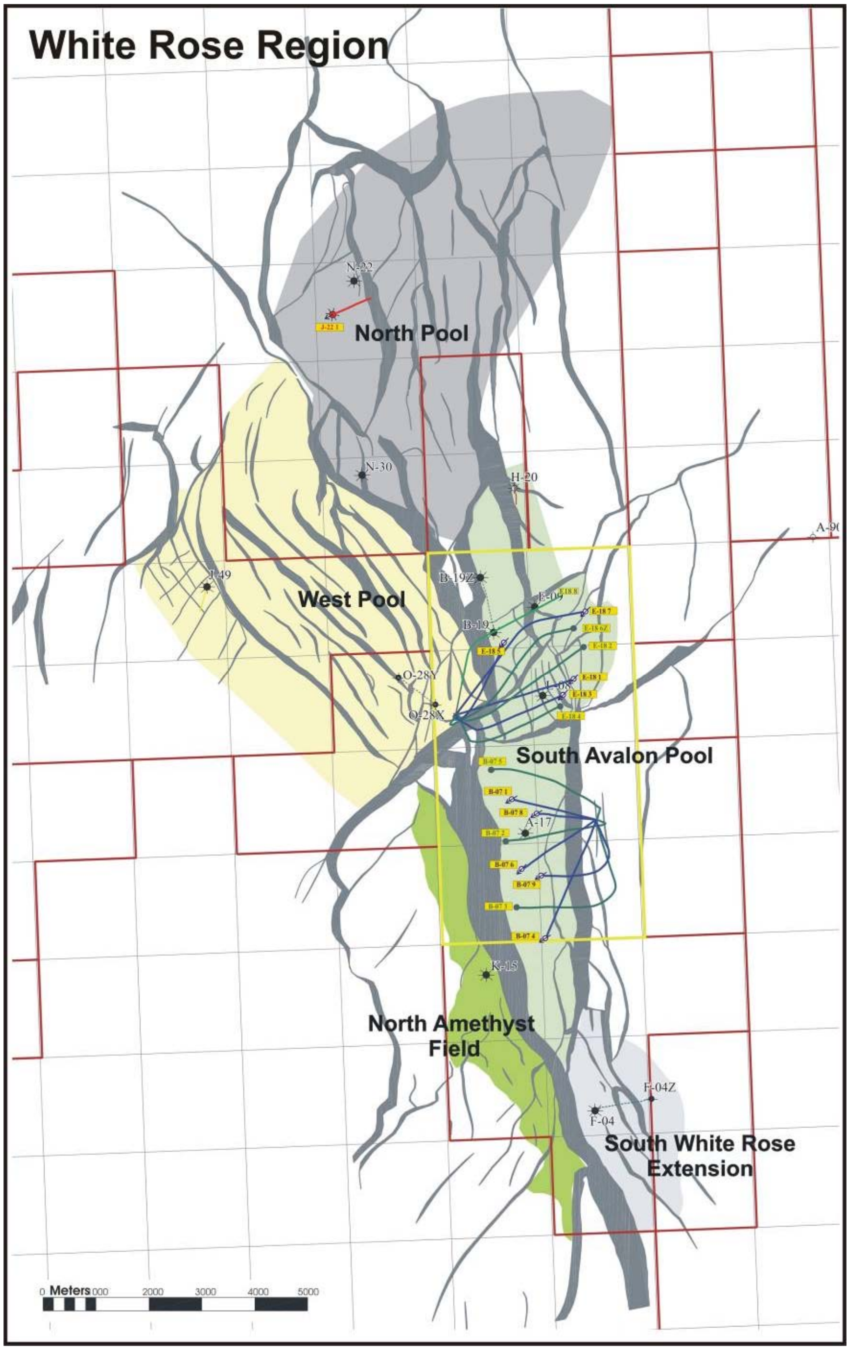



**Figure 1-2 Location of North Amethyst Field**

## 1.2 History of the Field Discovery

In 2006 the North Amethyst K-15 exploration well, to the southwest of the White Rose field, was drilled on White Rose Significant Discovery Licence 1044 to a depth of 2,566 metres.

## 1.3 Co-Venturers and Their Respective Interests

Husky is developing the North Amethyst Satellite Tie-back with its co-venturer Petro-Canada. The average interests of the co-venture parties in the project are:

- Husky Oil Operations Ltd. 72.5 percent
- Petro-Canada 27.5 percent

## 1.4 Land Ownership

The North Amethyst field is situated on Significant Discovery Licences (SDL) 1024 and 1044, Production Licence (PL) 1006 and Exploration Licence (EL) 1045. Husky and its co-venturer Petro-Canada hold the same working interest in the three licences. Husky has submitted a Commercial Discovery Declaration for North Amethyst which will be followed by a Production Licence to include the portion of North Amethyst on EL 1045.

## 1.5 Management

Husky, as the White Rose Field Operator, will manage the development of the North Amethyst Satellite Tie-back and subsequent operations. The Operator's authority, role, responsibility and reporting requirements are outlined in the White Rose Exploration, Appraisal, Development and Operating Agreement that is already in place.

## 1.6 Canada-Newfoundland and Labrador Benefits Commitments

As with the core White Rose Development, Husky's *Canada-Newfoundland and Labrador Benefits Guidelines* will continue as a governing document to guide how Husky and its contractors conduct business. A Benefits Plan for the North Amethyst Satellite Tie-back has been prepared and submitted to the C-NLOPB as a separate report (Husky Document No. SR-SRT-RP-0006).

## 1.7 Schedule

A high level preliminary conceptual schedule for development of the North Amethyst Satellite Tie-back is provided in Figure 1-3.

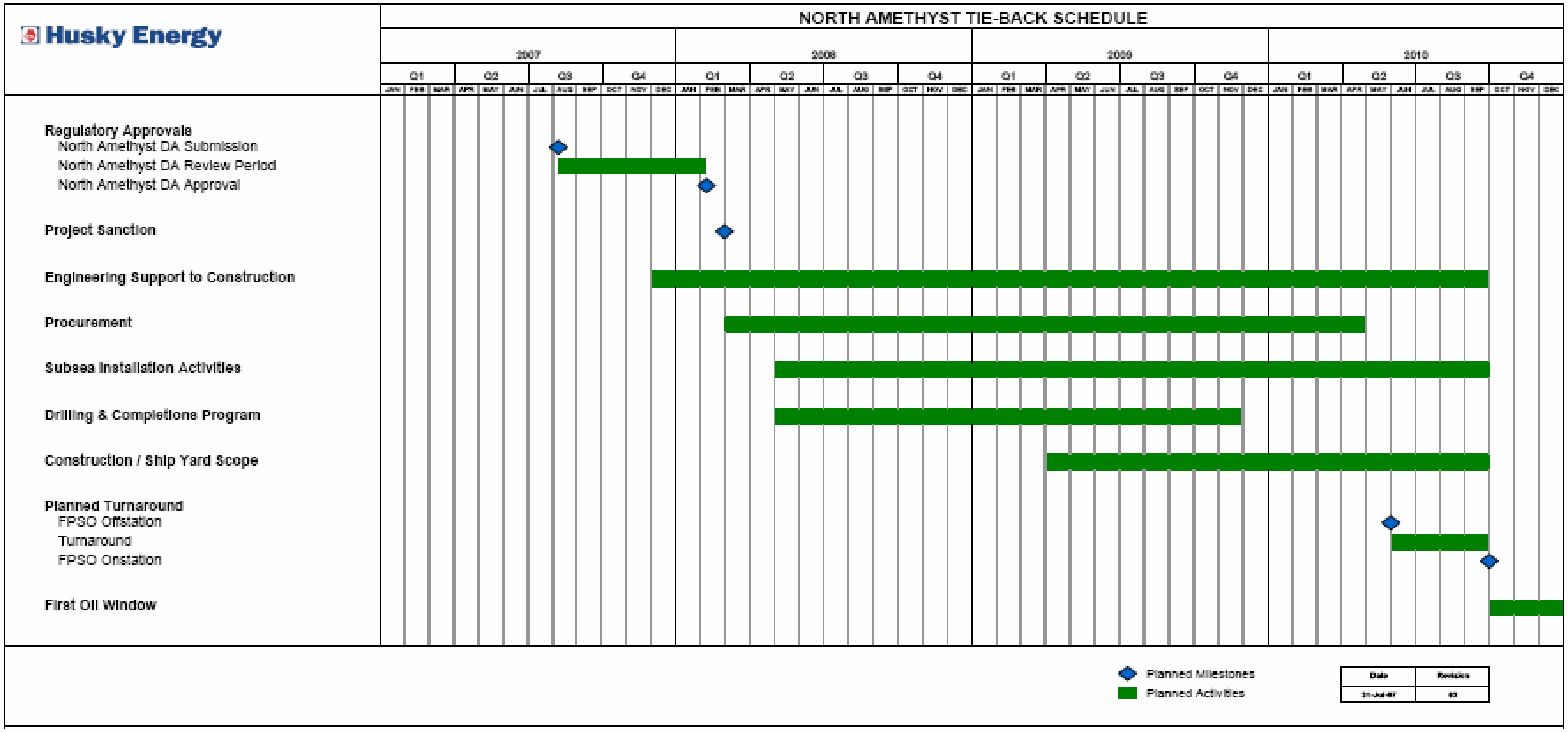



**Figure 1-3 Preliminary Conceptual Development Schedule for the North Amethyst Satellite Tie-Back**

# 2.0 Geology, Geophysics and Petrophysics

The North Amethyst field is located on the eastern margin of the Jeanne d'Arc Basin. The Jeanne d'Arc basin is one of a series of interconnected sedimentary basins which were formed on the Grand Banks of Newfoundland as a result of the Early Mesozoic break-up of the Pangea continental mass and the birth of the Atlantic Ocean (Figure 2-1).

The Jeanne d'Arc basin is a fault-bounded basin trending north-north-west to south-south-east encompassing an area of roughly 10,500 $km^2$ (Figure 2-2). The North Amethyst field, on the eastern margin of the basin, lies in close proximity to the Voyager Fault, which forms the southeastern edge of the basin.

The current geologic interpretation used for geological modeling is an updated version of that presented in the DA for the White Rose oilfield submitted in 2001. At the time of the White Rose submission there were seven delineation wells in the greater White Rose region that included the South, West, and North White Rose sub-regions. The updated model currently includes all wells within the core White Rose development region as well as the F-04 and F-04Z wells drilled in the SWRX region in 2003 (Figure 2-3). This brings the total number of wells in the region to 31. The F-04 and F-04Z penetrations of the reservoir section in the SWRX region confirmed the presence and quality of the Ben Nevis reservoir to the south of the White Rose core development, further delineating the shoreface trend. The K-15 well was drilled into the North Amethyst structure confirming the presence and quality of the reservoir to the west of the main producing pool (Figure 2-3).

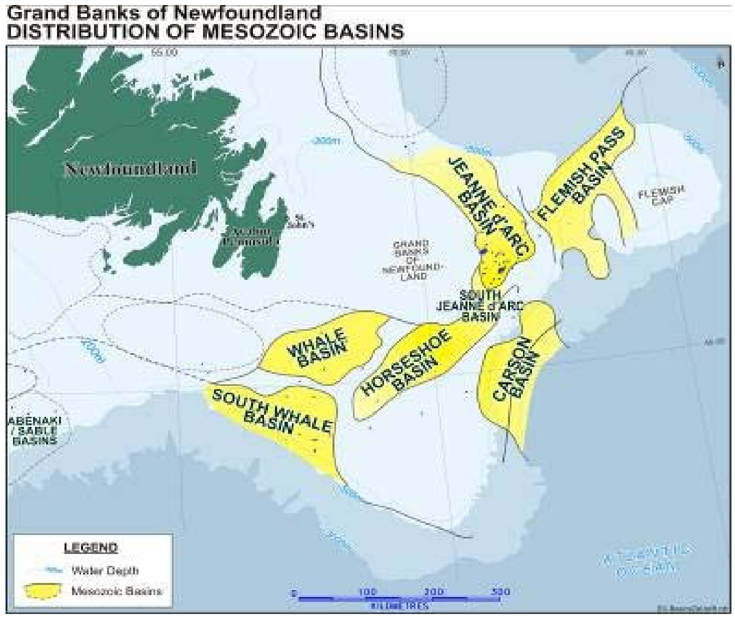



**Figure 2-1 Grand Banks of Newfoundland Distribution of Mesozoic Basins**


**Figure 2-2 Major Structural Elements, Jeanne d'Arc Basin**

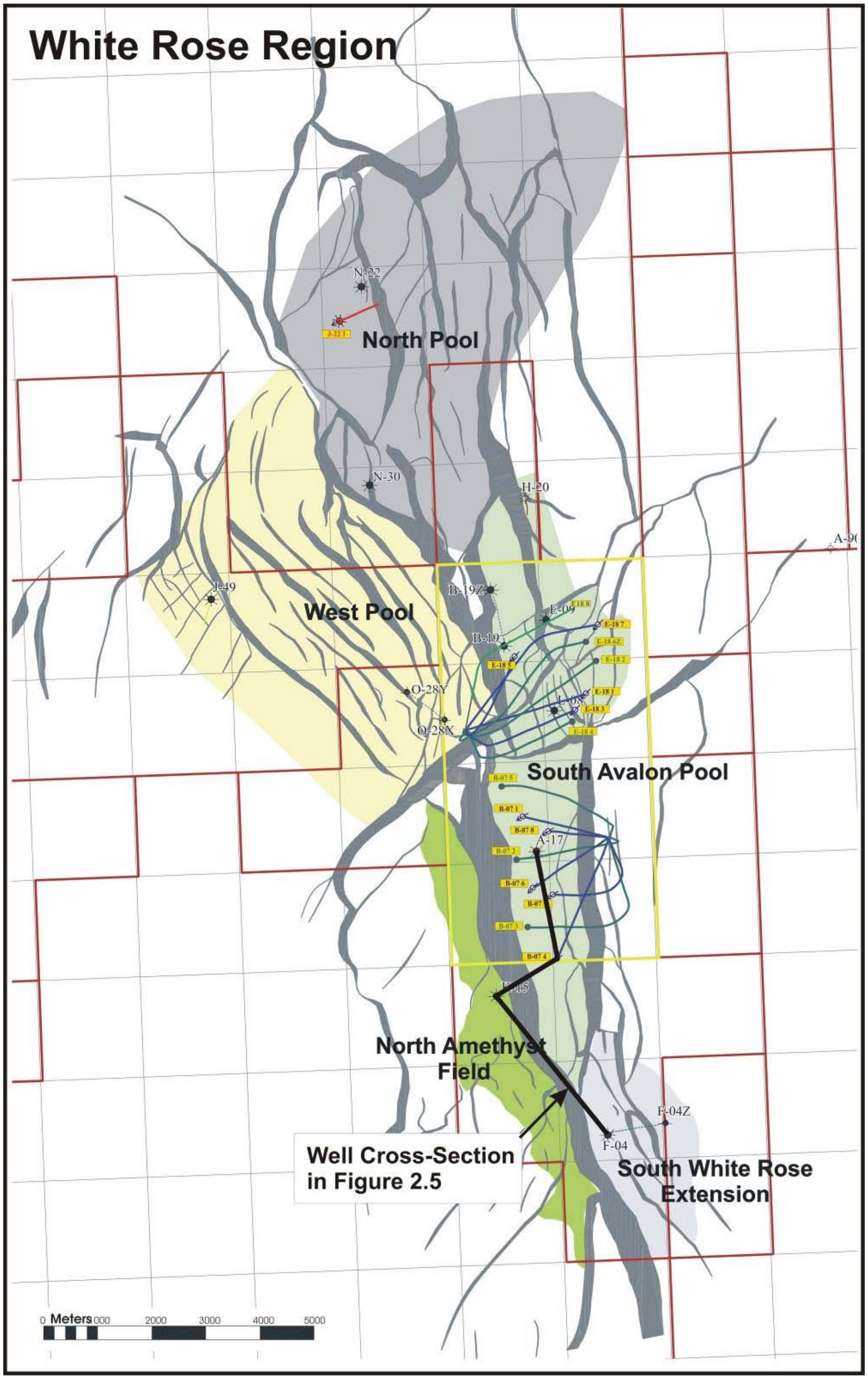



**Figure 2-3 Location Map of the North Amethyst Field in the Greater White Rose Region**

Development drilling has provided six vertical/deviated penetrations of the Ben Nevis reservoir (J-22 1, E-18 1, B-07 1, B-07 4, B-07 6, and B-07 8) and 11 horizontal penetrations (E-18 2, E-18 3, E-18 4, E-18 5, E-18 6, E-18 7, E-18 8, B-07 2, B-07 3, B-07 5 and B-07 9). Although information from these wells has provided a concentrated data set for modeling purposes, no unexpected results were encountered. The same is true for the delineation wells B-19, B-19Z and O-28Y. The O-28X well, drilled in the summer of 2006, encountered a fault which was not previously mapped. This fault has now been incorporated into the geological model. As a result, no material changes have been made to the depositional framework for the Ben Nevis Formation as proposed in 2001. Furthermore, no material changes have been made to the static geological model as provided in the White Rose DA. The K-15 well encountered Ben Nevis sandstone approximately 600 m shallower then the main producing White Rose field. The higher porosity and permeability values evident in the K-15 well were largely attributed to less compaction. These values are incorporated into the geological model.

The results of the F-04 and F-04Z wells have been tied to seismic data, and F-04 was used in developing the velocity model for depth conversion. Aside from these minor shifts, the geophysical interpretation has not materially changed since the original White Rose DA submission. The K-15 well came in very close to prognosis, again confirming the validity of the depth conversion in the greater White Rose region.

However, a note of clarification is required regarding the naming convention used in the White Rose DA. The reservoir section was termed the ‘Avalon’ in the 2001 submission. It is now believed the reservoir section lies upon the mid-Aptian unconformity, is middle Aptian-Albian in age, and is an overall fining-upward package within a transgressive systems tract, and thus is likely to be the Ben Nevis Formation. Reasons for this are twofold. First, biostratigraphic evidence suggests that the reservoir package at White Rose rests unconformably upon Barremian to early Aptian-aged strata (zonations as in Ainsworth et al.). Second, seismic defines Jurassic through lower Cretaceous subcrop edges, indicating that the mid-Aptian unconformity at the base of the reservoir is an angular unconformity. When this is taken in a regional context, the reservoir section at White Rose correlates favorably to the back-stepping transgressive Ben Nevis Formation. Note that with the two naming conventions spanning the work done in this compilation, Ben Nevis (BN) and Ben Nevis-Avalon (BNA) are used interchangeably throughout this report.

## 2.1 Geology

Current geological understanding places the Ben Nevis reservoir in North Amethyst in a region of shallow marine lower shoreface deposition trending southwest-northeast (Figure 2-4). This has been confirmed by the additional well penetrations drilled since the White Rose DA submission. Internal divisions of the Ben Nevis formation represent seven parasequence sets: the BN_ramp, BN_Shell_Cmt, BN_1, BN_2, BN_3, BN_4, and BN_5 from base to top respectively (Figure 2-5). These units correspond with coarsening upwards cycles evident in distal wells (such as H-20), but lose resolution where the net-to-gross ratio is high, and sand-on-sand intra-formational contacts exist. In these regions, including North Amethyst, the internal divisions are highly interpretational, but can be correlated through the area nonetheless.

Figure 2-6 illustrates the sequence stratigraphic framework of the Ben Nevis Formation in the North Amethyst field. Armentrout defines the parasequence set as 4$^{th}$ order cycles that generally are 6 m to 250 m thick, 50 km$^2$ to 50,000 km$^2$ in aerial extent, and have a depositional duration of 0.1 to 0.5 Ma. Based on the assumption that these types of cycles apply to the Ben Nevis at White Rose, then the main correlation surfaces used throughout the field (in red on the cross section A-A' in Figure 2-5) are marking 4$^{th}$ order flooding surfaces bounding the parasequence sets outlined in Figure 2-6. The highly interpretive small scale cycles defined by the grey correlation lines in Figure 2-6 are then representative of 5$^{th}$ order flooding surfaces that frame parasequences. These finer scale surfaces are used only to assist in defining the surfaces associated with the parasequence set division. This maintains consistency in correlation and improves the static modeling framework, and has been incorporated into the updated reservoir model for the SWRX area.

The North Amethyst field is situated on a large rotated fault block adjacent to the Terrace portion (A-17 block) of the White Rose South Avalon Pool. The principal reservoir is the Lower Cretaceous Ben Nevis Formation, which consists of predominantly very fine-grained quartzose sandstones deposited in a shallow marine shoreface setting. The North Amethyst field is separated from the Terrace by the West Terrace Fault. This fault occurred after the deposition of the Ben Nevis sands and exhibits around 600 m of throw. The difference in the overall stratigraphic thickness between the Terrace and North Amethyst is almost entirely seen within the Nautilus shales as the Ben Nevis reservoir is similar in thickness to South Avalon Pool wells (Figure 2-5).

The gross sandstone thickness exceeds 200 meters while the net to gross ratio exceeds 90% in some areas of the field.

As presented in the White Rose DA, three main facies associations (FA) and several diagenetic components are identified at White Rose and these extend into the North Amethyst region:

1. FA1: Lower Shoreface Storm Deposits. Consisting of well sorted very fine grained sandstone, this FA is the main reservoir rock type in the region. Facies encountered within this grouping are low-angle (hummocky to swaley) laminated sandstone, massive sandstone, and parallel laminated sandstone. Varying amounts of shell bioclastic and sideritised shale ripup clasts are present as lags along basal scour contacts.

2. FA2: Lower Shoreface Fairweather Deposits. These intervals consist of heavily bioturbated siltsone to silty-sandstone to sandstone. Primary sedimentary structures are rarely preserved.

2. FA3: Marine Deposits. Representing the distal component of White Rose region deposition, the facies types for this group are laminated and massive silty-shale to shale, with some minor bioturbated intervals.

a. Diagenetic Components. Although not representative of a primary depositional feature, due to the abundance of secondary components in the reservoir rock, these have been separated into three groups. Calcite cement is dominant within the Ben Nevis Formation (Fm) and consists of two types. Calcite nodules are defined by their round edges as seen in both core and on image logs and likely have poor lateral continuity. Calcite nodules can also be concentrated along shell lag intervals, appearing more lenticular and usually exhibiting convolute edges. Although more continuous than singular nodules, these occurrences are not likely to form intra-reservoir barriers. A third type, siderite nodules, are not significant in terms of reservoir proportion but are locally present, commonly within mud-lined trace fossils. These components are not as prevalent within the North Amethyst field due largely to the shallower burial history but are still recognized.

These facies associations have been incorporated within the static reservoir model and the resultant dynamic model used in simulation.

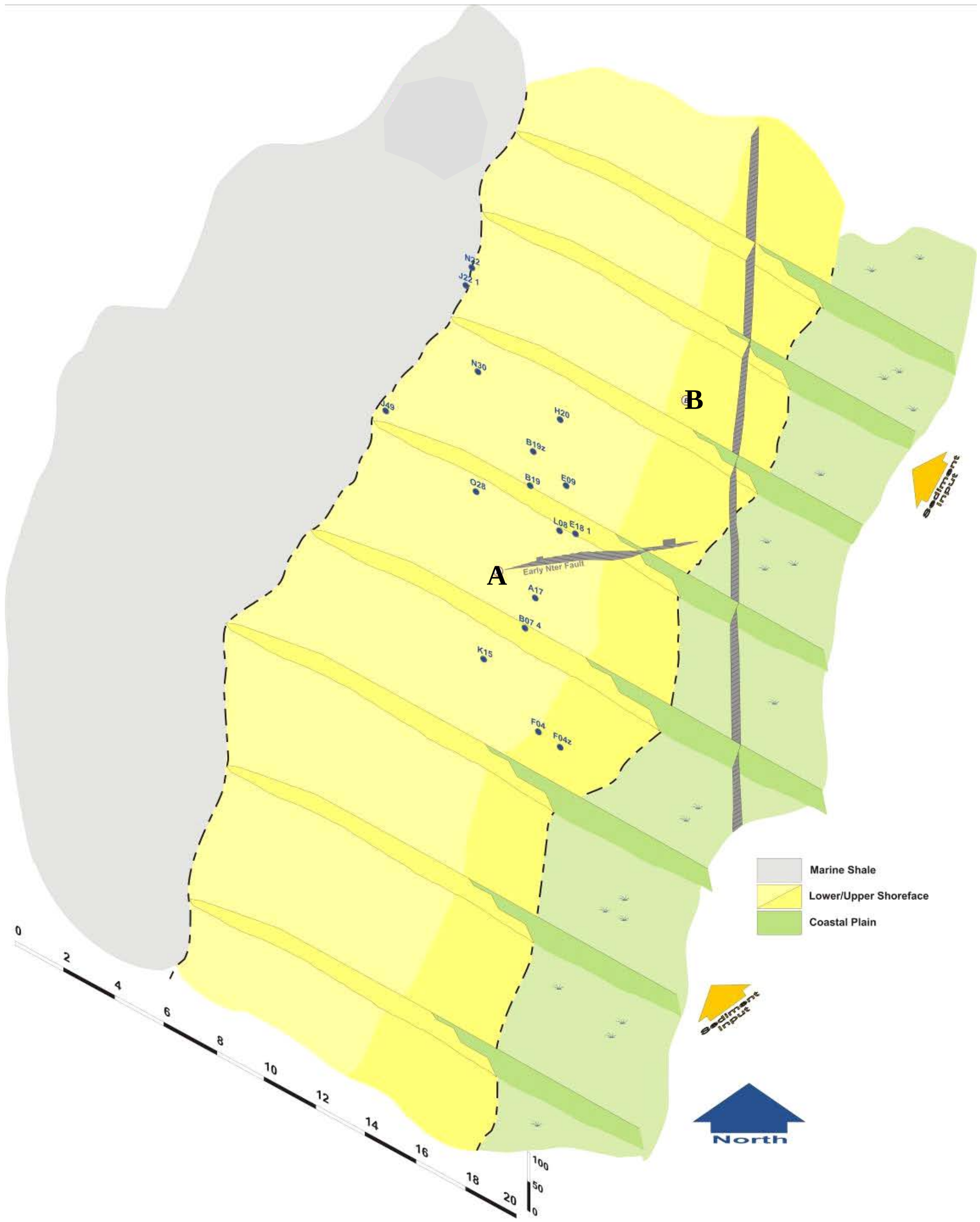



**Figure 2-4 Schematic of Arial Distribution of Shoreface Sandstone and Early Moving Faults Related to the Initial Phases of Ben Nevis Fm Depostion**

**(Note development wells not displayed). A-Early NTer fault movement resulting in increased accommodation space and thicker Ben Nevis Fm relative to the southern field extents. B-increased region of accommodation east of the H-20 well.**

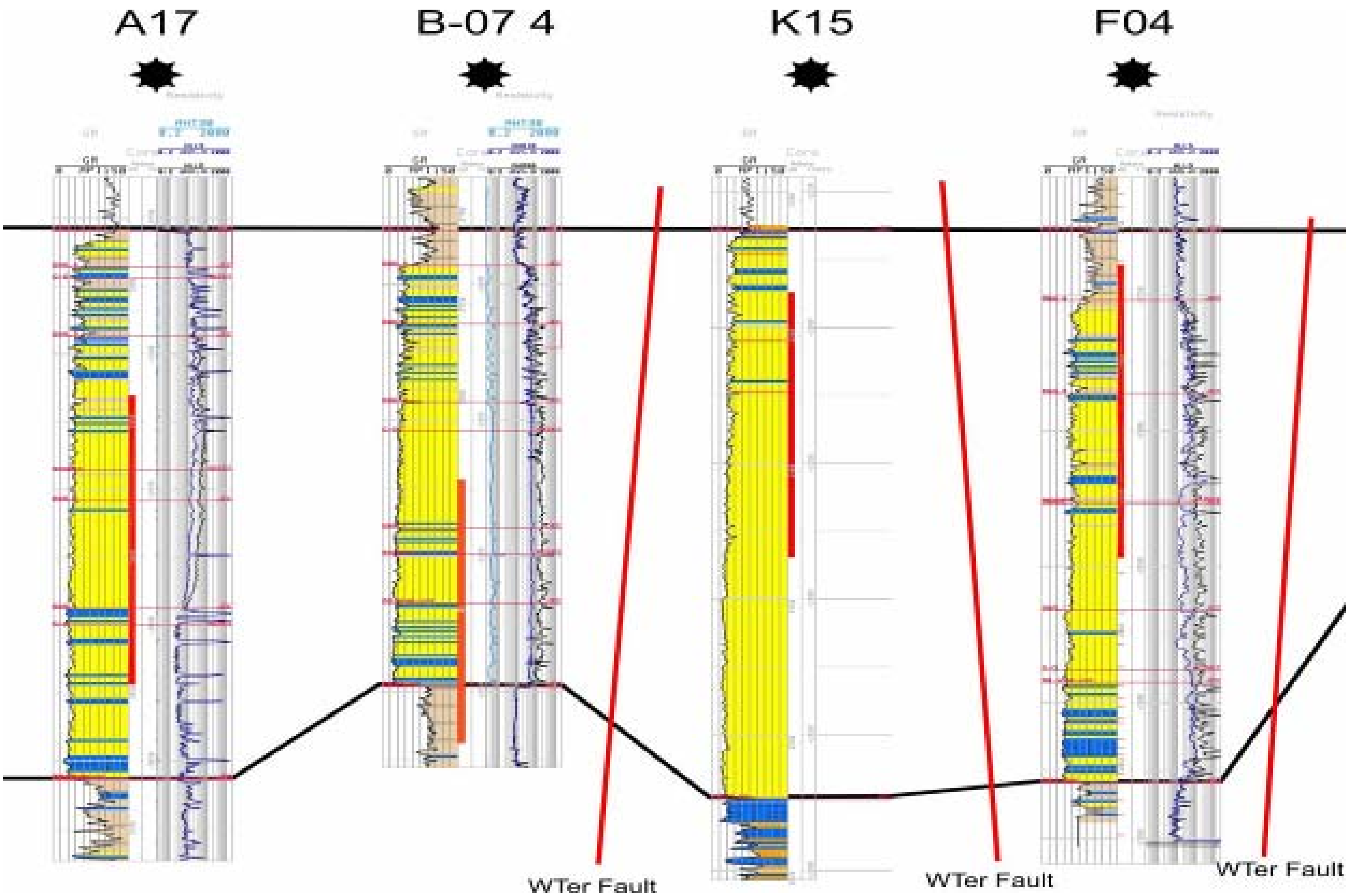



**Figure 2-5 Structural Section Terrace to North Amethyst to SWRX Region as shown on Figure 2.3**

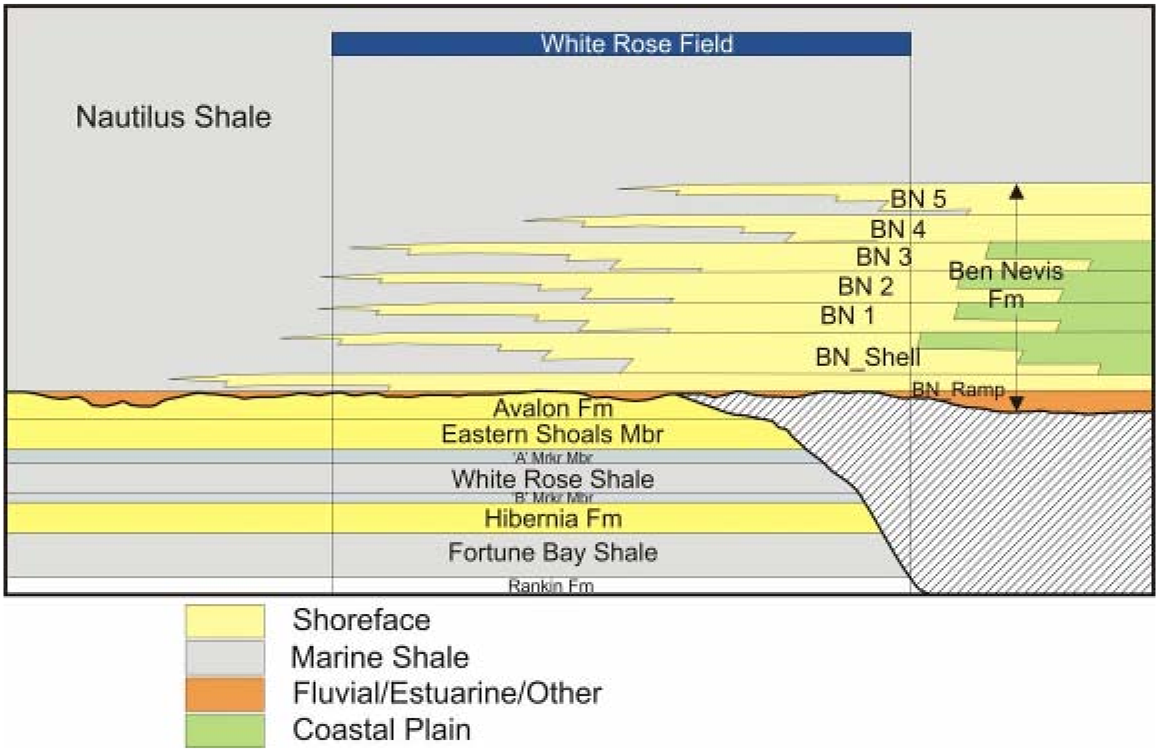



**Figure 2-6 White Rose/North Amethyst Stratigraphy Illustrating the Internal Divisions of the Ben Nevis Formation**

Time structure and depth structure maps are discussed in Section 2.2, Geophysics. Figures 2-7 to 2-14 illustrate the sand, reservoir, hydrocarbon and pore volume thicknesses as indicated.

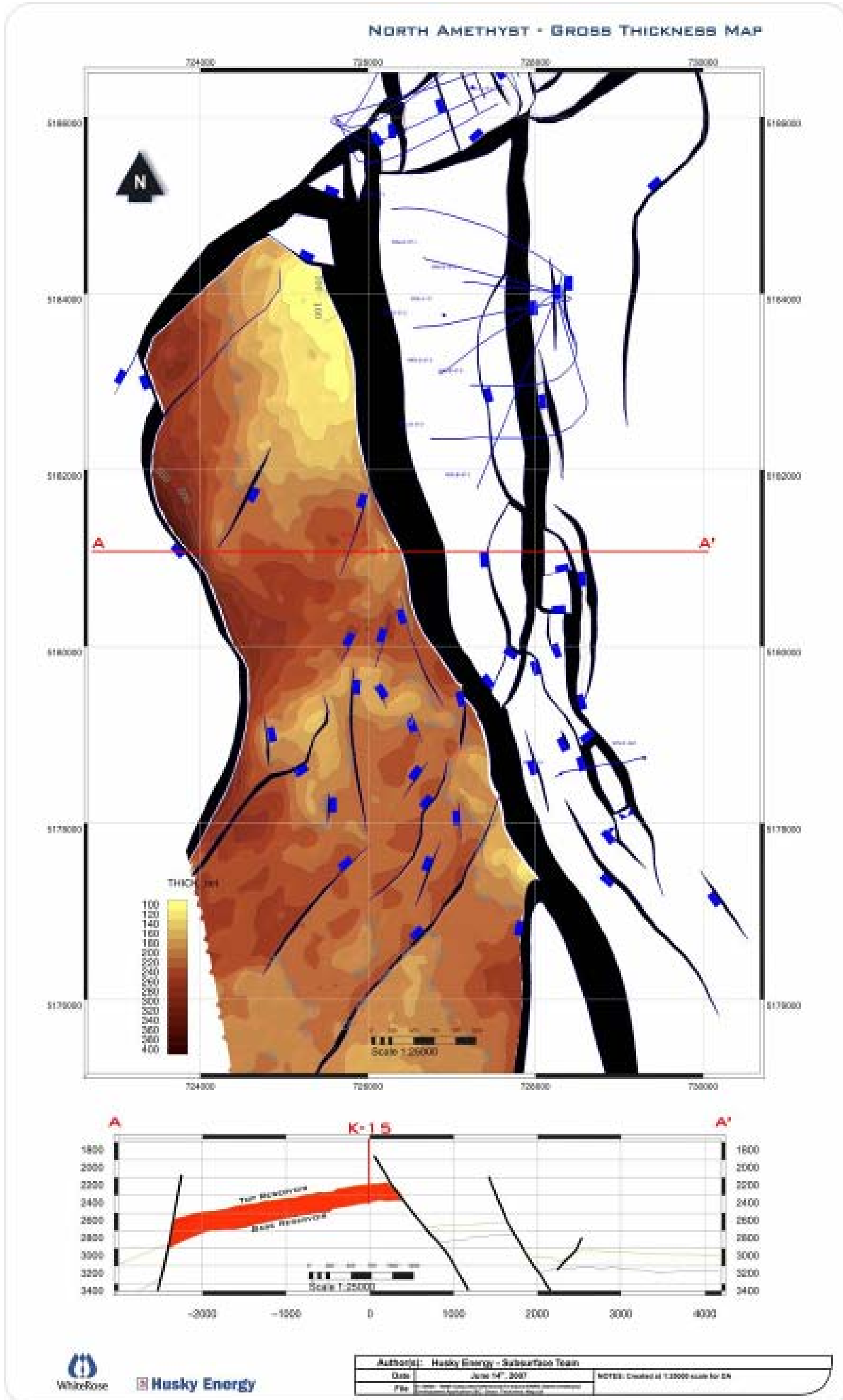



**Figure 2-7 Gross Ben Nevis Isochore Map and Cross Section**

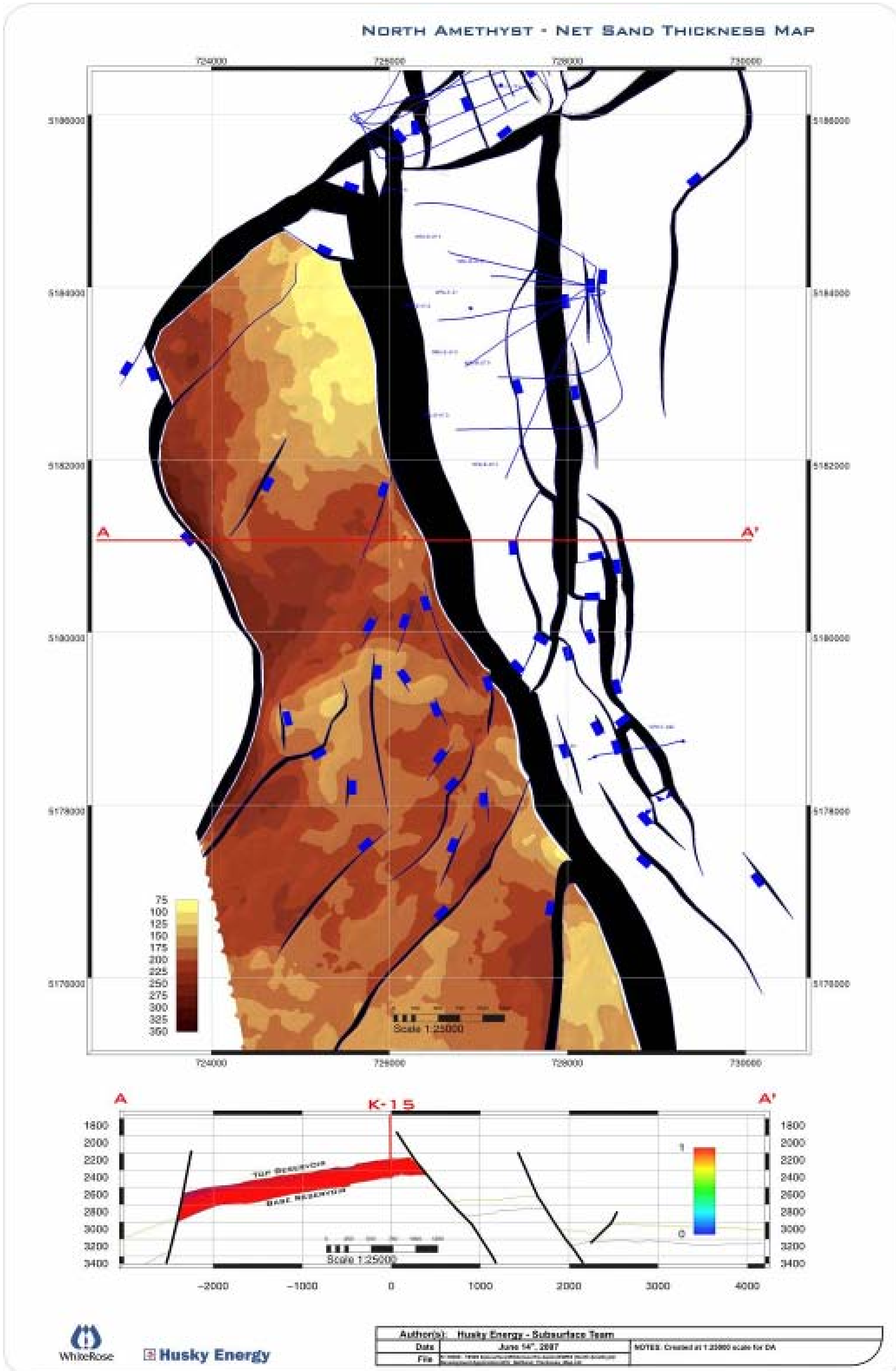



Figure 2-8 Net Ben Nevis Sand Isochore Map and Cross Section

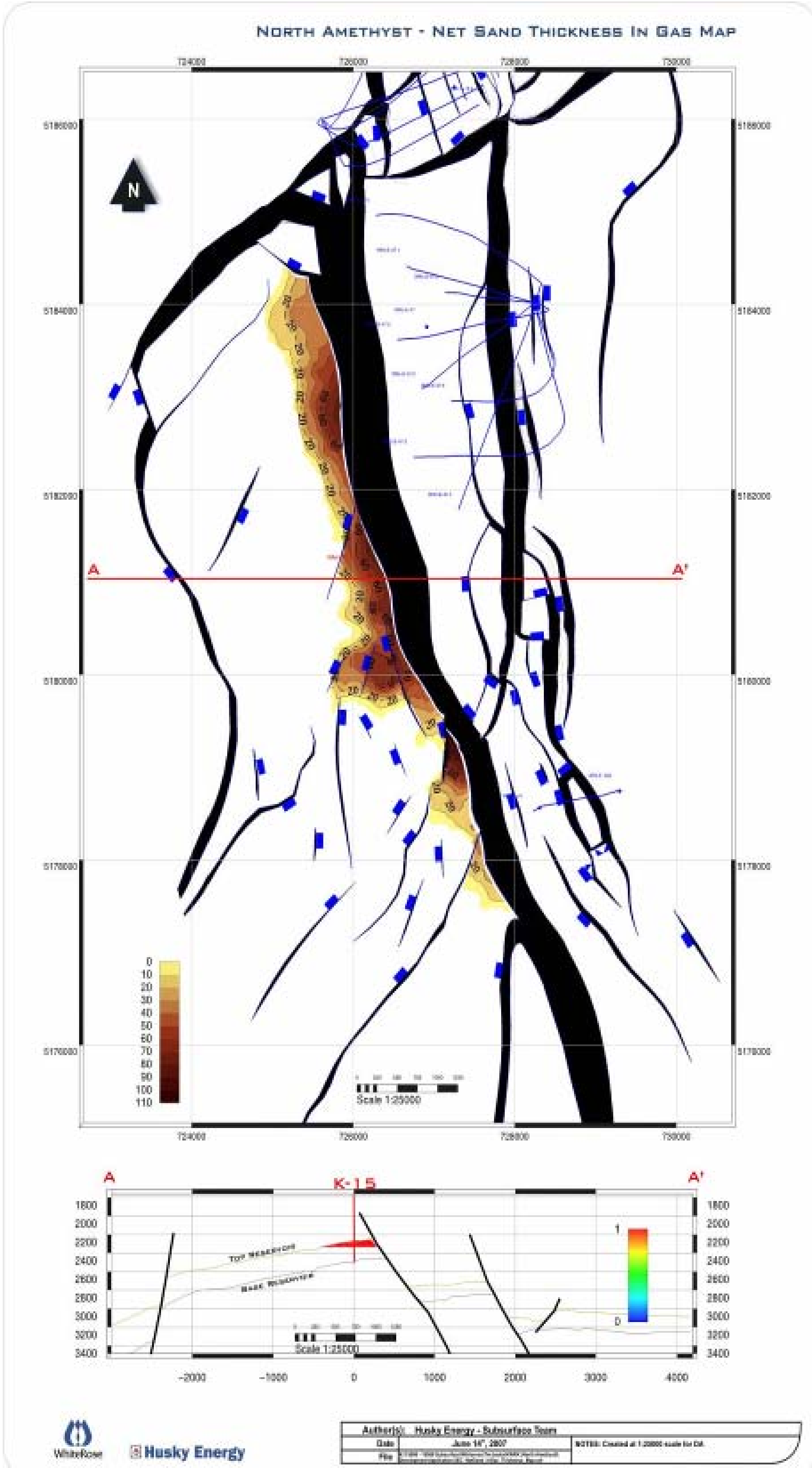



**Figure 2-9 Net Ben Nevis Sand in Gas Isochore Map and Cross Section**

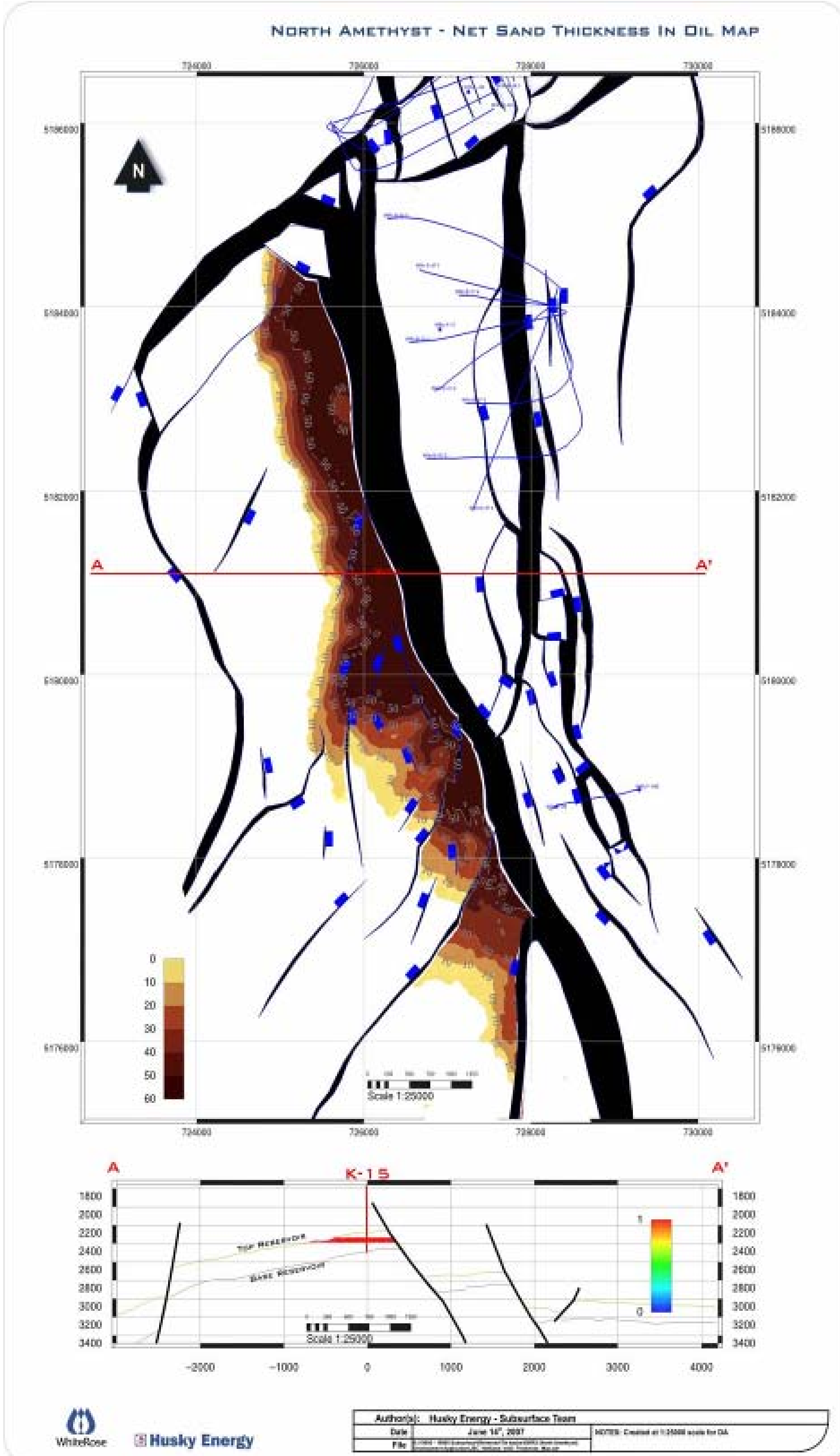



Figure 2-10 Net Ben Nevis Sand in Oil Isochore Map and Cross Section

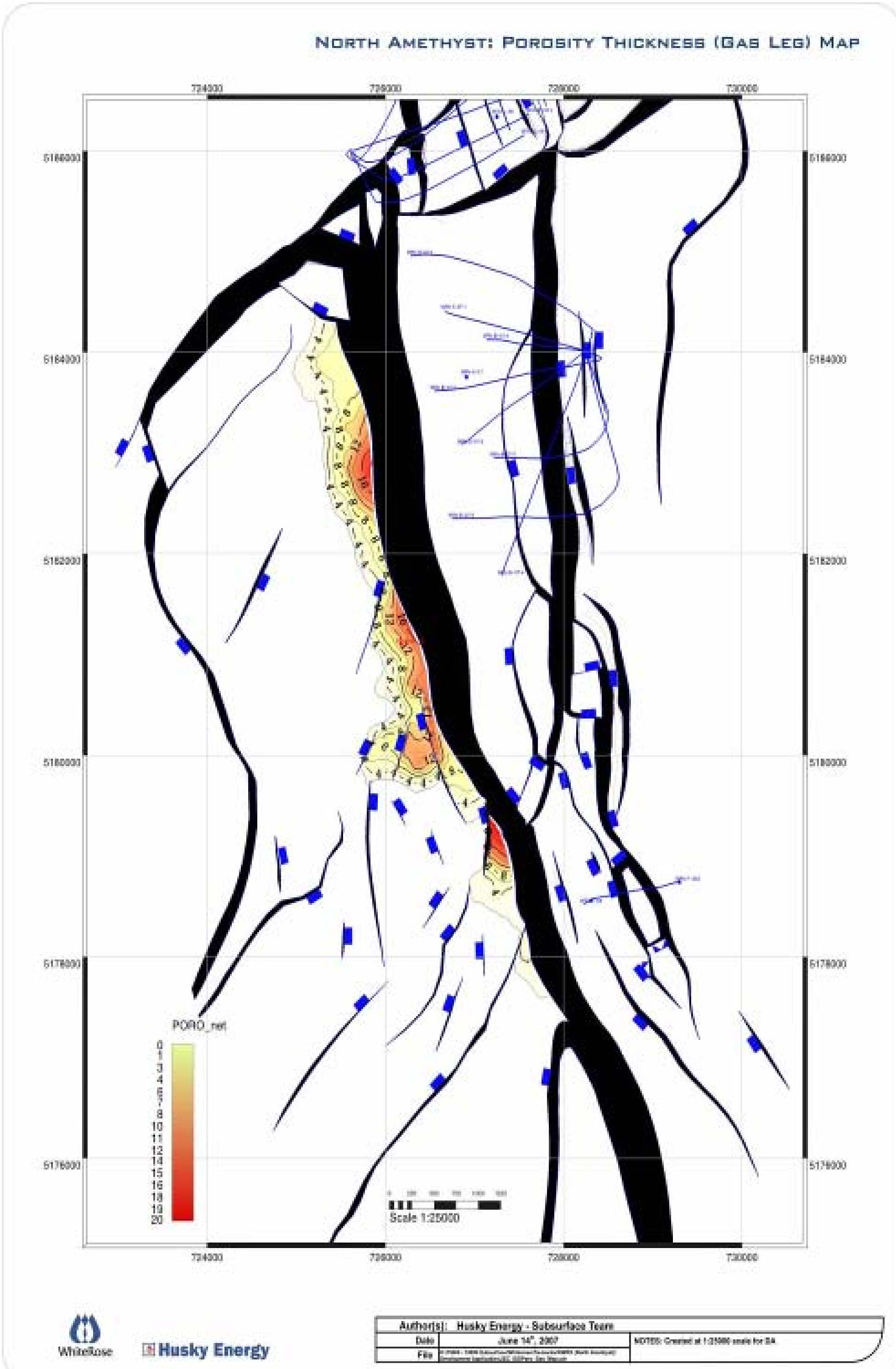



**Figure 2-11 Ben Nevis Porosity (Gas Leg) Isochore Map**

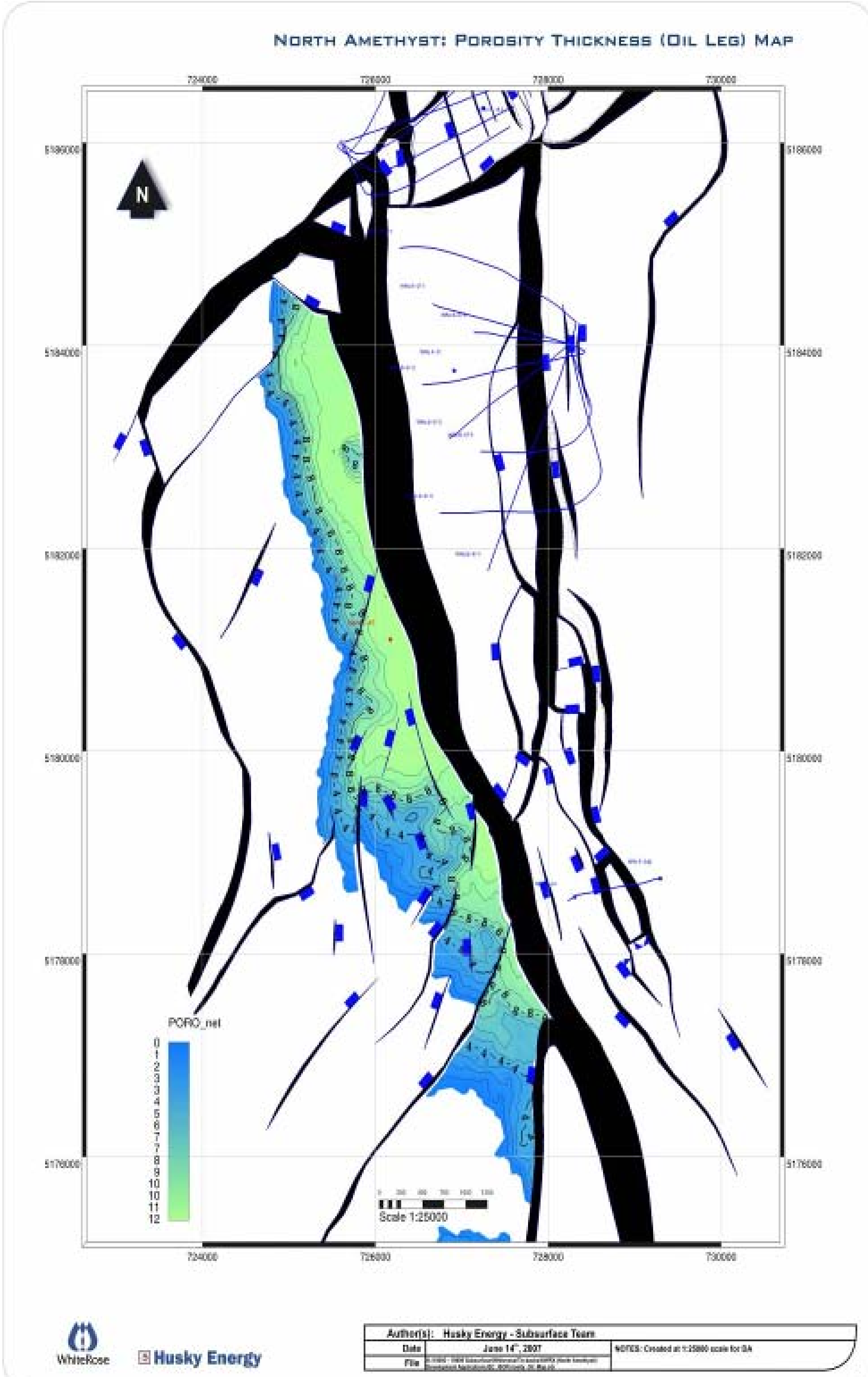



**Figure 2-12 Ben Nevis Porosity (Oil Leg) Isochore Map**

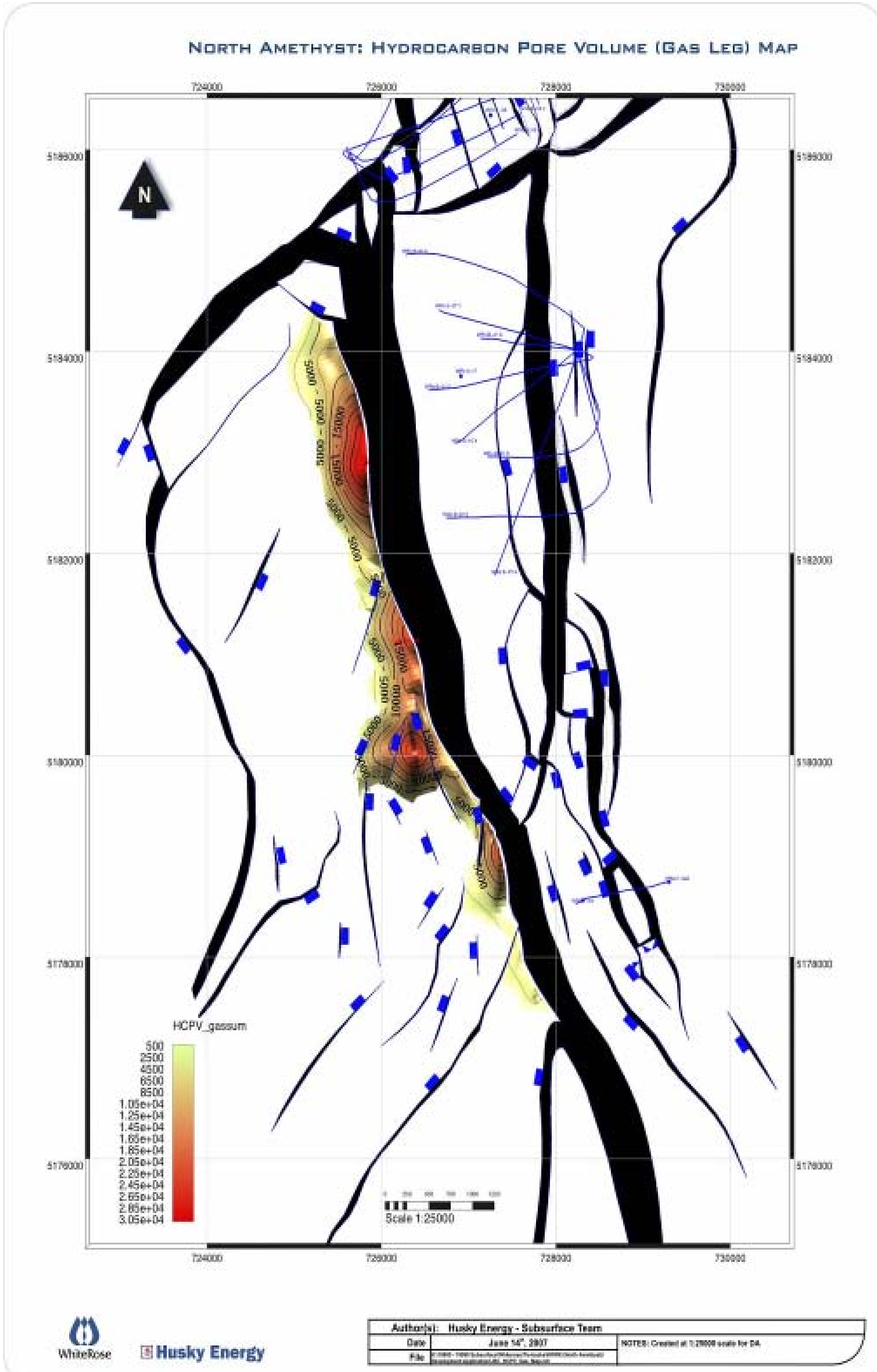



Figure 2-13 Ben Nevis Hydrocarbon Pore Volume (Gas Leg) Isochore Map

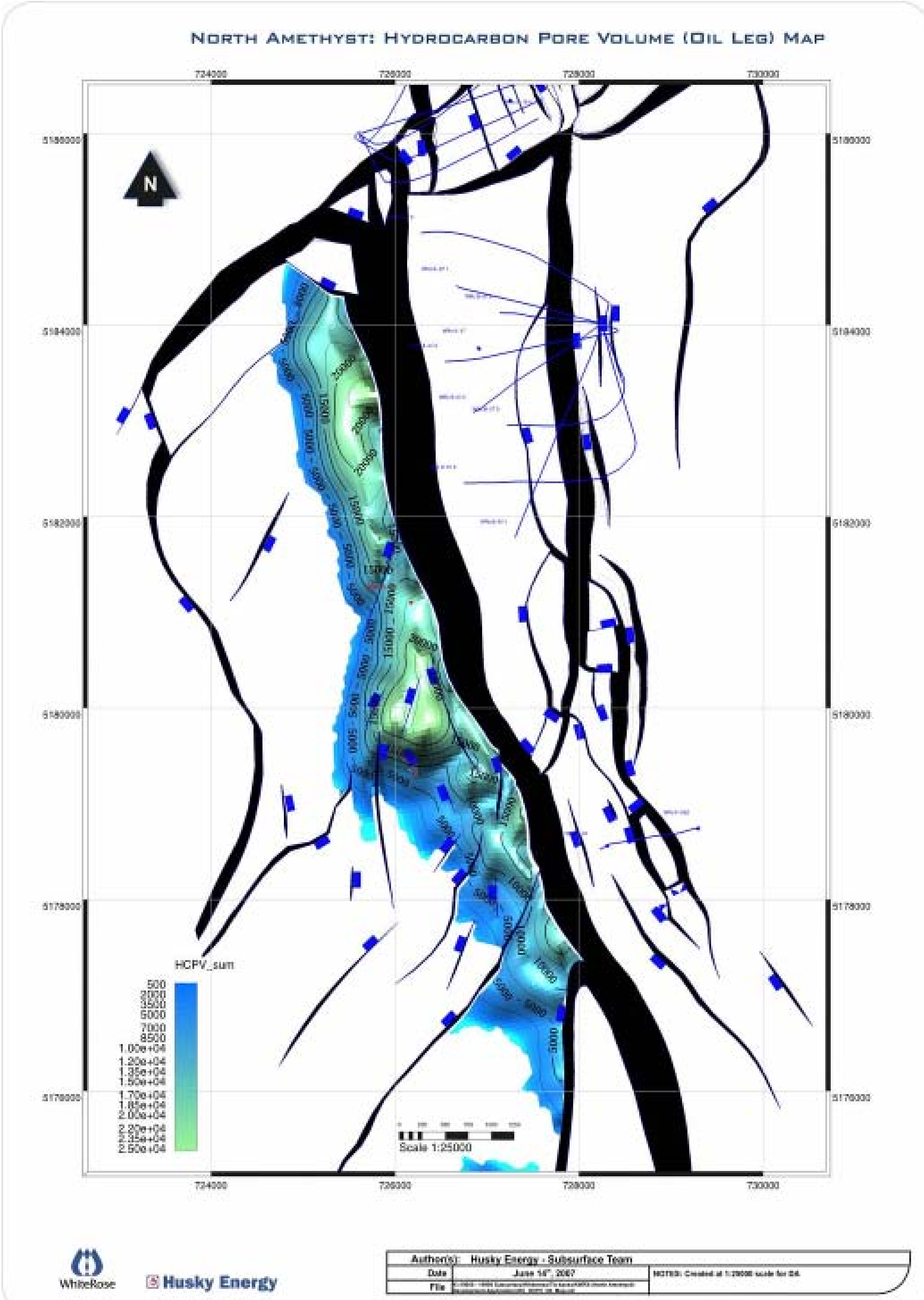



**Figure 2-14 Ben Nevis Hydrocarbon Pore Volume (Oil Leg) Isochore Map**

## 2.2 Geophysics

This Section describes the seismic data and geophysical mapping specific to the North Amethyst field.

**Seismic Data Acquisition**

North Amethyst is covered by three seismic surveys (PGS 97 3-D, Breton, and GSI) (Figure 2-15). These surveys were completed for different purposes, in different years, and with different field geometrical configurations.

The PGS 97 3-D survey was shot during June-July 1997 and covers a hexagonal shaped area of 311 km², comprised mostly of the known White Rose hydrocarbon accumulations. The seismic ship R.V. Ramform Explorer, operated by PGS Exploration AS, conducted the 3-D geophysical survey on behalf of Husky and its co-venturers. A total of 13,328.4 line km of seismic reflection profiles were collected in 40 variable length swaths, recorded in an east-west direction. The most extended lines were 25 km long while the shortest were 14 km long (Boyd Exploration 1997).

The PGS 97 data was acquired with a dual source/eight streamer configuration. Streamer length was 4,025 m and separation between streamers was 100 m resulting in a 4,025 m by 700 m acquisition footprint. A number of 8 X 162 channels were recorded with a 2 m/s sampling rate and 7 s recording length. The two/three air gun arrays were distanced at 50 m and fired in a flip-flop manner every 25 m. The resulting line spacing was 25 m and data is 40-fold. The signature of the tuned air gun array was excellent and stable throughout the program. Accurate Wide Area Differential Global Positioning System (DGPS) primary positioning was used throughout, in combination with land-based STARFIX positioning (better than 2 m accuracy).

The Breton 3-D survey purchased by Husky and others in 1999 was used for seismic interpretation over a 46 km² area located in the southeastern portion of the White Rose Complex. This survey was a group shoot acquired by Esso and its partners in 1990 with the M.V. Geco Searcher and was initially used as a work commitment for an Exploration License awarded to Esso, Chevron, Shell and Talisman. The Breton survey was acquired with dual streamer/dual source configuration. Streamer length was 2,800 m, streamer separation was 150 m, source separation was 75 m and the shot interval alternating was 18.75 m. This field layout resulted in a line spacing of 37.5 m and trace spacing of 12.5 m.

Husky purchased the GSI 85 seismic survey for regional interpretation of the eastern Jeanne d'Arc Basin and early delineation of the White Rose Complex. This was an exploration three-dimensional survey (Reconnaissance 3-D) acquired with single source/single streamer configuration and a 200 m line spacing. The cable had 120 hydrophone groups and its length was 3,024 m, resulting in 60-fold data. There is a total overlap between the GSI Reconnaissance 3-D and the PGS 97 3-D survey and partial overlap with the Breton survey. Due to its poorer quality, the GSI survey was used only for interpretation of a small 78 km$^2$ area situated outside the newer surveys. Further information regarding the acquisition parameters of the GSI 85 program resides with the C-NLOPB office in St. John's.

**Seismic Data Processing**

Three different seismic surveys cover the White Rose area: 1) PGS 1997; 2) Breton 1990 and 3) GSI 1985 (Figure 2-15). The three surveys were processed together in 2000 to get a complete picture over the White Rose field and this cube was used for the North Amethyst interpretation.

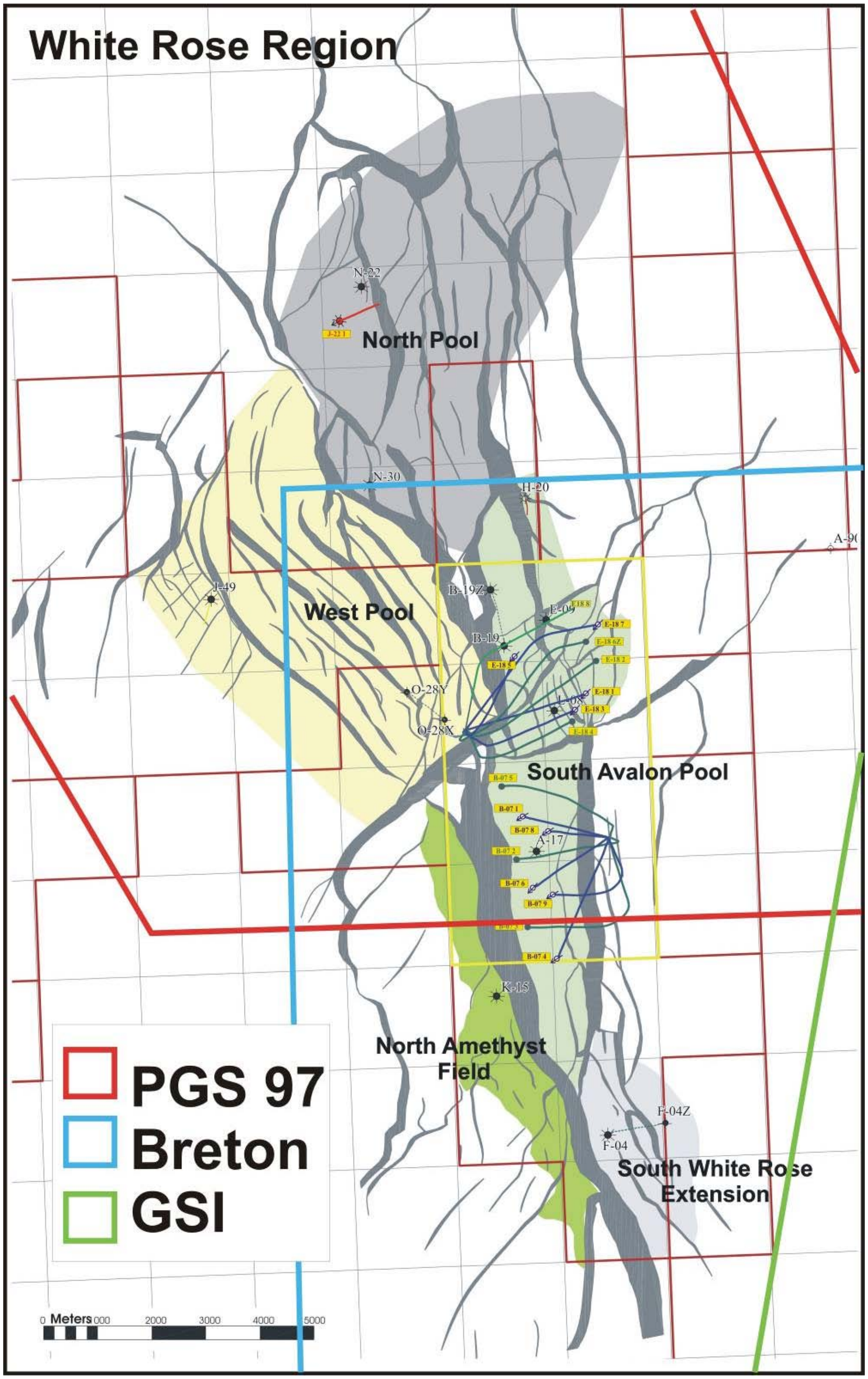



**Figure 2-15 North Amethyst 3-D Surveys**

**Seismic Interpretation - Synthetic Ties**

The main wells used to correlate the seismic markers in North Amethyst were the Fortune G-57 and North Amethyst K-15. An excellent fit can be seen between the synthetics generated from the sonic and density logs and the seismic data. An example of the individual well synthetic is provided in Figure 2-16

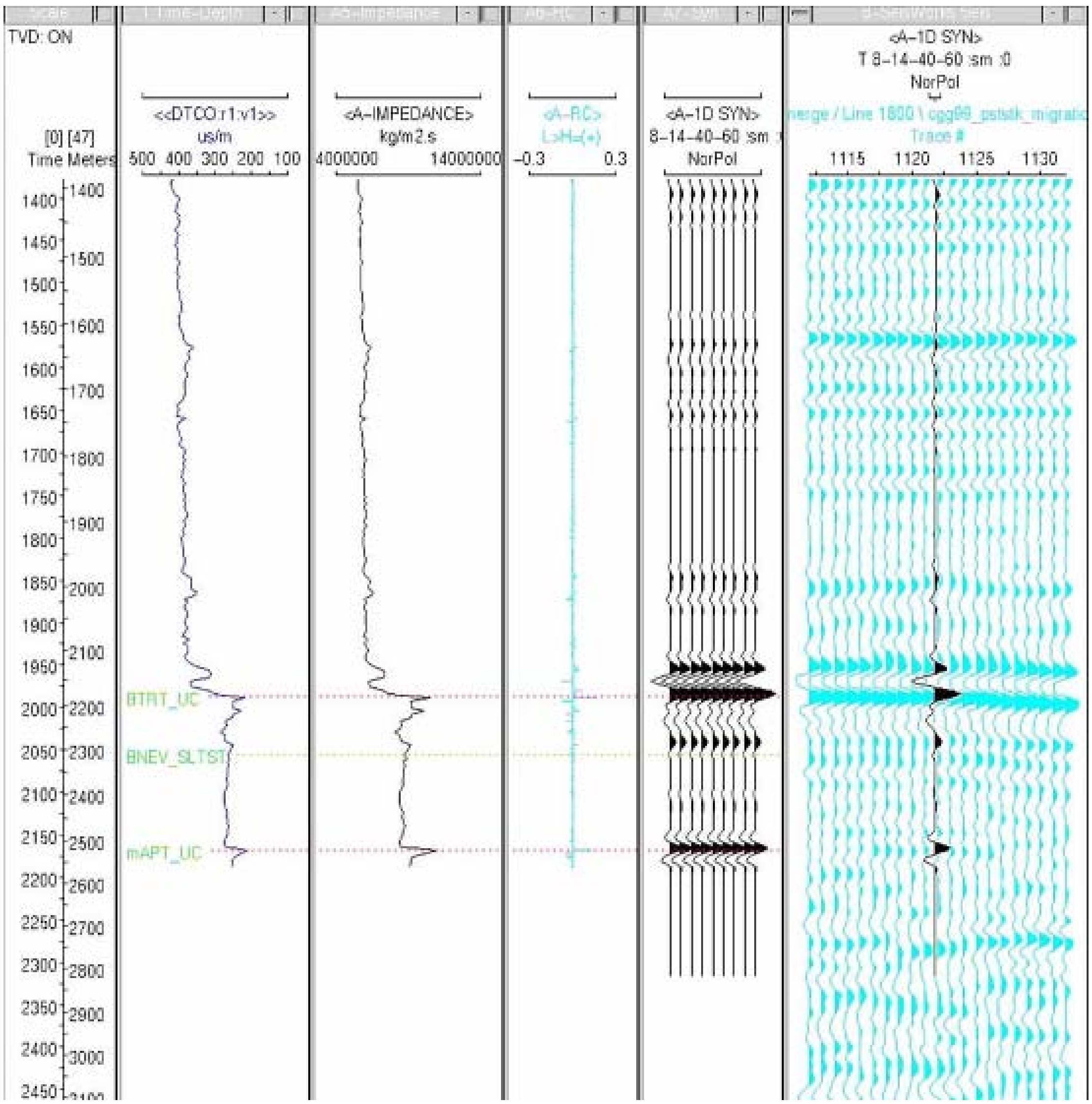



**Figure 2-16 K-15 Synthetic**

**Seismic Markers**

A large number of wells from the White Rose area provided correlation points with the stratigraphy over the North Amethyst area. The ties between the synthetic seismograms, corridor stack VSPs, and marine seismic data are generally good. Most data correlation problems occur due to the low impedance contrast between the BNA sandstone reservoir and surrounding rocks and the complexity of faulting. Mapping the top and the bottom of the BNA Formation is generally a challenge.

Data quality over the area is good to moderate and faults are less complex compared to other areas around the White Rose field.

Seismic interpretation was performed on all available lines and crosslines (25 m by 25 m line grid) and confirmed with arbitrary lines, animation files, time slices and continuity slices. The interpretation was completed using a Sun operating system and Landmark Seisworks. Three displays on screen or hardcopy: 1) seismic line or time slice; 2) time-structure map; and 3) trend continuity maps were used to interactively interpret the area.

Three seismic markers were correlated and mapped over the entire area: the Base Tertiary Unconformity (Figure 2-17), the Top BNA (Figures 2-18) and the mApt Unconformity (Base BNA) (Figure 2-19).

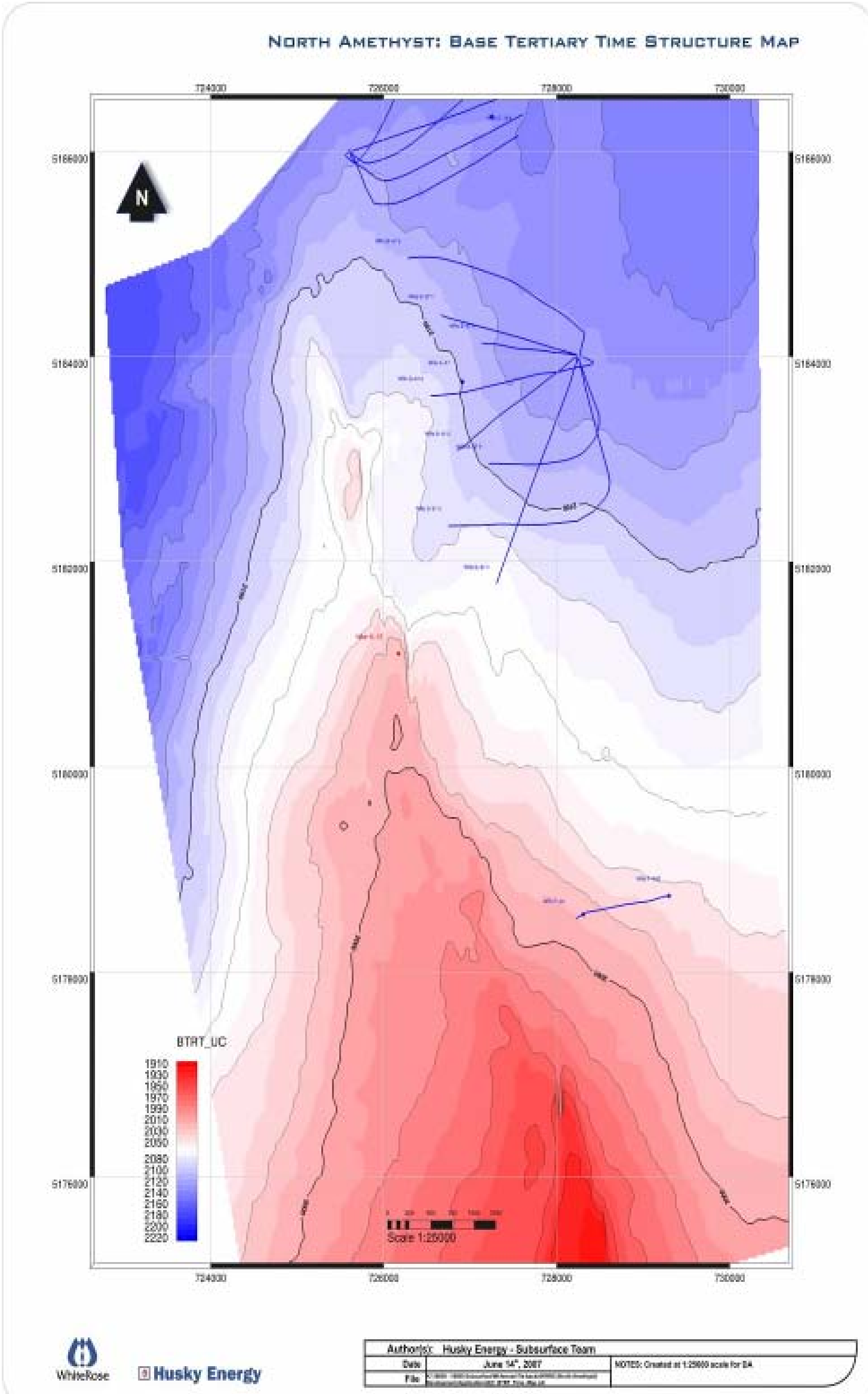



**Figure 2-17 Base Tertiary Unconformity Time Structure**

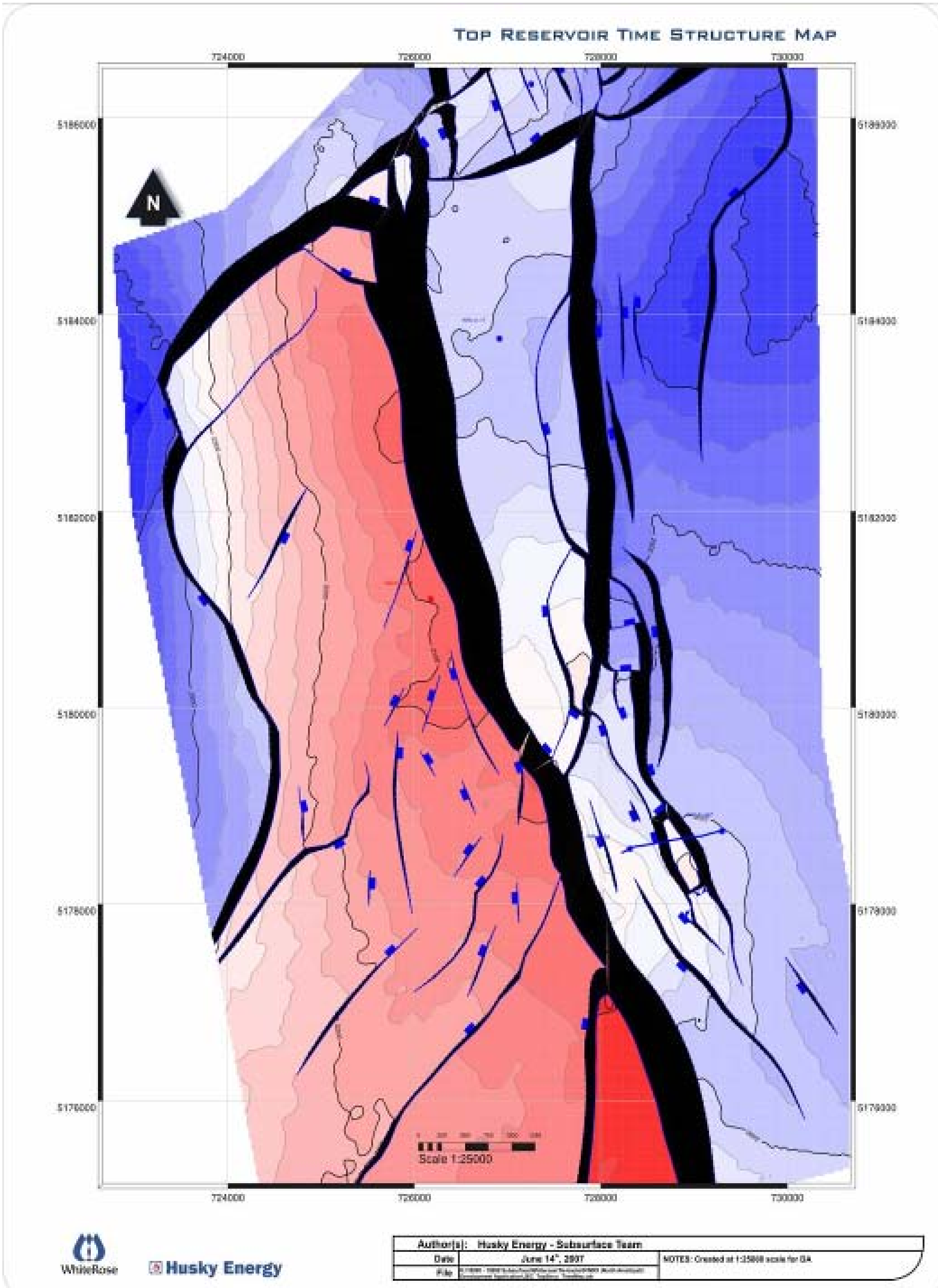



**Figure 2-18 Top Ben Nevis Avalon Time Structure**

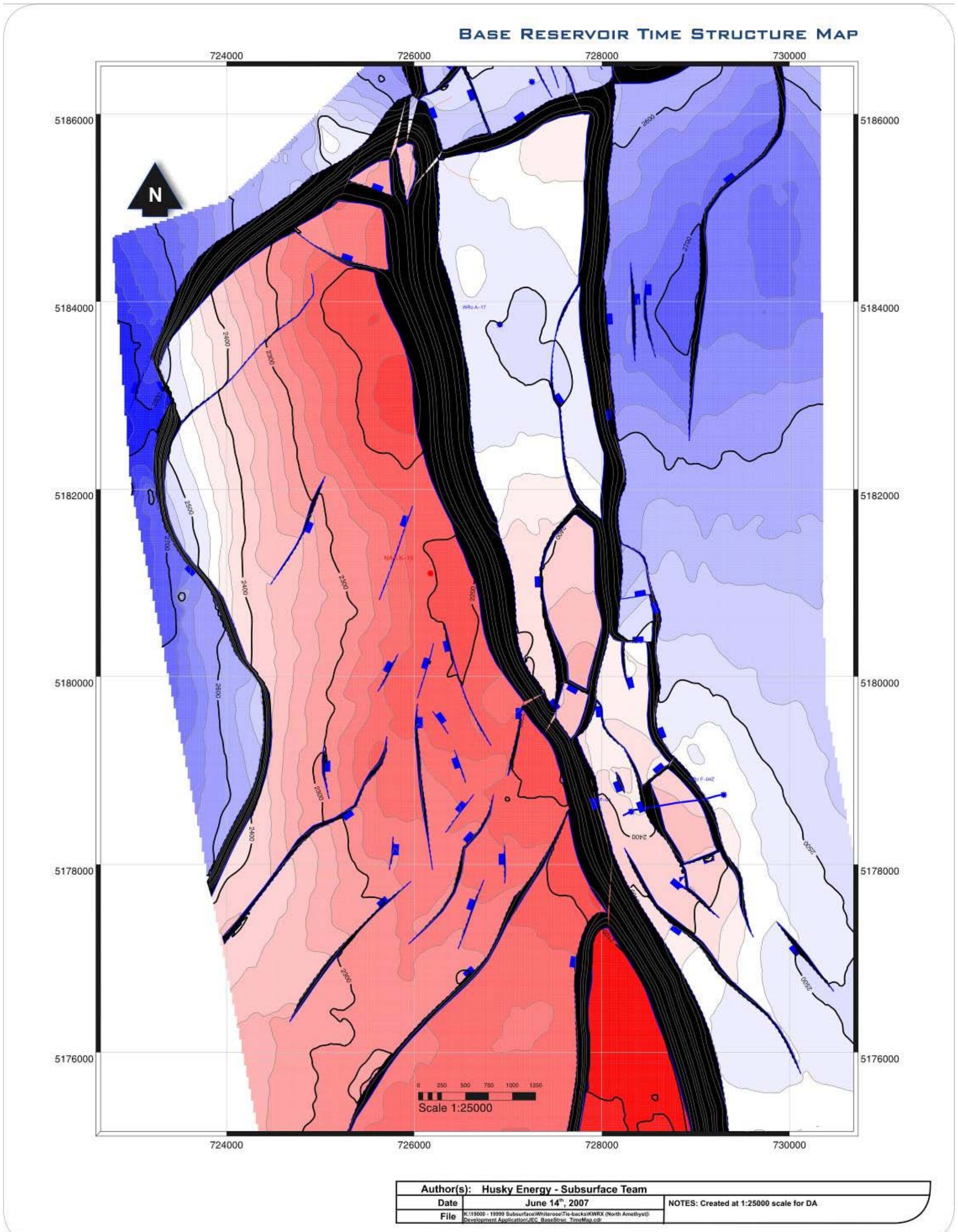



**Figure 2-19 Base Ben Nevis Avalon Time Structure**

The Base Tertiary Unconformity is generally a consistent, strong amplitude reflector caused by a high positive impedance contrast between the Mesozoic and overlying Tertiary layers. The Base Tertiary is defined as a maximum value of a peak on seismic displays. The quality of the reflector deteriorates in areas affected by faulting or channel incision where an amplitude decrease is observed and the marker may change polarity.

The Top BNA Formation reflector is a low amplitude peak that can be mapped over the entire North Amethyst area. The marker is affected by multiples. In highly faulted areas, the marker is low quality and very hard to follow (Figures 2-20 and 2-21).

The mApt unconformity (Base of BNA Formation) is, in general, a medium to high reflectivity peak, but it may change to low amplitude or even change polarity as it truncates layers of different age and composition (Figures 2-20 and 2-21).

Two interpreted, migrated seismic sections are included, to illustrate the main structural elements and tie the wells in the area (Figure 2-20 and 2-21). Their locations are shown on the seismic sections index map (Figure 2-22).

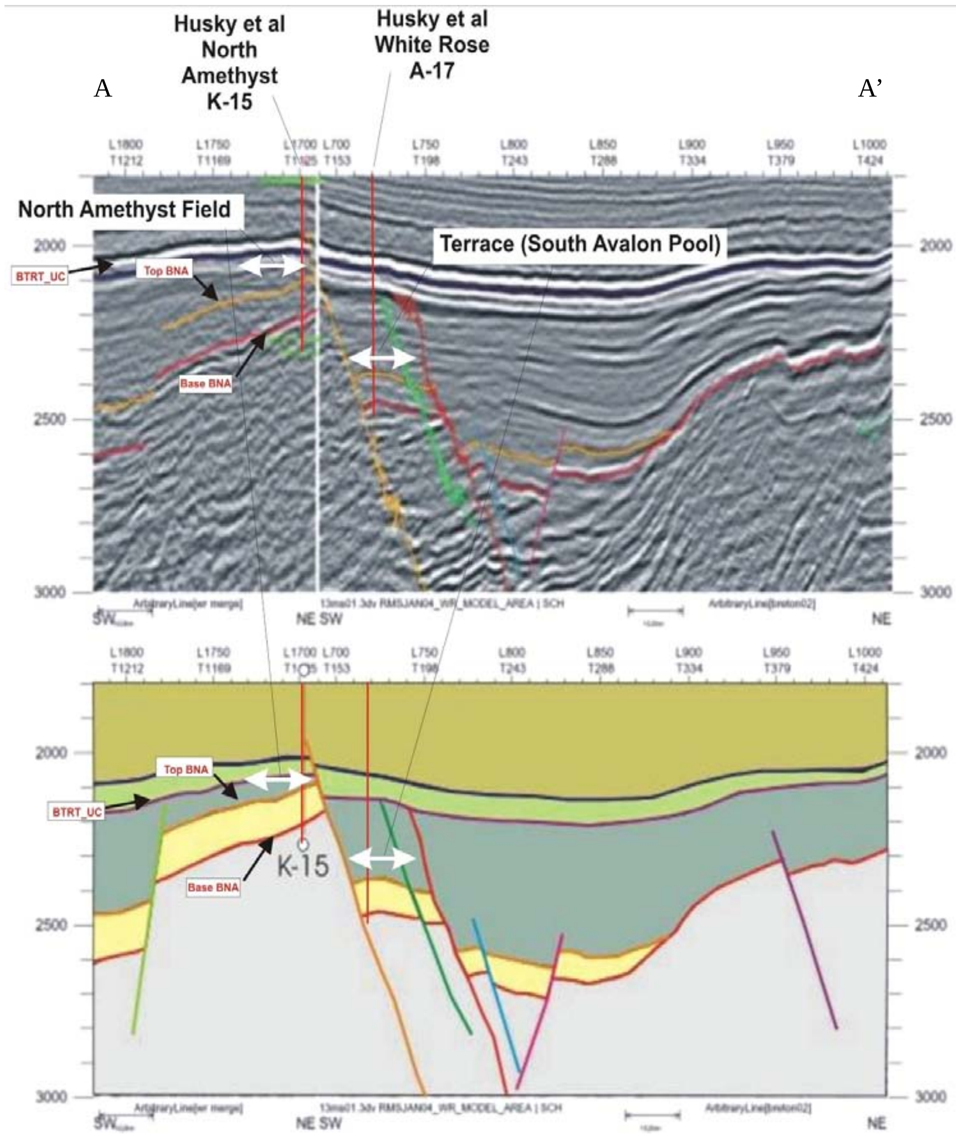



**Figure 2-20 Seismic and Schematic Section through the Central Area of the North Amethyst Structure (Line runs southwest to northeast intersecting the Amethyst ridge, Terrace and SWRX blocks)**

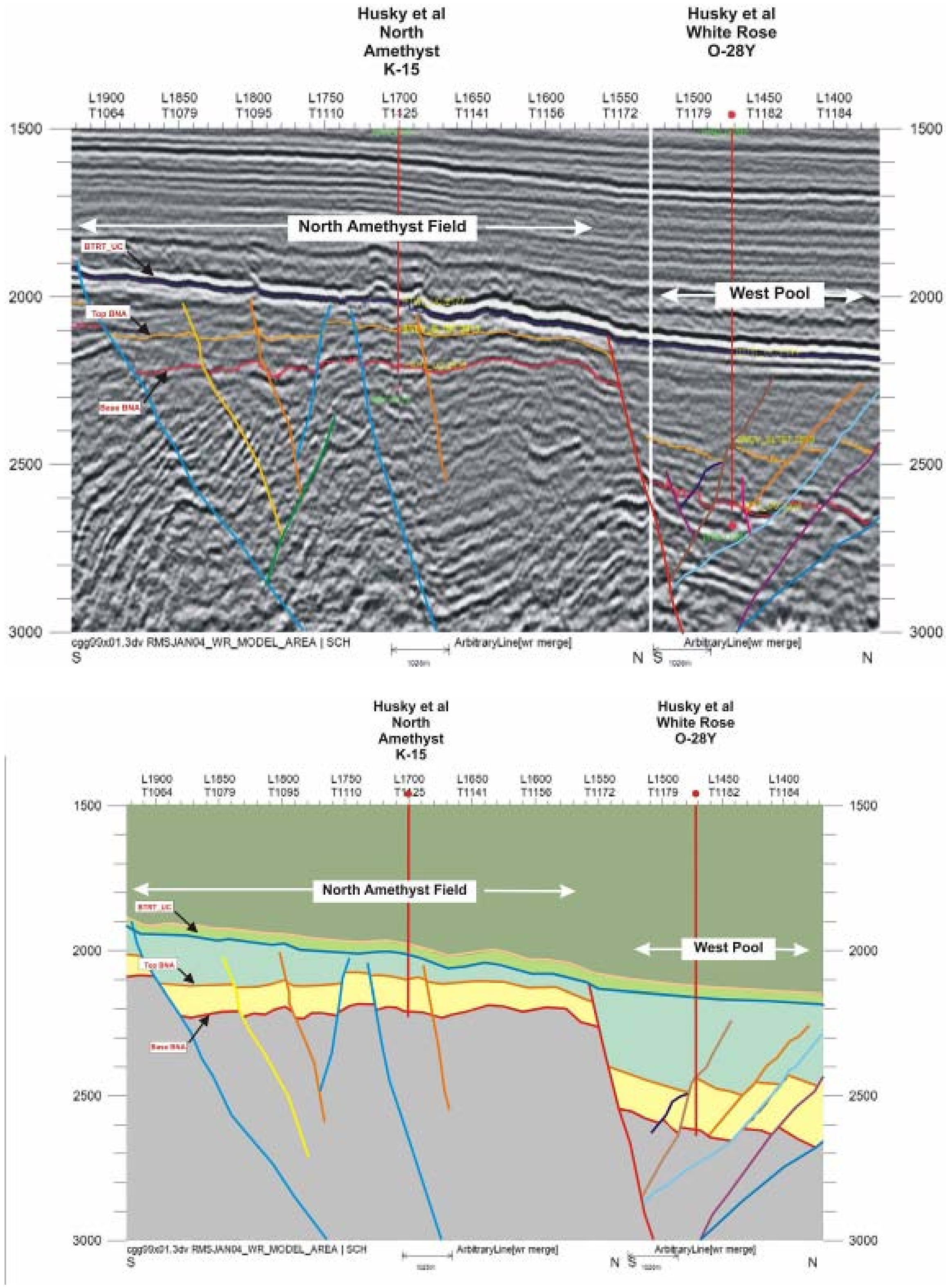



**Figure 2-21 Seismic and Schematic Section through North Amethyst and the West Pool of White Rose Area (Line runs south to north intersecting K-15 and O-28Y wells)**

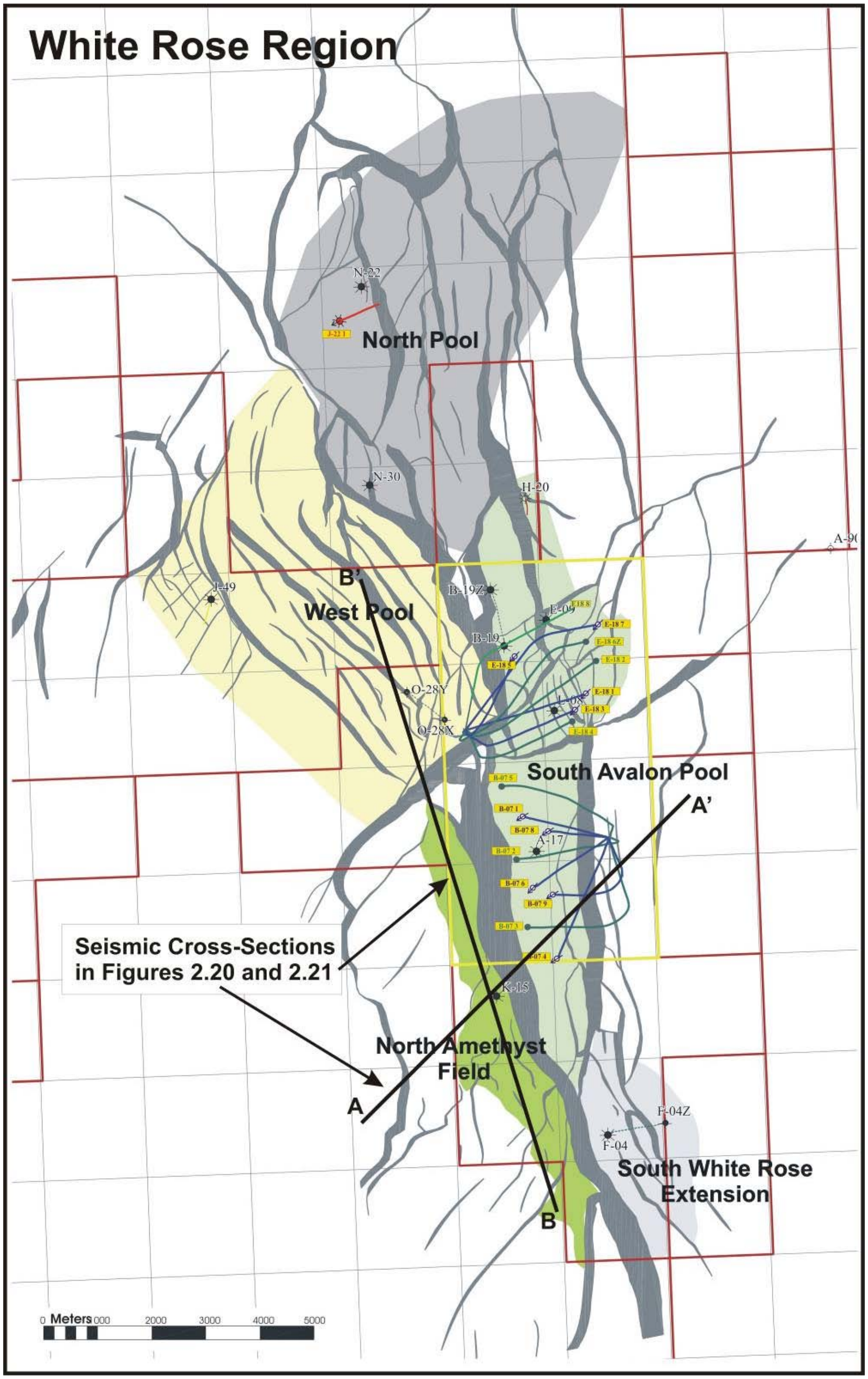



**Figure 2-22 Seismic Sections Index Map**

**Structural Maps**

The time-structure maps illustrated above (Figures 2-17, 2-18 and 2-19, Base Tertiary Unconformity time-structure, Top BNA Formation time-structure and mApt Unconformity (Base BNA) time-structure) were subjected to the depth conversion method described below to create the following depth structural maps (Figures 2-23, 2-24 and 2-25, Base Tertiary Unconformity depth-structure, Top BNA Formation depth-structure and mApt Unconformity (Base BNA) depth-structure).

**Time-to-Depth Conversion**

The Vo,K method, where Vo is the 'instantaneous' velocity and K is the gradient, was used for the White Rose regional depth conversion.

Data from sixteen (16) wells in the region were compiled, inspected, corrected, conditioned and analyzed for Vo,K parameters.

A two layer model was developed based on the geology, presence of seismically resolvable unconformities, and the corresponding internally consistent velocity responses. Tertiary and Cretaceous sedimentary zones were each considered as macro-layers. The Tertiary sediments consist of mostly mudstones and shales of the Banquereau Formation. The Cretaceous layer, defined by the Base of Tertiary Unconformity and the mid–Aptian Unconformity, is structurally complex with evidence of extensional faulting during deposition of the Nautilus shales and Ben Nevis-Avalon reservoir sandstone. It is composed of mainly thin Dawson Canyon shales and limestones and a thick Nautilus Formation shale overlying the reservoir.

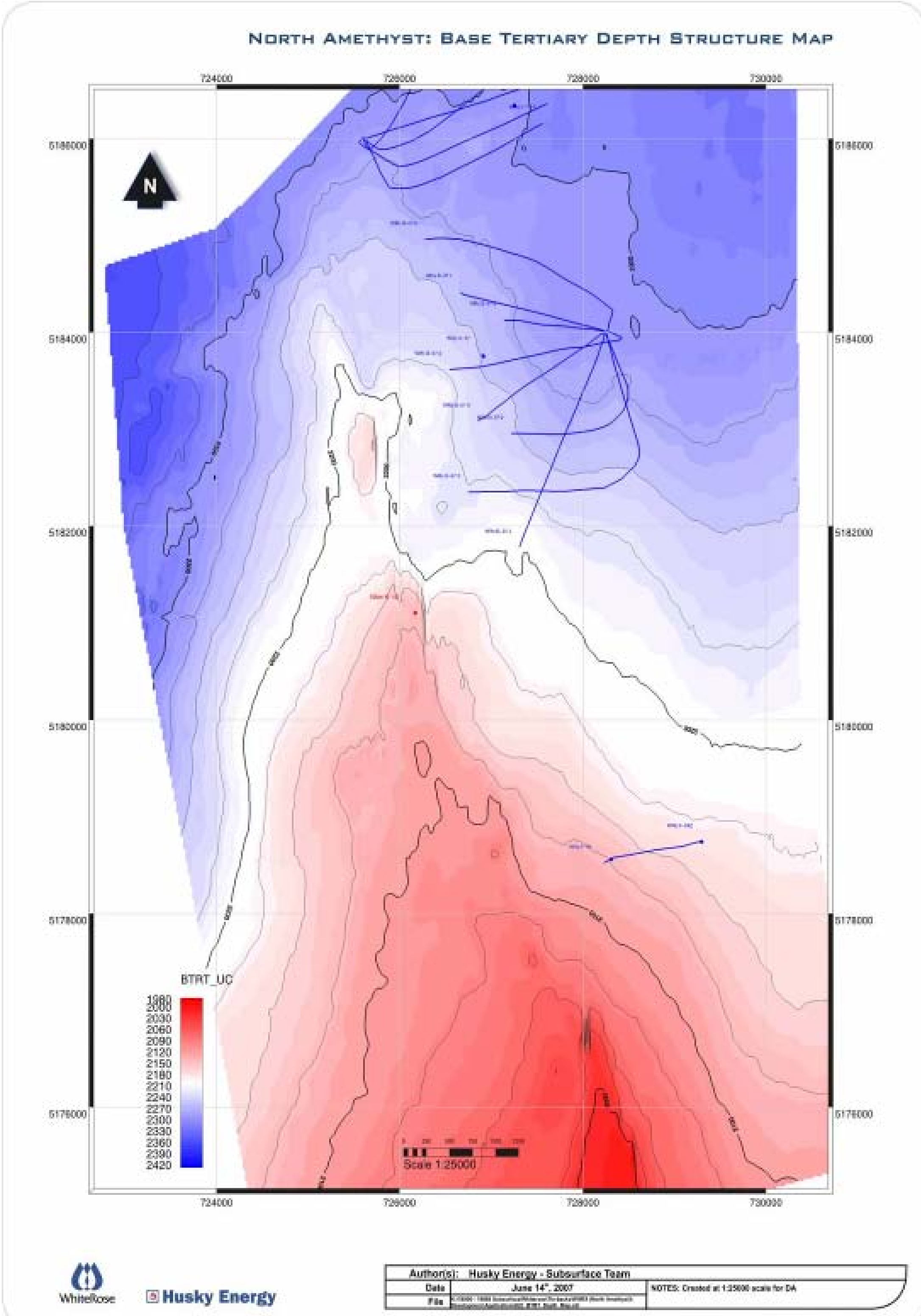



**Figure 2-23 Base Tertiary Uconformity Depth Structure**

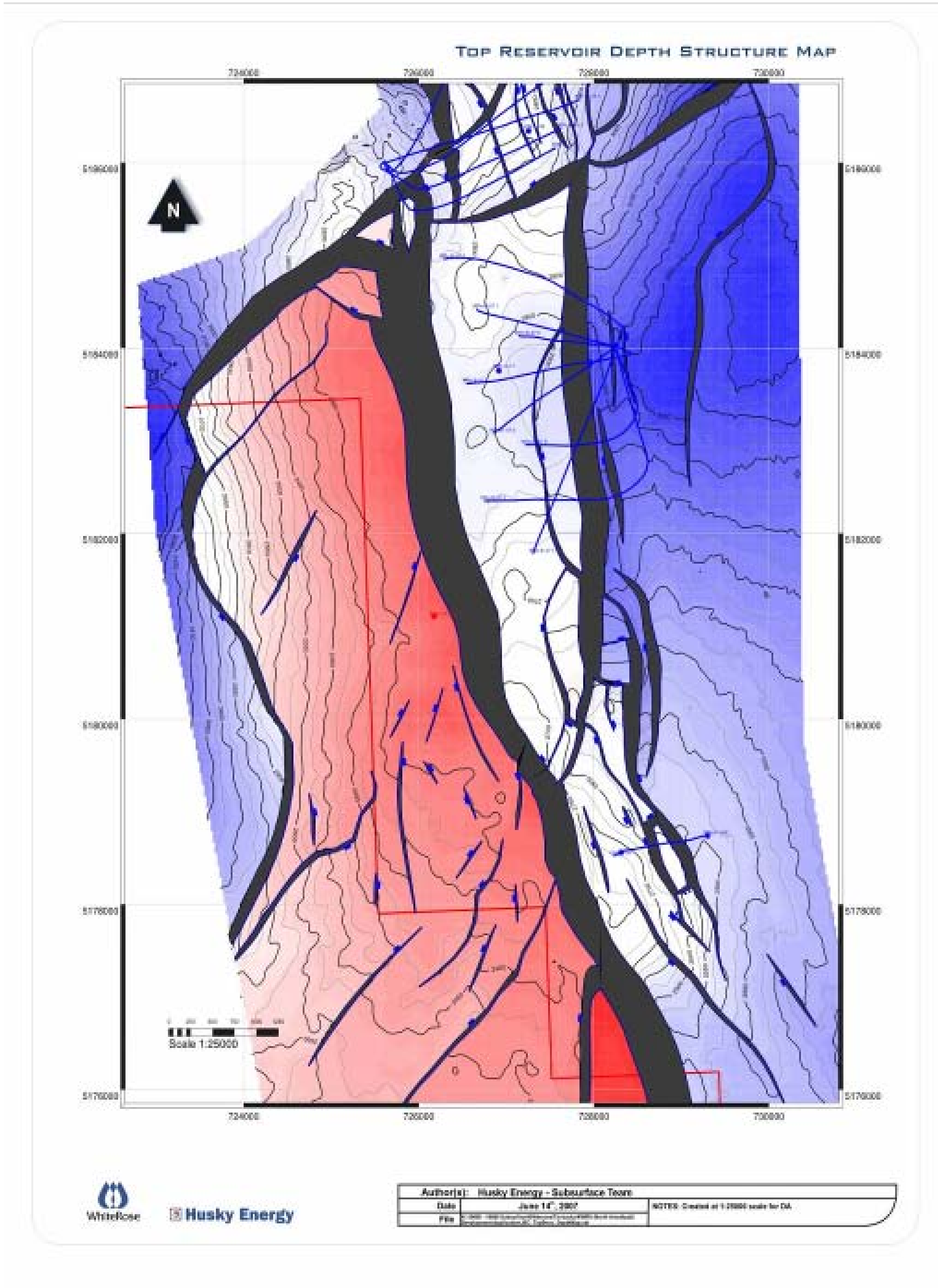



**Figure 2-24 Top Ben Nevis Avalon Depth Structure**

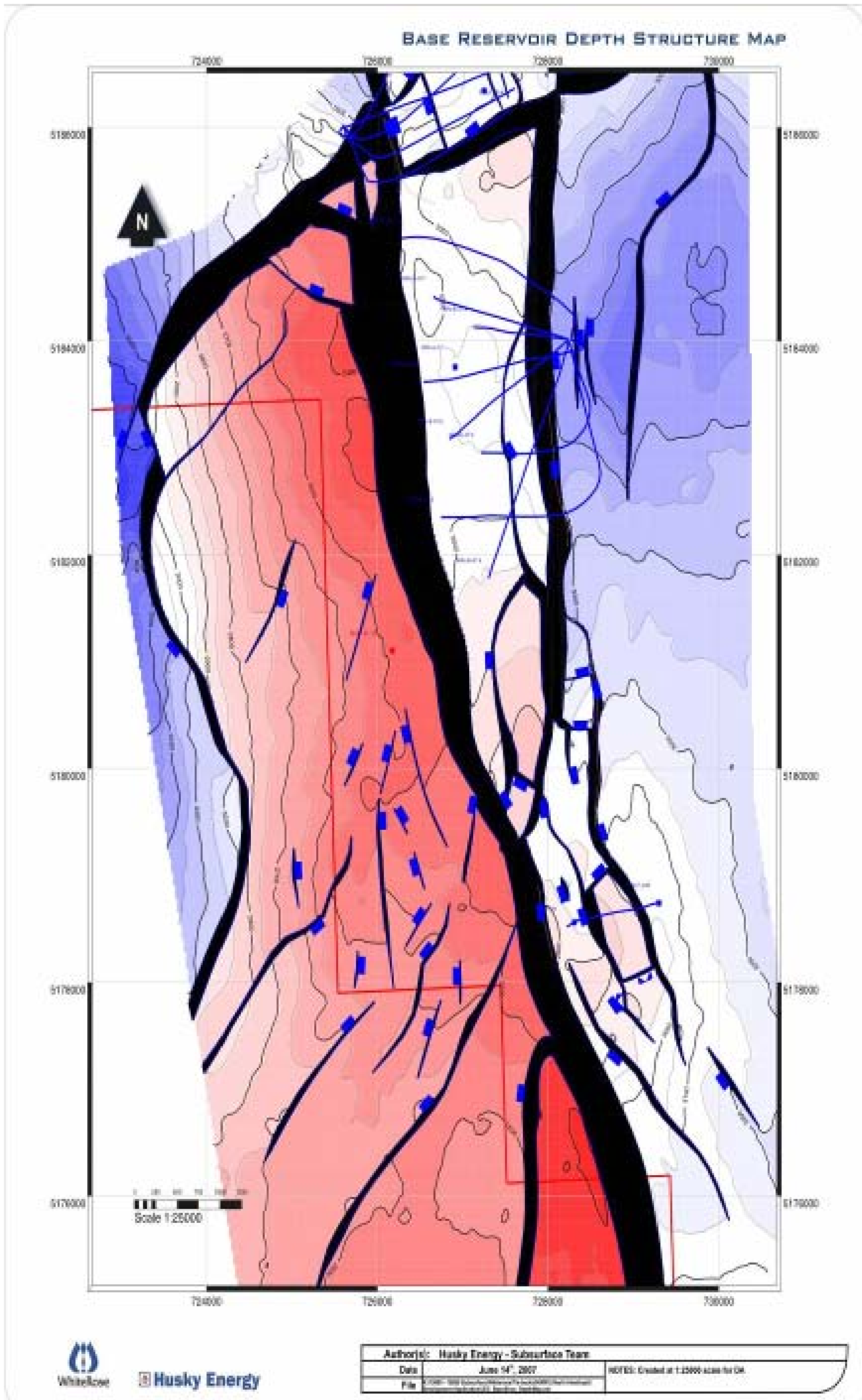



**Figure 2-25 Base Ben Nevis Avalon Depth Structure**

### Shallow Hazards

No significant shallow drilling hazards have been encountered over the White Rose Field during exploration, delineation, or development drilling. Hazards such as high-amplitude, shallow events were not identified during the inspection, study and reporting on various 2-D and 3-D high-resolution geophysical data vintages. The only concern raised by the 1997 shallow 3-D reprocessed data is the presence of a possible gas chimney centered on the crest of the White Rose High that extends in a small area toward southwest. At this time, no delineation or development drilling is planned in the area affected by possible gas contamination. A new high resolution survey is being planned for the North Amethyst glory hole in 2007.

## 2.3 Petrophysics

Tables 2-1, 2-2 and 2-3 compare the petrophysical parameters of all of the wells in the White Rose area. Table 2-4 provides the petrophysical summary for the entire Ben Nevis interval. Table 2-5 illustrates White Rose petrophysical parameters and Table 2-6 illustrates the different fluid contacts evident in the White Rose region.

**Table 2-1 Petrophysical Summary from the Gas Leg Intervals**

| | Gas Leg | | | | | | |
|---|---|---|---|---|---|---|---|
| | Well | Type | Top Depth (m TVD ss) | Gross Thickness (m) | Net:Gross | Porosity (%) | Permeability (mD) |
| White Rose Development Region | H20 | Delineation | 2807.1 | 100 | 0.2 | 13 | 14 |
| | O-28Y | Delineation | N/A | N/A | N/A | N/A | N/A |
| | B19z | Delineation | 2857.2 | 43.6 | 6.1 | 12.8 | 34.7 |
| | B19 | Delineation | 2779.5 | 94 | 25.4 | 14 | 68.2 |
| | E09 | Delineation | 2784 | 82 | 18 | 13 | 41 |
| | L08 | Delineation | 2771.2 | 102 | 46.8 | 15.6 | 92.6 |
| | E18 1 | Injector | N/A | N/A | N/A | N/A | N/A |
| | E18 2 | Producer | N/A | N/A | N/A | N/A | N/A |
| | E18 3 | Injector | N/A | N/A | N/A | N/A | N/A |
| | E18 4 | Producer | N/A | N/A | N/A | N/A | N/A |
| | A17 | Delineation | 2854.5 | 19.5 | 3.9 | 15 | 91.3 |
| | B07 1 | Injector | 2758.53 | 113 | 47.5 | 16.3 | 139.5 |
| | B07 2 | Producer | N/A | N/A | N/A | N/A | N/A |
| | B07 3 | Producer | N/A | N/A | N/A | N/A | N/A |
| | B07 4 | Injector | 2752.46 | 157.5 | 75.6 | 16 | 125.5 |
| | B07 5 | Producer | N/A | N/A | N/A | N/A | N/A |
| | B07 6 | Injector | 2819.03 | 66 | 0.66 | 12.5 | 33.7 |
| | B07 8 | Injector | 2851.88 | 20.52 | 4.72 | 11.5 | 25 |
| | B07 9 | Injector | N/A | N/A | N/A | N/A | N/A |
| SWRX | F04 | Delineation | 2700.06 | 191.3 | 118.6 | 17.2 | 140.5 |
| | F04z | Delineation | 2881.98 | 6 | 1.26 | 15.8 | 95.4 |
| NA | K-15 | Exploration | 2267.9 | 66 | 46.2 | 18.5 | 111 |

**Table 2-2 Petrophysical Summary for the Oil Leg Intervals**

| | Oil Leg | | | | | | |
|---|---|---|---|---|---|---|---|
| | Well | Type | Top Depth (m TVD ss) | Gross Thickness (m) | Net:Gross | Porosity (%) | Permeability (mD) |
| White Rose Development Region | H20 | Delineation | 2872.1 | 150 | 4.5 | 17 | 87 |
| | O-28Y | Delineation | 2890.61 | 281.8 | 84.53 | 16.1 | 95 |
| | B19z | Delineation | 2893.56 | 128 | 48.5 | 15.4 | 86.9 |
| | B19 | Delineation | 2871.9 | 129.4 | 95.75 | 16 | 114.63 |
| | E09 | Delineation | 2869.4 | 138.2 | 100.9 | 16 | 72.6 |
| | L08 | Delineation | 2872 | 137.7 | 114.3 | 17 | 133 |
| | E18 1 | Injector | N/A | N/A | N/A | N/A | N/A |
| | E18 2 | Producer | N/A | 2071.6 | 1781.6 | 17 | 140 |
| | E18 3 | Injector | N/A | N/A | N/A | N/A | N/A |
| | E18 4 | Producer | N/A | 1247 | 1097.73 | 17 | 130 |
| | A17 | Delineation | 2874.4 | 125.3 | 92.7 | 16.4 | 99 |
| | B07 1 | Injector | 2871.52 | 113.75 | 91 | 16.5 | 140.5 |
| | B07 2 | Producer | N/A | 1102 | 881.8 | 16 | 140.5 |
| | B07 3 | Producer | N/A | 1075 | 982.2 | 17 | 170 |
| | B07 4 | Injector | 2858.94 | 131.5 | 99.9 | 17 | 156 |
| | B07 5 | Producer | N/A | 1447 | 1230 | 17.8 | 146 |
| | B07 6 | Injector | 2871.99 | 106.8 | 83.31 | 17 | 172 |
| | B07 8 | Injector | 2871.54 | 122 | 98.9 | 15.2 | 103 |
| | B07 9 | Injector | N/A | N/A | N/A | N/A | N/A |
| SWR | F04 | Delineation | 2888.26 | 42 | 19.3 | 16.6 | 126.05 |
| | F04z | Delineation | 2887.94 | 79.5 | 27 | 17 | 142.2 |
| NA | K-15 | Exploration | 2333.9 | 52.5 | 51.97 | 22.6 | 320 |

**Table 2-3 Petrophysical Summary for the Water Leg Intervals**

| | Water Leg | | | | | | |
|---|---|---|---|---|---|---|---|
| | Well | Type | Top Depth (m TVD ss) | Gross Thickness (m) | Net Sand :Gross | Porosity (%) | Permeability (mD) |
| White Rose Development Region | H20 | Delineation | 3003.2 | 237.5 | 114 | 15 | 47 |
| | O-28Y | Delineation | 3170.09 | 109.5 | 46 | 15.3 | 69.6 |
| | B19z | Delineation | 3004.81 | 191.6 | 147.5 | 16 | 110.7 |
| | B19 | Delineation | 2999.9 | 110.5 | 81.73 | 15.6 | 91.36 |
| | E09 | Delineation | 3008.3 | 111.5 | 83.6 | 15 | 69 |
| | L08 | Delineation | 3009 | 63 | 42.1 | 14.6 | 68.1 |
| | E18 1 | Injector | N/A | N/A | N/A | N/A | N/A |
| | E18 2 | Producer | N/A | N/A | N/A | N/A | N/A |
| | E18 3 | Injector | N/A | 1352 | 987.1 | 15 | 75.7 |
| | E18 4 | Producer | N/A | N/A | N/A | N/A | N/A |
| | A17 | Delineation | 3000 | 58 | 41 | 16 | 85 |
| | B07 1 | Injector | N/A | N/A | N/A | N/A | N/A |
| | B07 2 | Producer | N/A | N/A | N/A | N/A | N/A |
| | B07 3 | Producer | N/A | N/A | N/A | N/A | N/A |
| | B07 4 | Injector | N/A | N/A | N/A | N/A | N/A |
| | B07 5 | Producer | N/A | N/A | N/A | N/A | N/A |
| | B07 6 | Injector | 2998.45 | 66.5 | 43.2 | 16.7 | 157 |
| | B07 8 | Injector | 2992.62 | 42.28 | 29.6 | 14.7 | 87 |
| | B07 9 | Injector | N/A | 454.9 | 341.1 | 16.5 | 144.8 |
| SWRX | F04 | Delineation | N/A | N/A | N/A | N/A | N/A |
| | F04z | Delineation | 2968.23 | 97.4 | 75 | 17.6 | 156.2 |
| NA | K-15 | Exploration | 2386.39 | 86.5 | 86.4 | 23.1 | 365 |

**Table 2-4 Petrophysical Summary Table for the Entire Ben Nevis Interval**

| | Total Ben Nevis Interval | | | | | | |
|---|---|---|---|---|---|---|---|
| | Well | Type | Top Depth (m TVD ss) | Gross Thickness (m) | Net Sand :Gross | Porosity (%) | Permeability (mD) |
| White Rose Development Region | H20 | Delineation | 2807.1 | 433.8 | 146.3 | 14.8 | 44.5 |
| | O-28Y | Delineation | 2890.61 | 388 | 138.63 | 15.2 | 77 |
| | B19z | Delineation | 2857.2 | 362.4 | 227.53 | 15.5 | 95 |
| | B19 | Delineation | 2779.5 | 330 | 212.7 | 15.7 | 96.5 |
| | E09 | Delineation | 2784 | 335.9 | 212.3 | 14.6 | 66.3 |
| | L08 | Delineation | 2771.2 | 300.9 | 213.9 | 16.3 | 109.8 |
| | E18 1 | Injector | 2840.42 | 242 | 188.6 | 16 | 91.6 |
| | E18 2 | Producer | N/A | N/A | N/A | N/A | N/A |
| | E18 3 | Injector | N/A | N/A | N/A | N/A | N/A |
| | E18 4 | Producer | N/A | N/A | N/A | N/A | N/A |
| | A17 | Delineation | 2854.5 | 203.1 | 142.4 | 16.1 | 92.4 |
| | B07 1 | Injector | 2758.53 | 226.3 | 140.8 | 16.3 | 140.5 |
| | B07 2 | Producer | N/A | N/A | N/A | N/A | N/A |
| | B07 3 | Producer | N/A | N/A | N/A | N/A | N/A |
| | B07 4 | Injector | 2752.46 | 285.5 | 176.4 | 16.5 | 142.5 |
| | B07 5 | Producer | N/A | N/A | N/A | N/A | N/A |
| | B07 6 | Injector | 2819.03 | 234.7 | 132.1 | 16.9 | 162 |
| | B07 8 | Injector | 2851.88 | 183.3 | 132.7 | 15 | 96.8 |
| | B07 9 | Injector | N/A | N/A | N/A | N/A | N/A |
| SWRX | F04 | Delineation | 2700 | 232.25 | 138.4 | 17.1 | 138 |
| | F04z | Delineation | 2881.98 | 183.3 | 114 | 17.3 | 149.5 |
| NA | K-15 | Exploration | 2267.9 | 205 | 184.5 | 22 | 290 |

## Table 2-5 White Rose Petrophysical Parameters

| Well | Formation | Gross Thickness h (m) | Net Reservoir h (m) | Net Pay HPT h (m) | Pay Avg Phi % | Pay Avg Sw % | Pay Avg Perm md |
|---|---|---|---|---|---|---|---|
| N-22 | Wyandot Gas | 9 | 8 | 6 | 19 | 30 | - |
| | Ben Nevis Gas | 124 | 65 | 36 | 16 | 19 | 29 |
| | Cape Broyle Gas | 54 | 8 | 1 | 15 | 49 | 49 |
| | Hibernia Oil | 288 | 84 | 37 | 12 | 29 | 19 |
| J-49 | Ben Nevis Gas | 137 | 16 | 7 | 14 | 33 | 14 |
| | Ben Nevis Oil | 38 | 32 | 25 | 14 | 23 | 41 |
| | Eastern Shoals Oil | 99 | 20 | 6 | 12 | 33 | 9 |
| N-30 | Ben Nevis Gas | 127 | 61 | 57 | 13 | 26 | 15 |
| | Ben Nevis Oil | 15 | 12 | 12 | 13 | 18 | 27 |
| | Eastern Shoals Oil | 50 | 10 | 10 | 14 | 31 | 16 |
| H-20 | Ben Nevis Gas | 58 | 11 | 0 | 0 | 0 | 0 |
| | Ben Nevis Oil | 115 | 59 | 5 | 16 | 0 | 0 |
| | Ben Nevis Transition | 10 | 9 | 0 | 0 | 0 | 0 |
| | Ben Nevis Water | 244 | 184 | 0 | 0 | 0 | 0 |
| E-09 | Ben Nevis Gas | 67 | 29 | 28 | 11 | 24 | 9 |
| | Ben Nevis Oil | 118 | 108 | 106 | 15 | 19 | 45 |
| | Ben Nevis Transition | 19 | 15 | 8 | 15 | 36 | 64 |
| | Avalon Water | 112 | 97 | - | - | - | - |
| | Hibernia Lwr1 Oil | 107 | 48 | 21 | 12 | 27 | 33 |
| | Hibernia Lwr2 Oil | 90 | 20 | 8 | 13 | 37 | 15 |
| L-08 | Ben Nevis Gas | 83 | 56 | 51 | 14 | 18 | 18 |
| | Ben Nevis Oil | 117 | 108 | 108 | 16 | 16 | 82 |
| | Ben Nevis Transition | 20 | 18 | 7 | 14 | 35 | 43 |
| | Ben Nevis Water | 63 | 56 | - | - | - | - |
| A-17 | Ben Nevis Gas** | 19.20** | 11.13** | 9 | 12** | 29** | 2* |
| | Ben Nevis Oil | 110 | 93 | 93 | 16 | 21 | 75 |
| | Ben Nevis Transition | 15 | 11 | 7 | 18 | 36 | 206 |
| | Ben Nevis Water | 58 | 47 | - | - | - | - |
| | **Major portion behind intermediate casing and not evaluated. Portion of gas zone in open hole contaminated with cement. | | | | | | |
| J-91 | Ben Nevis Gas | | | | | | |
| | Ben Nevis Oil | | | | | | |
| | Ben Nevis Transition | | | | | | |
| | Ben Nevis Water | 257 | 117 | - | 18 | - | - |
| F-04 Low Deviation Well | Ben Nevis Gas*** | 163 | 126 | 126 | 17 | 13 | 123 |
| | Ben Nevis Oil** | 43 | 17 | 17 | 16 | 17 | 63 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water** | - | - | - | - | - | - |
| F-04Z Deviated Well | Ben Nevis Gas | 13 | 3 | 3 | 10 | 35 | 15 |
| | Ben Nevis Oil | 81 | 30 | 30 | 14 | 27 | 74 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | 98 | 87 | 87 | 15 | - | 93 |

| Well | Formation | Gross Thickness h (m) | Net Reservoir h (m) | Net Pay HPT h (m) | Pay Avg Phi % | Pay Avg Sw % | Pay Avg Perm md |
|---|---|---|---|---|---|---|---|
| B07_1 Vertical Injector Through Reservoir | Ben Nevis Gas | 83 | 55 | 55 | 14 | 19 | 77 |
| | Ben Nevis Oil | 113 | 96 | 96 | 16 | 14 | 125 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | - | - | - | - | - | - |
| B07_2 Horizontal Producer | Ben Nevis Gas | - | - | - | - | - | - |
| | Ben Nevis Oil**** | 1,098 | 883 | 883 | 16 | 10 | 140 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | - | - | - | - | - | - |
| B07_4 Deviated Injector | Ben Nevis Gas | 116 | 81 | 81 | 14 | 13 | 80 |
| | Ben Nevis Oil | 128 | 113 | 113 | 16 | 9 | 136 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | - | - | - | - | - | - |
| B07_6 Vertical Injector Through Reservoir | Ben Nevis Gas | 13 | 1 | 1 | 11 | 37 | 15 |
| | Ben Nevis Oil | 127 | 92 | 92 | 15 | 21 | 108 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | 55 | 47 | 47 | 15 | - | 96 |
| B07_3 Horizontal Producer | Ben Nevis Gas | - | - | - | - | - | - |
| | Ben Nevis Oil | 1,075 | 982 | 982 | 17 | 9 | 171 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | - | - | - | - | - | - |
| B07_5 Horizontal Producer | Ben Nevis Gas | - | - | - | - | - | - |
| | Ben Nevis Oil | 1,434 | 1,230 | 1,230 | 18 | 10 | 146 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | - | - | - | - | - | - |
| B07_8 Vertical Injector Through Reservoir | Ben Nevis Gas | 20 | 10 | 4 | 12 | 43 | 28 |
| | Ben Nevis Oil | 121 | 101 | 101 | 15 | 16 | 105 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | 42 | 135 | 24 | 15 | - | 89 |
| B07_9 Horizontal Injector | Ben Nevis Gas | - | - | - | - | - | - |
| | Ben Nevis Oil | - | - | - | - | - | - |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | 455 | 341 | 341 | 17 | - | 145 |
| J22_1 Deviated Gas Injector | Wyandot Gas | - | - | - | - | - | - |
| | Ben Nevis Gas | 160 | 44 | 44 | 18 | 11 | 189 |
| | Ben Nevis Oil | - | - | - | - | - | - |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | - | - | - | - | - | - |
| E18_1 Vertical Injector Through Reservoir | Ben Nevis Gas | - | - | - | - | - | - |
| | Ben Nevis Oil | 111 | 84 | 84 | 16 | 19 | 95 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | 131 | 96 | 96 | 15 | | 60 |
| E18_2 Horizontal Producer | Ben Nevis Gas | - | - | - | - | - | - |
| | Ben Nevis Oil | 2,066 | 1,782 | 1,782 | 17 | 13 | 131 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | - | - | - | - | - | - |
| E18_3 Horizontal Injector | Ben Nevis Gas | - | - | - | - | - | - |
| | Ben Nevis Oil | - | - | - | - | - | - |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | 1,361 | 987 | 987 | 15 | - | 76 |

| Well | Formation | Gross Thickness h (m) | Net Reservoir h (m) | Net Pay HPT h (m) | Pay Avg Phi % | Pay Avg Sw % | Pay Avg Perm md |
|---|---|---|---|---|---|---|---|
| E18_4 Horizontal Producer | Ben Nevis Gas | - | - | - | - | - | - |
| | Ben Nevis Oil | 1,240 | 1,098 | 1,098 | 17 | 13 | 130 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | - | - | - | - | - | - |
| E18_5 Horizontal Injector | Ben Nevis Gas | - | - | - | - | - | - |
| | Ben Nevis Oil | - | - | - | - | - | - |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | 859 | 716 | 716 | 16 | - | 94 |
| E18-6 Horizontal Producer | Ben Nevis Gas | - | - | - | - | - | - |
| | Ben Nevis Oil | 2,135 | 1,697 | 1,697 | 16 | 16 | 115 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | - | - | - | - | - | - |
| E18_7 Horizontal Injector | Ben Nevis Gas | - | - | - | - | - | - |
| | Ben Nevis Oil | - | - | - | - | - | - |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | 1,204 | 1,029 | 835 | 16 | - | 92 |
| B-19 | Ben Nevis Gas | 94 | 25 | 25 | 14 | 23 | 68 |
| | Ben Nevis Oil | 129 | 96 | 96 | 16 | 19 | 115 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | 110 | 82 | 82 | 16 | - | 91 |
| B-19Z Deviated Well | Ben Nevis Gas | 37 | 5 | 5 | 13 | 36 | 35 |
| | Ben Nevis Oil | 110 | 42 | 42 | 15 | 30 | 87 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | 170 | 131 | 131 | 16 | - | 111 |
| O-28Y | Ben Nevis Gas | - | - | - | - | - | - |
| | Ben Nevis Oil | 282 | 85 | 85 | 16 | 21 | 95 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | 110 | 46 | 46 | 15 | - | 70 |
| O-28X Deviated Well | Ben Nevis Gas | - | - | - | - | - | - |
| | Ben Nevis Oil | 70 | 1 | 1 | 15 | 36 | 80 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | - | - | - | - | - | - |
| K-15 | Ben Nevis Gas | 66 | 46 | 46 | 19 | 12 | 111 |
| | Ben Nevis Oil | 53 | 52 | 52 | 23 | 11 | 320 |
| | Ben Nevis Transition | - | - | - | - | - | - |
| | Ben Nevis Water | 87 | 86 | 86 | 23 | - | 365 |

*Thicknesses for wells from F-04 onward are based on measured depth for comparison against modeled values

**Reservoir and oil pay summations for development wells are based on 3mD permeability to air for comparison against modeled RMS values.

***Gas pay summations for development wells are based on 0.5 mD permeability to air for comparison against modeled RMS values.

****Summary covers analysis interval for B07_2 – Openhole interval is 1133.0m MD

**Table 2-6 Fluid Contacts, White Rose Region**

| Well | Formation | Contact | Log Depth (m TVD) | Subsea Depth (m SS TVD) |
|---|---|---|---|---|
| L-61 | Ben Nevis | Oil/Water | | |
| L-61 | Ben Nevis | Top of Transition | 2986 | 2963.1 |
| L-61 | Ben Nevis | Bottom of Transition | 3007 | 2984.1 |
| | | | | |
| N-22 | Hibernia | Oil/Water | 3631.3 | 3603.6 |
| | | | | |
| J-49 | Ben Nevis | Gas/Oil | 3092.6 | 3069.7 |
| J-49 | Ben Nevis | Oil/Water | 3154 | 3131.1 |
| | | | | |
| N-30 | Ben Nevis | Gas/Oil | 3039.2 | 3014.2 |
| | | | | |
| H-20 | Ben Nevis | Gas/Oil (Estimated) | 2901.3 | 2874.9 |
| H-20 | Ben Nevis | Oil/Water | | |
| H-20 | Ben Nevis | Top of Transition | 3016.7 | 2990.3 |
| H-20 | Ben Nevis | Bottom of Transition | 3027.2 | 3000.8 |
| | | | | |
| E-09 | Ben Nevis | Gas/Oil | 2894.8 | 2871.8 |
| E-09 | Ben Nevis | Oil/Water | | |
| E-09 | Ben Nevis | Top of Transition | 3013 | 2990 |
| E-09 | Ben Nevis | Bottom of Transition | 3032.5 | 3009.5 |
| | | | | |
| L-08 | Ben Nevis | Gas/Oil | 2897 | 2872 |
| L-08 | Ben Nevis | Oil/Water | | |
| L-08 | Ben Nevis | Top of Transition | 3014 | 2989 |
| L-08 | Ben Nevis | Bottom of Transition | 3034.5 | 3009.5 |
| | | | | |
| A-17 | Ben Nevis | Gas/Oil | 2899.7 | 2874.7 |
| A-17 | Ben Nevis | Oil/Water | | |
| A-17 | Ben Nevis | Top of Transition | 3010 | 2985 |
| A-17 | Ben Nevis | Bottom of Transition | 3024.5 | 2999.5 |
| | | | | |
| J-91 | Ben Nevis | Wet | - | - |
| | | | | |
| F-04 | Ben Nevis | Gas/Oil | 2910.5 | 2887.5 |
| F-04 | Ben Nevis | Oil/Water | | |
| F-04 | Ben Nevis | Top of Transition | | |
| F-04 | Ben Nevis | Bottom of Transition | | |
| | | | | |
| F-04Z | Ben Nevis | Gas/Oil | | |
| F-04Z | Ben Nevis | Oil/Water | 2991.3 | 2968.2 |
| F-04Z | Ben Nevis | Top of Transition | | |
| F-04Z | Ben Nevis | Bottom of Transition | | |
| | | | | |
| B07_1 | Ben Nevis | Gas/Oil | 2895 | 2872 |
| B07_1 | Ben Nevis | Oil/Water | | |
| B07_1 | Ben Nevis | Top of Transition | | |
| B07_1 | Ben Nevis | Bottom of Transition | | |

| Well | Formation | Contact | Log Depth (m TVD) | Subsea Depth (m SS TVD) |
|---|---|---|---|---|
| B07_2 | Ben Nevis | Gas/Oil | | |
| B07_2 | Ben Nevis | Oil/Water | horizontal producer | |
| B07_2 | Ben Nevis | Top of Transition | | |
| B07_2 | Ben Nevis | Bottom of Transition | | |
| | | | | |
| B07_4 | Ben Nevis | Gas/Oil | 2882 | 2858.94 |
| B07_4 | Ben Nevis | Oil/Water | | |
| B07_4 | Ben Nevis | Top of Transition | | |
| B07_4 | Ben Nevis | Bottom of Transition | | |
| | | | | |
| B07_6 | Ben Nevis | Gas/Oil | | |
| B07_6 | Ben Nevis | Oil/Water | 3021.5 | 2998.5 |
| B07_6 | Ben Nevis | Top of Transition | | |
| B07_6 | Ben Nevis | Bottom of Transition | | |
| | | | | |
| B07_3 | Ben Nevis | Gas/Oil | | |
| B07_3 | Ben Nevis | Oil/Water | horizontal producer | |
| B07_3 | Ben Nevis | Top of Transition | | |
| B07_3 | Ben Nevis | Bottom of Transition | | |
| | | | | |
| B07_5 | Ben Nevis | Gas/Oil | | |
| B07_5 | Ben Nevis | Oil/Water | horizontal producer | |
| B07_5 | Ben Nevis | Top of Transition | | |
| B07_5 | Ben Nevis | Bottom of Transition | | |
| | | | | |
| B07_8 | Ben Nevis | Gas/Oil | 2894.54 | 2871.54 |
| | Ben Nevis | Oil/Water | 3015.62 | 2992.62 |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of Transition | | |
| | | | | |
| B07_9 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | water injector | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of Transition | | |
| | | | | |
| J22_1 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | | |
| | Ben Nevis | Top of Transition | | |
| | Eastern Shoals | Bottom of Transition | | |
| | | | | |
| | | | | |
| E18_1 | Ben Nevis | Gas/Oil | 2895.6 | 2872.6 |
| | Ben Nevis | Oil/Water | 3032.07 | 3009.07 |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of Transition | | |

| Well | Formation | Contact | Log Depth (m TVD) | Subsea Depth (m SS TVD) |
|---|---|---|---|---|
| E18_2 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | horizontal producer | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of Transition | | |
| | | | | |
| E18_3 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | horizontal injector | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| E18_4 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | horizontal producer | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| E18_5 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | horizontal injector | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| E18_6 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | horizontal producer | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| E18_7 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | horizontal injector | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| B-19 | Ben Nevis | Gas/Oil | 2871.9 | 2824.9 |
| | Ben Nevis | Oil/Water | 2999.9 | 2952.9 |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| B-19Z | Ben Nevis | Gas/Oil | 2893.56 | 2846.56 |
| | Ben Nevis | Oil/Water | 3004.81 | 2957.81 |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| O-28Y | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | 3217.09 | 3170.09 |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| O-28X | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| K-15 | Ben Nevis | Gas/Oil | 2380.9 | 2333.9 |
| | Ben Nevis | Oil/Water | 2433.39 | 2386.39 |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |

One well, North Amethyst K-15, defines the North Amethyst field (Figure 2-26). The results from K-15 indicate an average porosity of 22.7% and average permeability of 340 md within the oil leg.

The North Amethyst well at K-15 illustrated a fairly sound seismic interpretation and velocity model in this area as predictions of the top and base of the reservoir were fairly accurate, typically within 5 to 10 m. The net to gross or reservoir quality of the Ben Nevis Sandstone in this well is slightly better than that seen in the adjacent Terrace wells of the South Avalon Pool as a result of under-compaction and a decrease in the amount of carbonate cement. Other than this aspect, the Ben Nevis sandstone, as predicted, is identical to the reservoir seen in the Terrace.

While the initial delineation wells were drilled with a water-based fluid, the more recent development wells have utilised a synthetic-based drilling fluid. Slightly different data acquisition methods are used in the synthetic drilling fluids, however the results from these methods are very similar to those determined with the water-based drilling fluids. The methods used to analyze the K-15 well are discussed in more detail later in this section.

Figure 2-27 illustrates a petrophysical summary of the North Amethyst K-15 well. The figure displays a computed log showing gas, oil and water overlaying porosity and lithology overlaying a gamma ray curve. The figure also summarizes contacts and average petrophysical parameters for the well. Figures 2-28 to 2-31 are similar displays for nearby wells including F-04, F-04Z, B-07 4 and A-17.

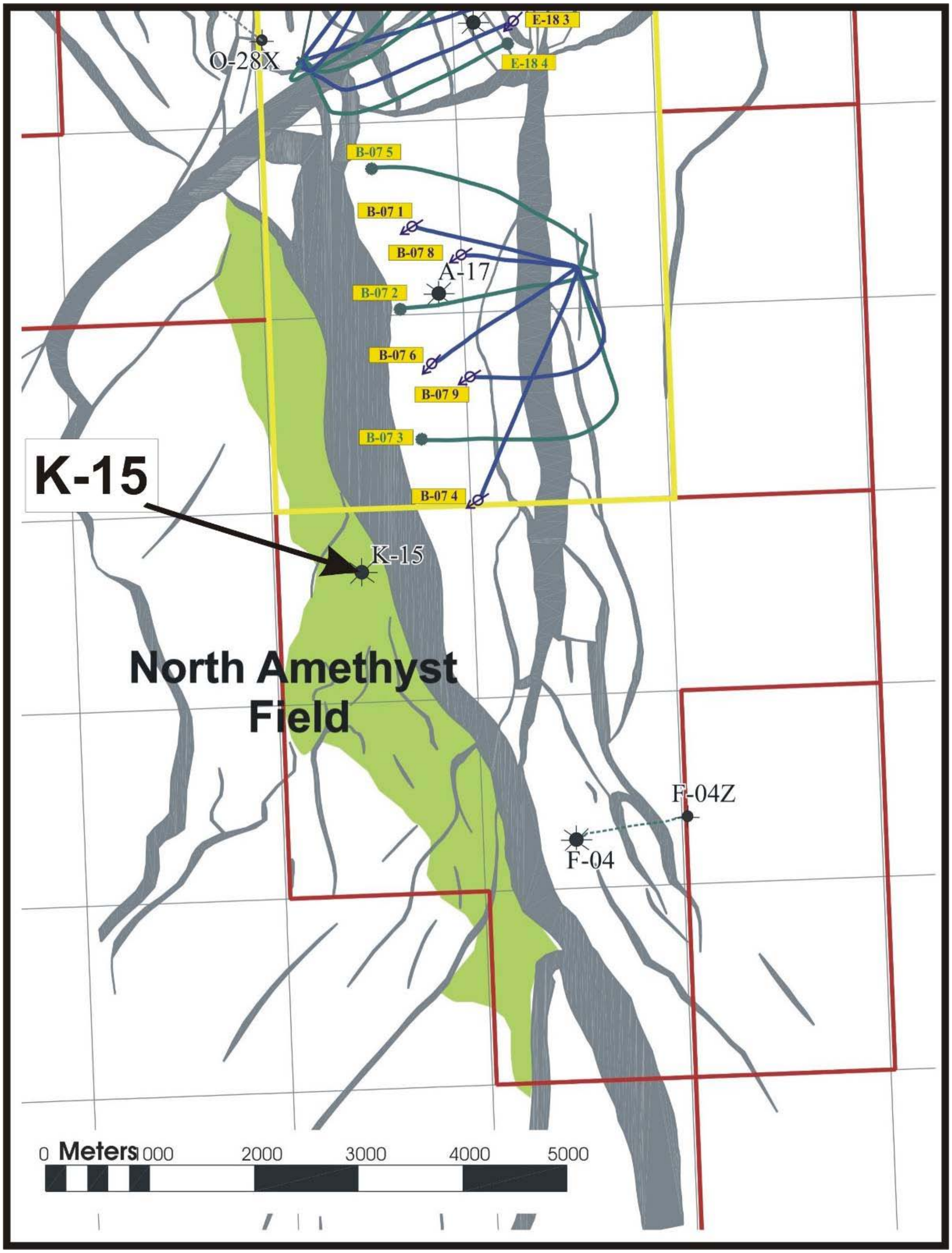



**Figure 2-26 Location of the K-15 Well**

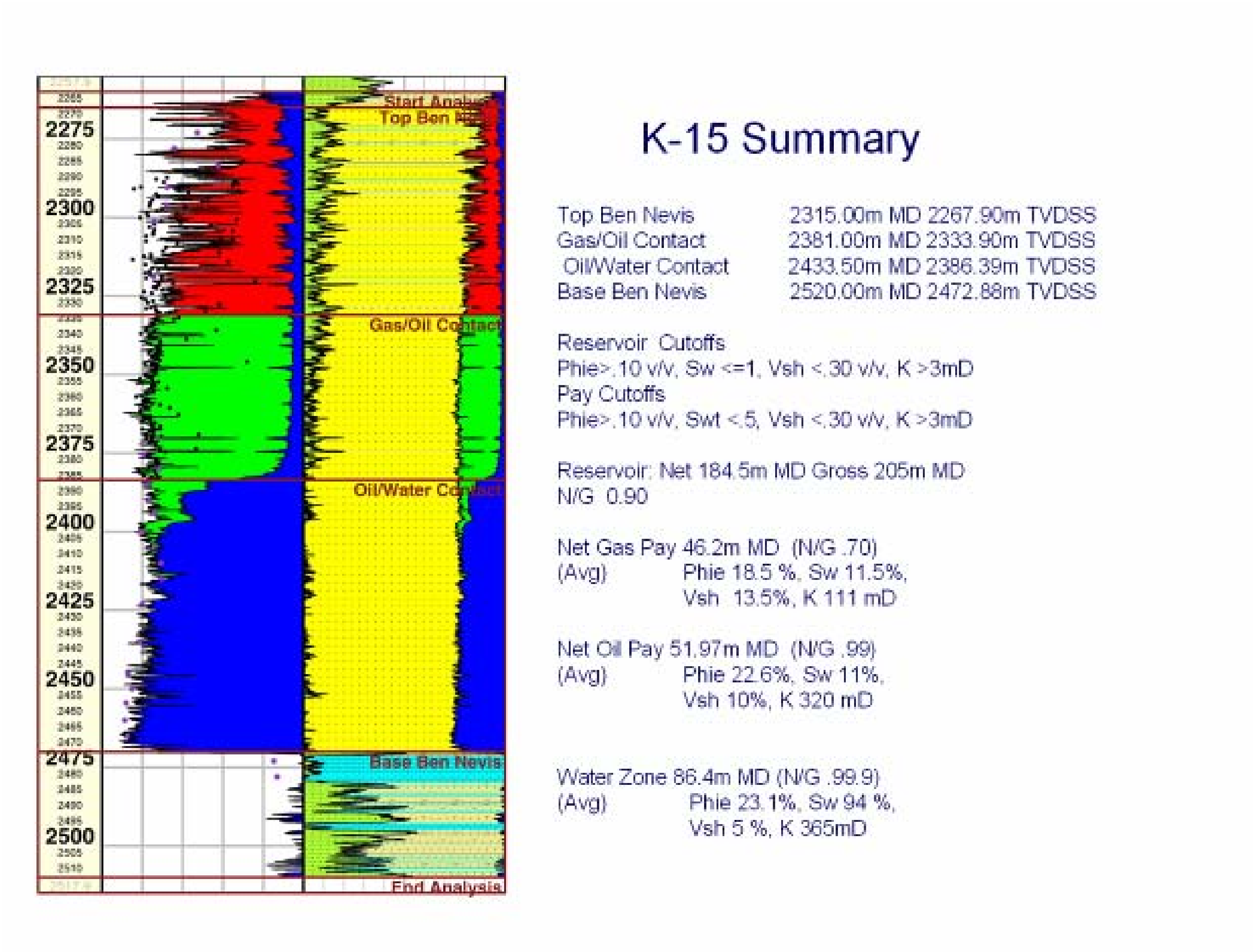
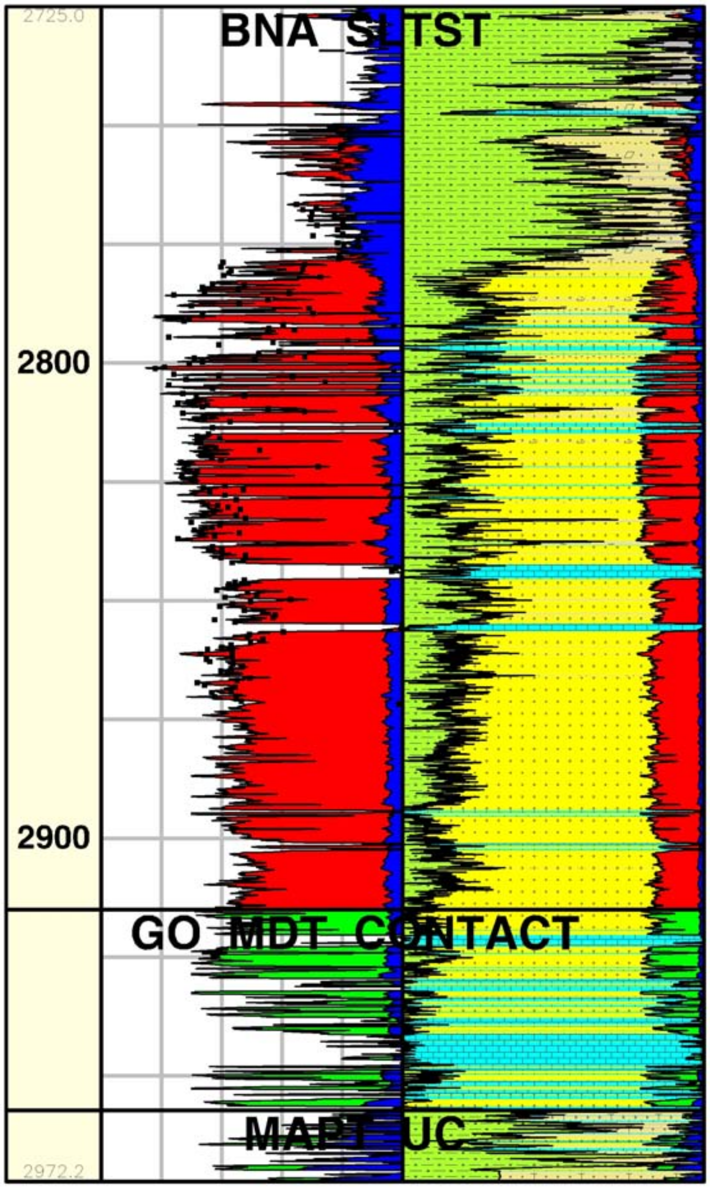



**Figure 2-27 K-15 Petrophysical Summary**




## F-04 Summary (20051012, HR)

| | |
|---|---|
| *BNA Siltstone* | ***2725.0m MD*** |
| *GO_MDT_Contact* | ***2915.0m MD*** |
| *Base BNA Reservoir* | ***2957.25m MD*** |

Reservoir Cutoffs
Phid>.10 v/v, Swt_Arch <=1, Vsh <.30 v/v, K >3mD
Pay Cutoffs
Phid>.10 v/v, Swt_Arch <.5, Vsh <.30 v/v, K >3mD

Reservoir: Net 138.4m MD Gross 190.0m MD N/G .63

| | |
|---|---|
| Net Gas Pay<br>(Avg) | 118.6m MD (N/G .62)<br>Phid .172v/v, Swt .11 v/v,<br>Vsh 0.002 v/v, K 140.5 mD |
| Net Oil Pay<br>(Avg) | 19.3m MD (N/G .46)<br>Phid 0.166v/v, Swt 0.10 v/v,<br>Vsh .01 v/v, K 126.05 mD |

WhiteRose Husky Energy

**Figure 2-28 F-04 Petrophysical Summary**

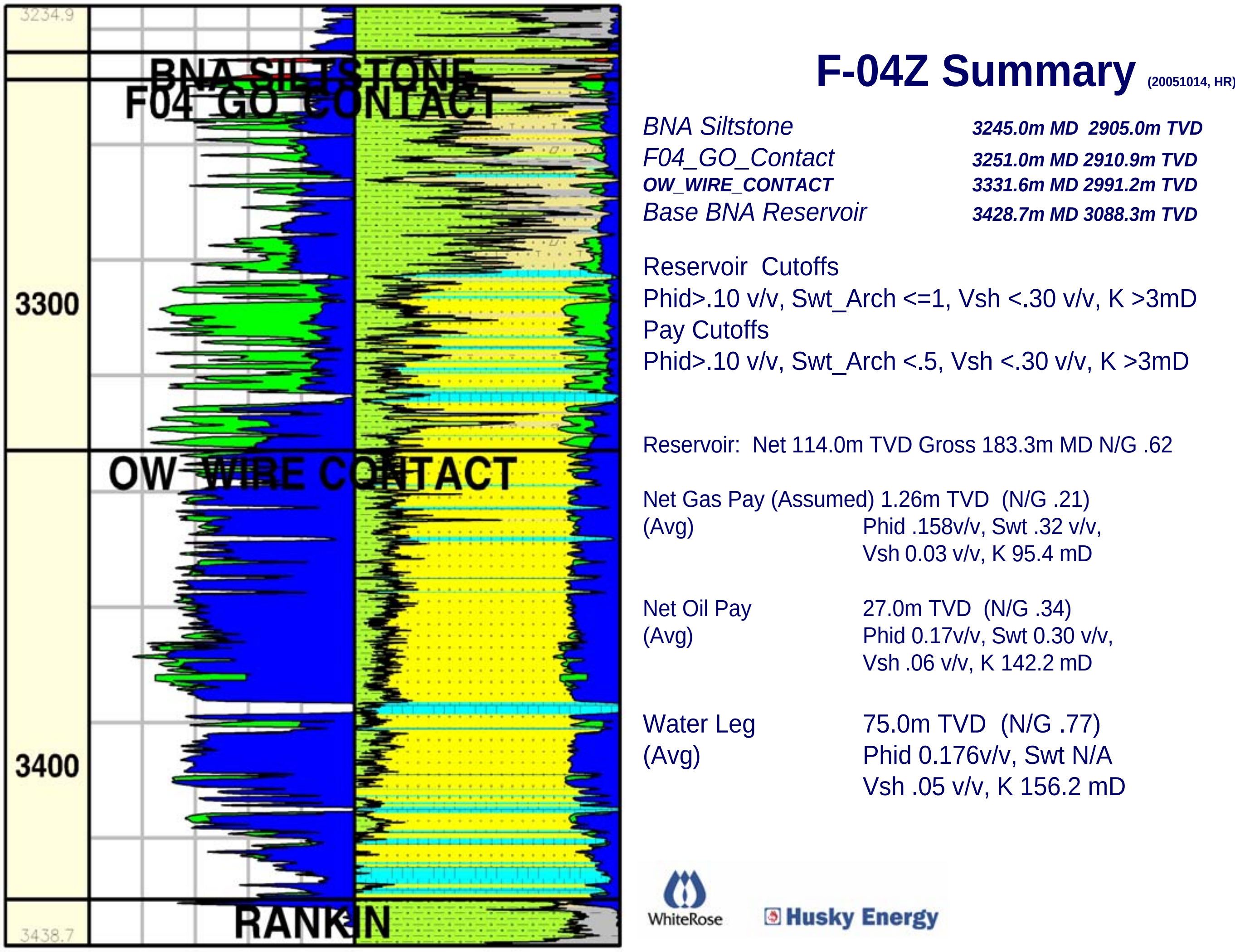



**Figure 2-29 F-04Z Petrophysical Summary**

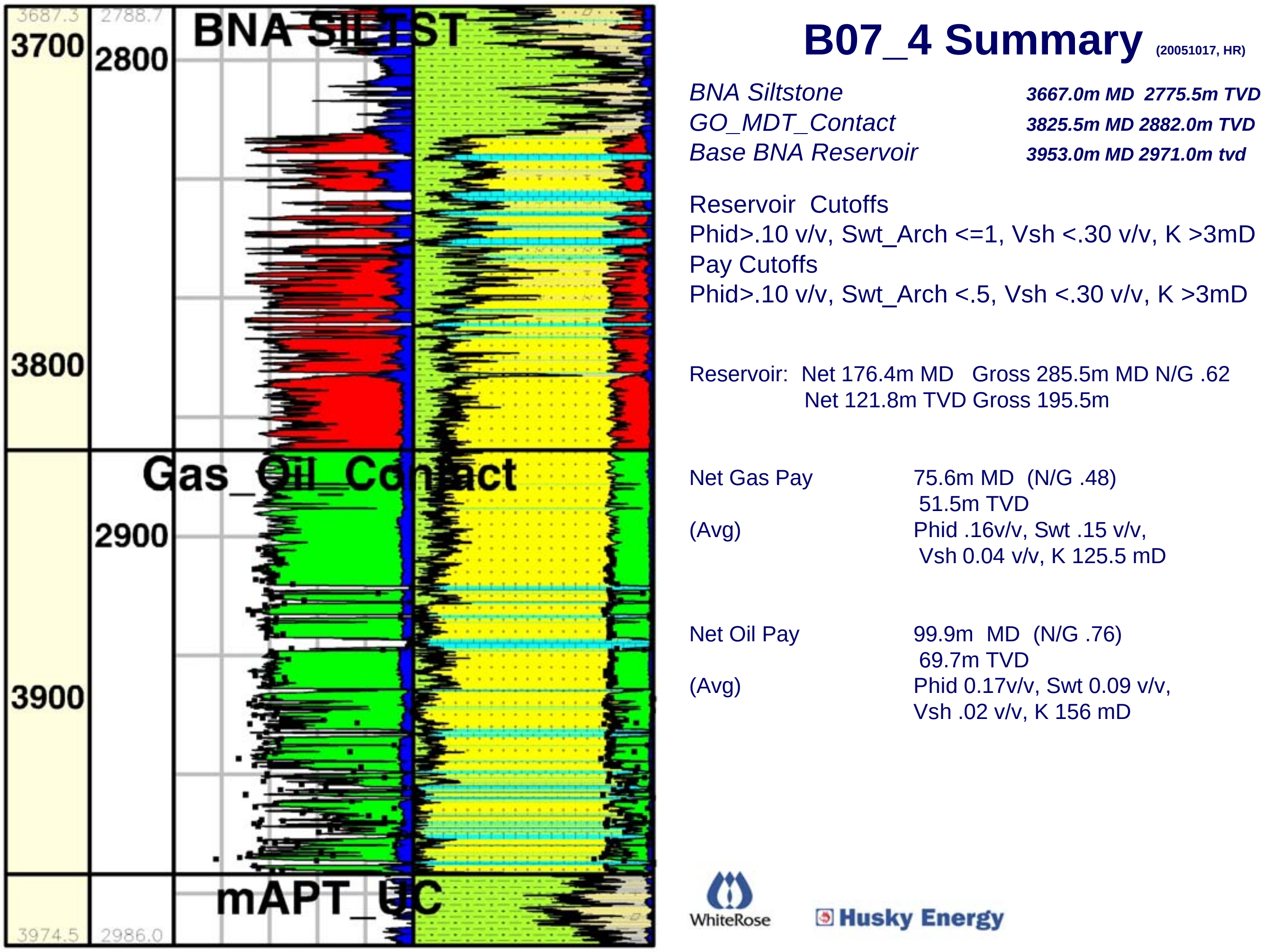
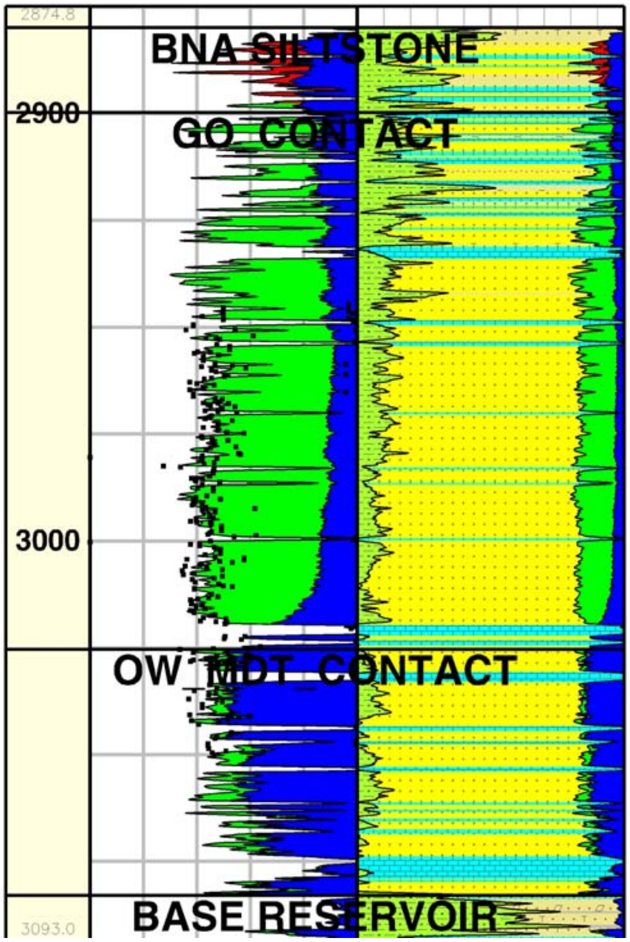



**Figure 2-30 B-07 4 Petrophysical Summary**




**A17 Summary** (20050928, HR)

| | |
|---|---|
| *BNA Siltstone* | *2879.8m MD 2854.5m TVDSS* |
| *GO_CONTACT* | *2899.7m MD 2874.4m TVDSS* |
| *OW_MDT_CONTACT* | *3025.3m MD 3000.0m TVDSS* |
| *Base BN (mAPT_UC)* | *3083.0m MD 3057.6m TVDSS* |

Reservoir Cutoffs
Phid>.10 v/v, Swt_Arch <=1, Vsh <.30 v/v, K >3mD
Pay Cutoffs
Phid>.10 v/v, Swt_Arch <.5, Vsh <.30 v/v, K >3mD

Reservoir: Net 142.4m MD Gross 203.1m MD
N/G 0.70

Net Gas Pay 3.9m MD (N/G .20)
(Avg) Phid 0.15v/v, Swt .38 v/v,
Vsh 0.12 v/v, K 91.3 mD

Net Oil Pay 92.7m MD (N/G .74)
(Avg) Phid 0.164v/v, Swt 0.19 v/v,
Vsh 0.08 v/v, K 98.8 mD

Water Zone 41.0m MD (N/G .71)
(Avg) Phid .16 v/v, Swt N/A,
Vsh 0.08 v/v, K 85.0 mD

WhiteRose Husky Energy

**Figure 2-31 A-17 Petrophysical Summary**

### 2.3.1 Petrophysical Analysis

#### 2.3.1.1 Petrophysical Analysis Data

The petrophysical evaluation of the North Amethyst K-15 log data used the Geolog 6.6 Program to compute porosity, water saturation and minerals volumes. This section details the evaluation of the Ben Nevis sandstone. Tables 2-7 and 2-8 summarize the logging runs conducted on K-15 and utilized in the evaluation. All the acquired logs appear to have good quality for the Ben Nevis sandstone.

**Table 2-7 K-15 Wireline Summary**

| Description | Hole Section | Depth | Comments |
|---|---|---|---|
| Descent #1 AIT/PEX/CMRPlus | 311 mm – vertical - - SBM | From Td to casing shoe | Nov, 01, 2006 . (15 hours) Good hole conditions.. Logged Resistivity, Neutron, Density, CMR Plus and GR all Logs were good quality. |

| | | | |
|---|---|---|---|
| Descent #2 MDT | 311 mm – vertical - - SBM | Reservoir section | Nov, 0, 2006 (30 hrs) MDT Pressure Tests conducted along BNA reservoir to establish fluid gradients and contacts. Oil samples taken at 2415m and 2390m; gas samples taken at 2375m and water sample taken; total of 12 bottles filled for testing. |
| Descent #1-3: GR/2Xobmi/DSI | 311 mm – vertical - - SBM | From Td to casing shoe | Nov 03, 2006 (08 hrs) Logged dual OBMI from TD- to base tertiary and the DSI from TD to Casing shoe |
| Descent #4 MDT with Dual Packer | 311 mm – vertical - - SBM | Reservoir section | Nov, 03, 2006 (18 hrs) MDT vertical interference test conducted at 2430. |
| Descent #4 MSCT | 311 mm – vertical - - SBM | Reservoir section | Nov 04, 2006 (13.5 hrs) MSCT Core samples drilled and taken along reservoir. |

**Table 2-8 K-15 LWD Summary**

| Description | Hole Section | Depth | Comments |
|---|---|---|---|
| GR-ARC | 311 mm – Vertical - - SBM | From Td to casing shoe | Gamma ray and phase/attenuation resistivity data acquired during the drilling the whole to TD. |

Conventional coring was conducted in the Ben Nevis reservoir section. In addition to conventional coring, sidewall cores were acquired in the lower section of the reservoir. Table 2-9 presents a summary of the core acquisitions. The values of the conventional core analysis, porosity, water saturation, maximum permeability, and grain density are presented in Table 2-10.

**Table 2-9 K-15 Core Summary**

| Well | Core Type | | Start | Finish | Recovery | Formation |
|---|---|---|---|---|---|---|
| K-15 | Conventional | Core #1 | 2335.3 | 2445.6 | 95.7 | Ben Nevis |
| K-15 | Sidewall | 25 recovered | 2323.0 | 2528.0 | | Ben Nevis/E. Shoals |

**Table 2-10 K-15 Core Analysis Results**

OMNI Laboratories, Inc.

**SUMMARY OF ROUTINE CORE ANALYSES RESULTS**

Vacuum Oven Dried at 180ºF Net Confining Stress: 800 psi

Husky Energy
Husky et al North Amethyst K15 Well
White Rose Field

Offshore
Newfoundland
File: M-36083

| Core Number | Sample Number | Sample Depth, meters | Permeability, millidarcys to Air | Permeability, millidarcys Klinkenberg | Porosity, percent Ambient | Porosity, percent 800 psi | Grain Density, gm/cc | Water Saturation, percent |
|---|---|---|---|---|---|---|---|---|
| 1 | 1-1 | 2335.04 | 100. | 88.7 | 20.3 | 20.2 | 2.67 | 6.9 |
| 1 | 1-2 | 2335.50 | 109. | 96.8 | 21.9 | 21.8 | 2.67 | |
| 1 | 1-3 | 2336.00 | 0.020 | 0.0086 | 10.2 | 10.1 | 2.71 | |
| 1 | 1-4 | 2336.50 | 41.9 | 35.6 | 20.8 | 20.8 | 2.67 | |
| 1 | 1-5 | 2337.00 | 0.027 | 0.012 | 9.8 | 9.7 | 2.67 | |
| 1 | 1-6 | 2337.50 | 0.133 | 0.080 | 10.5 | 10.4 | 2.67 | 30.0 |
| 1 | 1-7 | 2338.00 | 368. | 342. | 24.2 | 24.1 | 2.65 | |
| 1 | 1-8 | 2338.50 | 433. | 404. | 25.2 | 25.0 | 2.65 | |
| 1 | 1-9 | 2339.00 | 42.2 | 35.9 | 18.5 | 18.4 | 2.66 | |
| 1 | 1-10 | 2339.50 | 63.8 | 55.4 | 17.1 | 17.0 | 2.66 | |
| 1 | 1-11 | 2340.00 | 195. | 178. | 21.9 | 21.8 | 2.65 | 6.0 |
| 1 | 1-12 | 2340.54 | 239. | 219. | 21.6 | 21.6 | 2.65 | |
| 1 | 1-13 | 2341.00 | 3.94 | 2.95 | 14.2 | 14.1 | 2.66 | |
| 1 | 1-14 | 2341.50 | 325. | 300. | 22.5 | 22.4 | 2.65 | |
| 1 | 1-15 | 2342.00 | 4.65 | 3.48 | 15.0 | 15.0 | 2.75 | |
| 1 | 1-16 | 2342.47 | 231. | 211. | 22.8 | 22.8 | 2.65 | 6.1 |
| 1 | 1-17 | 2343.00 | 164. | 148. | 22.9 | 22.9 | 2.67 | |
| 1 | 1-18 | 2343.50 | 42.5 | 36.1 | 17.6 | 17.6 | 2.65 | |
| 1 | 1-19 | 2344.00 | 211. | 193. | 21.1 | 21.0 | 2.65 | |
| 1 | 1-20 | 2344.50 | 419. | 390. | 21.8 | 21.7 | 2.66 | |
| 1 | 1-21 | 2345.00 | 377. | 350. | 23.3 | 23.2 | 2.65 | 3.8 |
| 1 | 1-22 | 2345.50 | 132. | 118. | 18.8 | 18.7 | 2.65 | |
| 1 | 1-23 | 2346.00 | 340. | 315. | 23.1 | 23.1 | 2.65 | |
| 1 | 1-24 | 2346.50 | 368. | 341. | 24.3 | 24.2 | 2.65 | |
| 1 | 1-25 | 2347.00 | 0.027 | 0.012 | 9.9 | 9.7 | 2.67 | |
| 1 | 1-26 | 2347.53 | 160. | 145. | 21.2 | 21.2 | 2.65 | 6.2 |
| 1 | 1-27 | 2348.00 | 72.5 | 63.3 | 18.3 | 18.2 | 2.65 | |
| 1 | 1-28 | 2348.50 | 324. | 300. | 22.2 | 22.2 | 2.65 | |
| 1 | 1-29 | 2349.00 | 2.04 | 1.50 | 13.8 | 13.7 | 2.66 | |
| 1 | 1-30 | 2349.50 | 286. | 263. | 22.9 | 22.9 | 2.65 | |
| 1 | 1-31 | 2350.00 | 45.1 | 38.5 | 17.5 | 17.3 | 2.65 | 9.6 |
| 1 | 1-32 | 2350.50 | 279. | 257. | 22.2 | 22.0 | 2.68 | |
| 1 | 1-33 | 2351.00 | 0.253 | 0.168 | 10.5 | 10.4 | 2.66 | |
| 1 | 1-34 | 2351.50 | 275. | 253. | 22.3 | 22.3 | 2.65 | |
| 1 | 1-35 | 2352.00 | 170. | 154. | 22.4 | 22.3 | 2.77 | |
| 1 | 1-36 | 2352.50 | 412. | 384. | 23.4 | 23.3 | 2.65 | 3.4 |
| 1 | 1-37 | 2353.00 | 7.73 | 5.98 | 12.3 | 12.3 | 2.66 | |
| 1 | 1-38 | 2353.50 | 1.29 | 0.936 | 10.5 | 10.5 | 2.66 | |
| 1 | 1-39 | 2354.00 | 259. | 238. | 23.4 | 23.3 | 2.66 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 1-40 | 2354.50 | 15.4 | 12.3 | 13.4 | 13.4 | 2.65 | |
| 1 | 1-41QL | 2355.00 | 78.8 | 69.1 | 18.8 | 18.7 | 2.69 | |
| 1 | 1-42 | 2355.50 | 19.8 | 16.1 | 13.0 | 12.9 | 2.66 | 12.1 |
| 1 | 1-43 | 2355.94 | 210. | 192. | 20.5 | 20.5 | 2.65 | |
| 1 | 1-45 | 2357.00 | 192. | 175. | 20.9 | 20.8 | 2.65 | |
| 1 | 1-46 | 2357.50 | 3.75 | 2.81 | 12.5 | 12.4 | 2.65 | |
| 1 | 1-47 | 2358.00 | 252. | 231. | 22.7 | 22.6 | 2.65 | |
| 1 | 1-48 | 2358.50 | 358. | 332. | 23.7 | 23.6 | 2.65 | 3.1 |
| 1 | 1-49 | 2359.00 | 300. | 277. | 22.7 | 22.7 | 2.65 | |
| 1 | 1-50 | 2359.50 | 253. | 233. | 25.4 | 25.3 | 2.71 | |
| 1 | 1-51 | 2360.01 | 0.215 | 0.140 | 11.2 | 11.2 | 2.67 | |
| 1 | 1-52 | 2360.50 | 232. | 212. | 22.0 | 21.9 | 2.65 | |
| 1 | 1-53 | 2361.00 | 357. | 331. | 23.5 | 23.4 | 2.65 | 4.0 |
| 1 | 1-54 | 2361.50 | 31.2 | 26.1 | 20.5 | 20.5 | 2.87 | |
| 1 | 1-55 | 2362.00 | 327. | 302. | 22.5 | 22.4 | 2.65 | |
| 1 | 1-56 | 2362.50 | 270. | 249. | 21.6 | 21.6 | 2.65 | |
| 1 | 1-57 | 2363.00 | 154. | 138. | 22.9 | 22.8 | 2.69 | |
| 1 | 1-58 | 2363.50 | 284. | 262. | 23.5 | 23.5 | 2.66 | 5.3 |
| 1 | 1-59 | 2364.00 | 307. | 284. | 22.8 | 22.7 | 2.65 | |
| 1 | 1-60 | 2364.50 | 214. | 195. | 21.1 | 21.1 | 2.65 | |
| 1 | 1-61 | 2365.00 | 400. | 372. | 23.4 | 23.4 | 2.65 | |
| 1 | 1-62 | 2365.50 | 172. | 156. | 21.1 | 21.1 | 2.65 | |
| 1 | 1-63 | 2366.00 | 0.014 | 0.0053 | 7.2 | 7.1 | 2.67 | 52.6 |
| 1 | 1-64 | 2366.50 | 143. | 128. | 19.4 | 19.3 | 2.65 | |
| 1 | 1-65 | 2367.00 | 275. | 253. | 21.5 | 21.4 | 2.65 | |
| 1 | 1-66 | 2367.53 | 297. | 274. | 21.8 | 21.8 | 2.65 | |
| 1 | 1-67 | 2368.00 | 345. | 320. | 22.3 | 22.3 | 2.65 | |
| 1 | 1-68 | 2368.50 | 356. | 330. | 21.9 | 21.9 | 2.65 | 4.0 |
| 1 | 1-69QL | 2369.00 | 305. | 282. | 21.0 | 21.0 | 2.64 | |
| 1 | 1-70 | 2369.50 | 469. | 439. | 23.7 | 23.6 | 2.65 | |
| 1 | 1-71 | 2369.97 | 246. | 225. | 22.6 | 22.4 | 2.66 | |
| 1 | 1-72 | 2370.50 | 127. | 114. | 19.9 | 19.7 | 2.65 | |
| 1 | 1-73 | 2371.00 | 169. | 153. | 20.6 | 20.4 | 2.77 | |
| 1 | 1-74 | 2371.50 | 487. | 456. | 24.1 | 24.1 | 2.65 | 2.8 |
| 1 | 1-75 | 2372.00 | 429. | 400. | 23.5 | 23.4 | 2.65 | |
| 1 | 1-76 | 2372.50 | 421. | 392. | 22.4 | 22.3 | 2.64 | |
| 1 | 1-77 | 2373.00 | 294. | 271. | 23.2 | 23.1 | 2.70 | |
| 1 | 1-78 | 2373.50 | 1.49 | 1.09 | 12.5 | 12.5 | 2.66 | |
| 1 | 1-79 | 2374.00 | 330. | 305. | 22.1 | 22.1 | 2.65 | 3.6 |
| 1 | 1-80 | 2374.50 | 378. | 351. | 22.7 | 22.6 | 2.64 | |
| 1 | 1-81 | 2375.00 | 369. | 343. | 23.4 | 23.3 | 2.64 | |
| 1 | 1-82 | 2375.50 | 237. | 217. | 22.0 | 21.9 | 2.64 | |
| 1 | 1-83 | 2376.00 | 25.7 | 21.2 | 14.6 | 14.6 | 2.65 | |
| 1 | 1-84 | 2376.53 | 175. | 158. | 21.8 | 21.8 | 2.65 | 5.8 |
| 1 | 1-85 | 2377.00 | 266. | 245. | 21.4 | 21.3 | 2.64 | |
| 1 | 1-86 | 2377.50 | 276. | 254. | 22.0 | 22.0 | 2.65 | |
| 1 | 1-87 | 2378.00 | 299. | 275. | 21.7 | 21.6 | 2.64 | |
| 1 | 1-88 | 2378.53 | 84.8 | 74.6 | 18.6 | 18.4 | 2.65 | |
| 1 | 1-89 | 2379.00 | 134. | 120. | 19.3 | 19.1 | 2.65 | 10.8 |
| 1 | 1-90 | 2379.53 | 289. | 267. | 22.1 | 22.0 | 2.64 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 1-91 | 2380.00 | 341. | 316. | 22.7 | 22.5 | 2.64 | |
| 1 | 1-92 | 2380.48 | 230. | 210. | 22.3 | 22.2 | 2.65 | |
| 1 | 1-93 | 2381.00 | 330. | 305. | 22.4 | 22.3 | 2.64 | |
| 1 | 1-94 | 2381.49 | 359. | 333. | 23.0 | 23.0 | 2.65 | 6.2 |
| 1 | 1-95 | 2382.00 | 369. | 342. | 23.4 | 23.4 | 2.65 | |
| 1 | 1-96 | 2382.50 | 3.80 | 2.84 | 13.0 | 13.0 | 2.65 | |
| 1 | 1-97 | 2383.00 | 308. | 285. | 22.2 | 22.0 | 2.64 | |
| 1 | 1-98 | 2383.48 | 421. | 392. | 24.2 | 24.2 | 2.64 | |
| 1 | 1-99QL | 2384.00 | 379. | 352. | 22.7 | 22.7 | 2.64 | |
| 1 | 1-100 | 2384.50 | 403. | 375. | 22.9 | 22.9 | 2.64 | 6.1 |
| 1 | 1-101 | 2385.00 | 341. | 315. | 22.1 | 22.1 | 2.64 | |
| 1 | 1-102 | 2385.48 | 33.5 | 28.1 | 17.4 | 17.3 | 2.64 | |
| 1 | 1-103 | 2386.00 | 240. | 220. | 21.3 | 21.2 | 2.64 | |
| 1 | 1-104 | 2386.50 | 230. | 210. | 21.3 | 21.2 | 2.64 | |
| 1 | 1-105 | 2387.00 | 285. | 262. | 22.7 | 22.6 | 2.64 | 5.8 |
| 1 | 1-106 | 2387.50 | 274. | 252. | 21.5 | 21.3 | 2.64 | |
| 1 | 1-108 | 2388.59 | 236. | 216. | 21.4 | 21.3 | 2.65 | |
| 1 | 1-109 | 2389.00 | 349. | 323. | 21.7 | 21.6 | 2.64 | |
| 1 | 1-110 | 2389.50 | 230. | 210. | 21.2 | 21.2 | 2.65 | |
| 1 | 1-111 | 2390.00 | 387. | 360. | 23.0 | 23.0 | 2.65 | 6.0 |
| 1 | 1-112 | 2390.50 | 348. | 322. | 22.3 | 22.3 | 2.65 | |
| 1 | 1-113 | 2391.00 | 435. | 405. | 22.5 | 22.5 | 2.65 | |
| 1 | 1-114 | 2391.50 | 327. | 303. | 21.6 | 21.6 | 2.64 | |
| 1 | 1-115 | 2392.00 | 164. | 149. | 21.4 | 21.3 | 2.64 | |
| 1 | 1-116 | 2392.50 | 0.040 | 0.020 | 8.4 | 8.4 | 2.65 | 39.3 |
| 1 | 1-117 | 2393.02 | 341. | 316. | 23.6 | 23.6 | 2.64 | |
| 1 | 1-118 | 2393.50 | 264. | 243. | 22.6 | 22.5 | 2.64 | |
| 1 | 1-119 | 2394.00 | 227. | 208. | 22.0 | 22.0 | 2.64 | |
| 1 | 1-121 | 2395.00 | 292. | 269. | 22.2 | 22.2 | 2.64 | |
| 1 | 1-122 | 2395.50 | 250. | 230. | 22.0 | 21.9 | 2.64 | 8.6 |
| 1 | 1-123 | 2396.00 | 277. | 255. | 22.1 | 22.1 | 2.64 | |
| 1 | 1-124 | 2396.50 | 349. | 324. | 23.5 | 23.5 | 2.64 | |
| 1 | 1-125 | 2397.03 | 324. | 300. | 23.0 | 23.0 | 2.64 | |
| 1 | 1-126 | 2397.50 | 392. | 364. | 24.3 | 24.3 | 2.64 | |
| 1 | 1-127 | 2397.92 | 276. | 254. | 22.5 | 22.4 | 2.64 | 7.3 |
| 1 | 1-128 | 2398.59 | 163. | 147. | 21.6 | 21.6 | 2.64 | |
| 1 | 1-129 | 2399.00 | 271. | 249. | 22.2 | 22.2 | 2.64 | |
| 1 | 1-130 | 2399.50 | 308. | 284. | 22.6 | 22.5 | 2.65 | |
| 1 | 1-131 | 2400.00 | 333. | 308. | 22.6 | 22.5 | 2.65 | |
| 1 | 1-132 | 2400.50 | 211. | 192. | 20.3 | 20.2 | 2.64 | 8.1 |
| 1 | 1-133 | 2401.00 | 363. | 337. | 22.3 | 22.3 | 2.65 | |
| 1 | 1-134 | 2401.50 | 380. | 353. | 23.5 | 23.4 | 2.65 | |
| 1 | 1-135 | 2402.00 | 356. | 330. | 23.3 | 23.2 | 2.64 | |
| 1 | 1-137 | 2403.00 | 558. | 524. | 24.9 | 24.8 | 2.64 | |
| 1 | 1-138 | 2403.50 | 361. | 335. | 23.5 | 23.4 | 2.65 | 5.2 |
| 1 | 1-139QL | 2404.00 | 579. | 544. | 23.7 | 23.6 | 2.64 | |
| 1 | 1-140 | 2404.50 | 340. | 315. | 23.1 | 23.0 | 2.64 | |
| 1 | 1-141 | 2405.00 | 308. | 284. | 22.6 | 22.5 | 2.64 | |
| 1 | 1-142 | 2405.50 | 275. | 253. | 21.3 | 21.3 | 2.64 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 1-143 | 2406.00 | 430. | 401. | 23.5 | 23.5 | 2.64 | |
| 1 | 1-144 | 2406.50 | 207. | 189. | 19.9 | 19.9 | 2.66 | 8.1 |
| 1 | 1-145 | 2407.00 | 554. | 520. | 24.2 | 24.1 | 2.64 | |
| 1 | 1-146 | 2407.47 | 420. | 391. | 24.3 | 24.3 | 2.64 | |
| 1 | 1-147 | 2408.00 | 581. | 546. | 24.2 | 24.2 | 2.64 | |
| 1 | 1-148 | 2408.50 | 161. | 146. | 18.6 | 18.5 | 2.64 | |
| 1 | 1-149 | 2409.00 | 212. | 194. | 22.8 | 22.8 | 2.64 | 9.4 |
| 1 | 1-150 | 2409.50 | 326. | 302. | 23.6 | 23.6 | 2.64 | |
| 1 | 1-151 | 2410.00 | 479. | 448. | 23.6 | 23.6 | 2.64 | |
| 1 | 1-152 | 2410.50 | 415. | 386. | 22.8 | 22.7 | 2.64 | |
| 1 | 1-153 | 2411.00 | 294. | 271. | 22.1 | 22.1 | 2.64 | |
| 1 | 1-154 | 2411.50 | 333. | 308. | 22.5 | 22.5 | 2.64 | 7.1 |
| 1 | 1-155 | 2412.00 | 207. | 189. | 21.3 | 21.3 | 2.64 | |
| 1 | 1-156 | 2412.50 | 203. | 185. | 21.3 | 21.3 | 2.65 | |
| 1 | 1-157 | 2413.00 | 305. | 281. | 24.0 | 23.9 | 2.64 | |
| 1 | 1-158 | 2413.50 | 264. | 242. | 22.6 | 22.6 | 2.64 | |
| 1 | 1-160 | 2414.50 | 257. | 236. | 22.4 | 22.4 | 2.64 | 7.9 |
| 1 | 1-161 | 2415.00 | 7.22 | 5.57 | 15.6 | 15.5 | 2.65 | |
| 1 | 1-162 | 2415.50 | 146. | 131. | 21.2 | 21.2 | 2.64 | |
| 1 | 1-163 | 2416.00 | 570. | 535. | 23.4 | 23.3 | 2.64 | |
| 1 | 1-164 | 2416.50 | 390. | 362. | 22.6 | 22.5 | 2.64 | |
| 1 | 1-165 | 2417.00 | 367. | 341. | 22.6 | 22.5 | 2.64 | 7.4 |
| 1 | 1-166 | 2417.50 | 387. | 360. | 22.7 | 22.6 | 2.65 | |
| 1 | 1-167 | 2418.00 | 327. | 302. | 22.0 | 22.0 | 2.64 | |
| 1 | 1-168 | 2418.50 | 341. | 316. | 22.0 | 21.9 | 2.64 | |
| 1 | 1-170 | 2419.50 | 9.97 | 7.83 | 16.0 | 16.0 | 2.65 | |
| 1 | 1-171QL | 2420.00 | 289. | 266. | 21.4 | 21.4 | 2.64 | |
| 1 | 1-172 | 2420.50 | 253. | 232. | 20.6 | 20.5 | 2.64 | 8.1 |
| 1 | 1-173 | 2421.00 | 425. | 396. | 22.8 | 22.7 | 2.64 | |
| 1 | 1-174 | 2421.50 | 497. | 465. | 23.6 | 23.5 | 2.64 | |
| 1 | 1-175 | 2422.03 | 513. | 480. | 23.8 | 23.8 | 2.64 | |
| 1 | 1-176 | 2422.50 | 297. | 274. | 21.9 | 21.8 | 2.64 | |
| 1 | 1-178 | 2423.50 | 228. | 208. | 21.7 | 21.7 | 2.64 | 9.1 |
| 1 | 1-179 | 2424.00 | 267. | 245. | 21.9 | 21.9 | 2.64 | |
| 1 | 1-180 | 2424.50 | 91.1 | 80.4 | 21.7 | 21.7 | 2.64 | |
| 1 | 1-181 | 2425.00 | 270. | 248. | 22.6 | 22.5 | 2.64 | |
| 1 | 1-182 | 2425.50 | 339. | 314. | 23.0 | 23.0 | 2.64 | |
| 1 | 1-183 | 2426.00 | 534. | 500. | 24.5 | 24.4 | 2.64 | 9.8 |
| 1 | 1-184 | 2426.50 | 275. | 253. | 22.2 | 22.2 | 2.64 | |
| 1 | 1-185 | 2427.00 | 477. | 446. | 24.4 | 24.4 | 2.64 | |
| 1 | 1-186 | 2427.50 | 216. | 197. | 21.9 | 21.9 | 2.64 | |
| 1 | 1-187 | 2428.00 | 465. | 435. | 23.7 | 23.7 | 2.64 | |
| 1 | 1-188 | 2428.50 | 466. | 435. | 22.6 | 22.4 | 2.64 | 20.0 |
| 1 | 1-189 | 2429.00 | 387. | 360. | 22.7 | 22.7 | 2.64 | |
| 1 | 1-190 | 2429.50 | 503. | 471. | 23.3 | 23.3 | 2.64 | |
| 1 | 1-191 | 2429.93 | 451. | 421. | 23.2 | 23.1 | 2.64 | |
| | | Average values: | 263. | 243. | 21.0 | 21.0 | 2.65 | 9.9 |

#### 2.3.1.2 Petrophysical Analysis Methodology

**Porosity/Permeability Relationships**

The routine core analysis data was depth shifted to tie with the wireline logs, then used to calibrate porosity logs and establish a porosity/permeability relationship for the Ben Nevis sand (Figure 2-32).

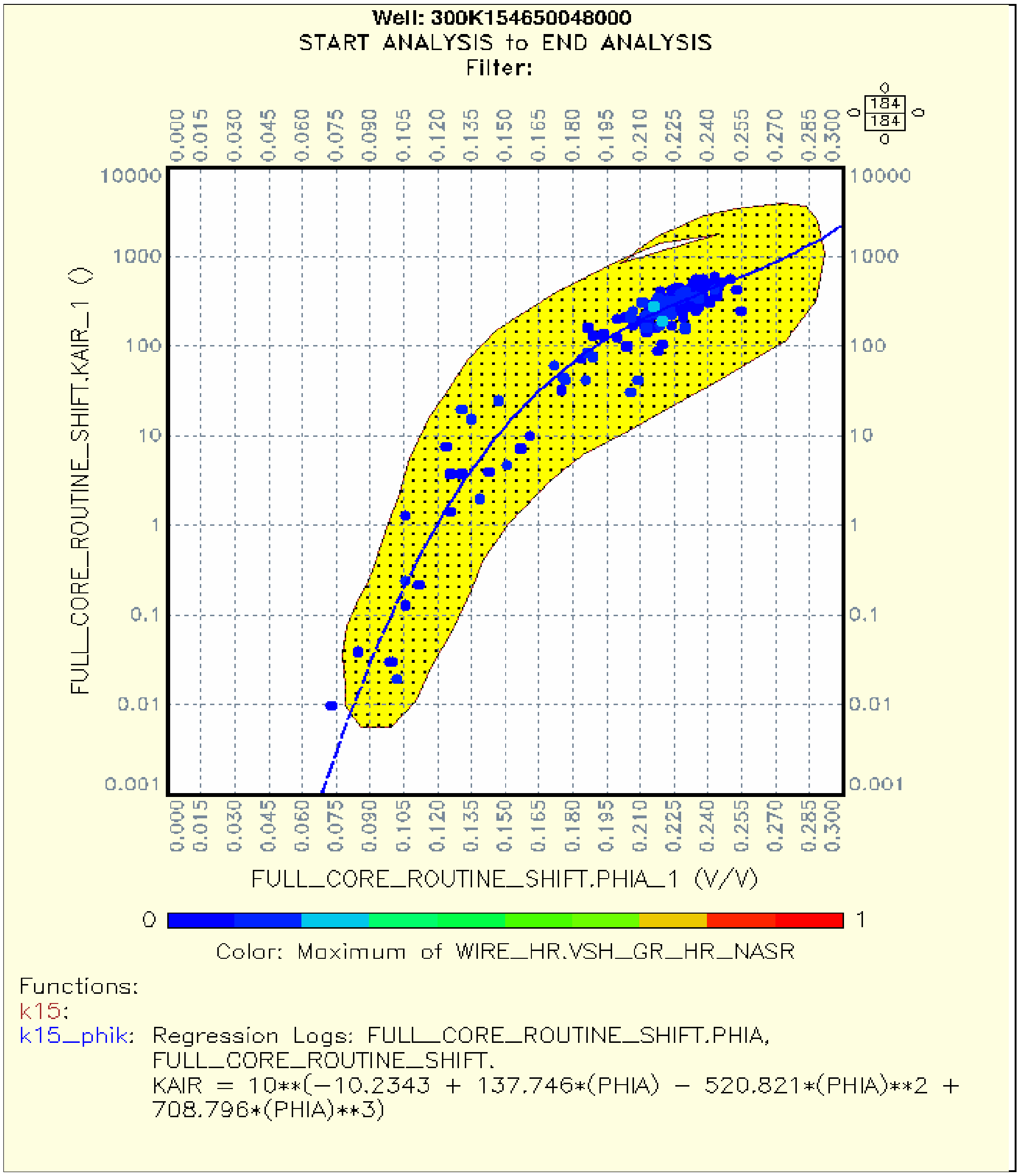



**Figure 2-32 K-15 Porosity/Permeability Relationship**

## Volume of Shale

The volume of shale has been calculated using the wellbore and mud weight corrected spectral Gamma Ray Log. A frequency plot (Figure 2-33) of the corrected Gamma Ray log through the Ben Nevis sand was used to determine the GR clean sand and GR shale end points used in the analysis.

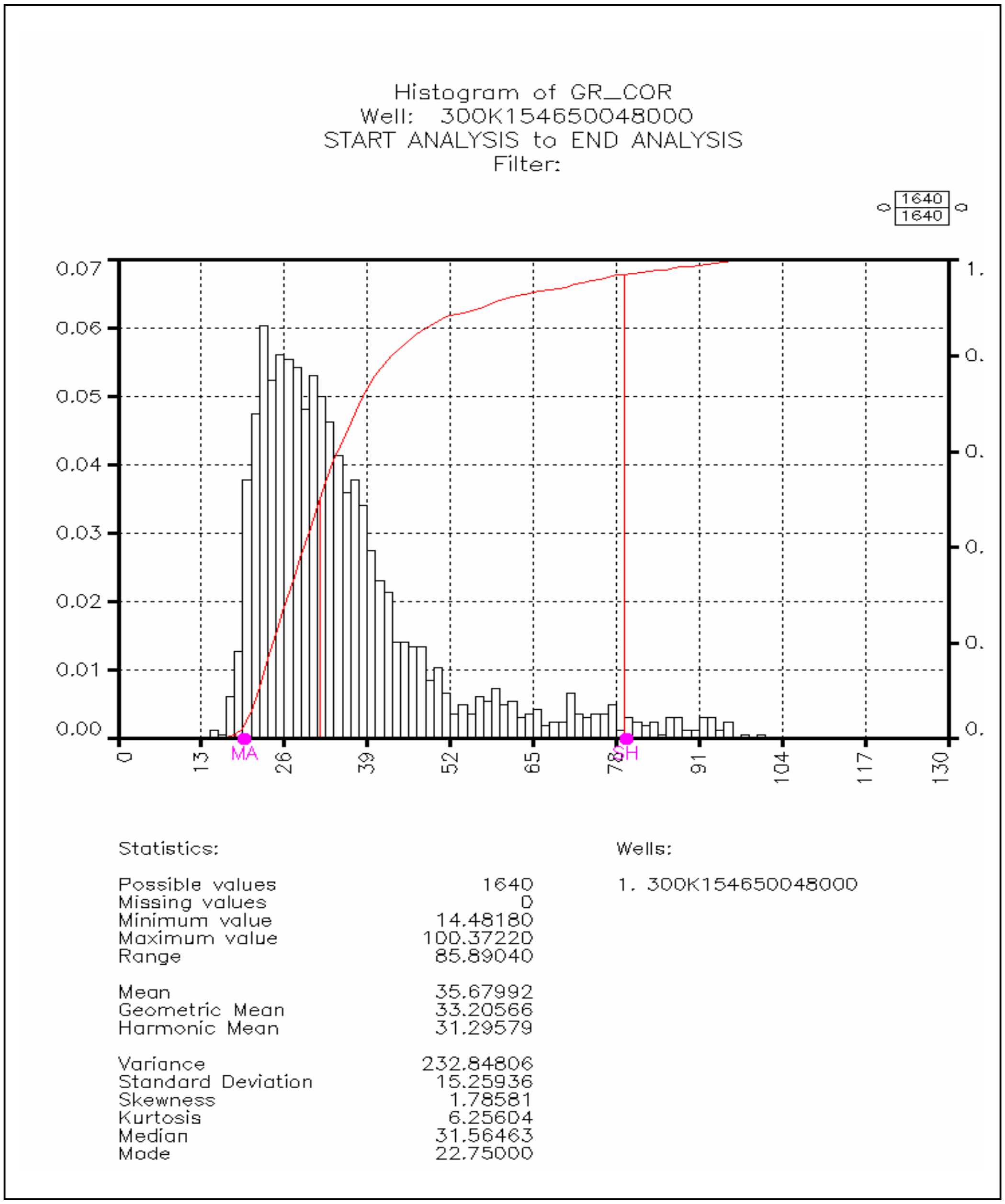



**Figure 2-33 GR Frequency Histogram for the Well K-15**

## Effective Porosity

The effective porosity was calculated using the density porosity log corrected for shale volume. The calculated porosity was adjusted to tie with core porosity values to correct the density porosity for the Hydrogen Index over the gas zone. The final computed density porosity matches very well with the core values throughout the reservoir and is also a very good match to the CMR effective porosity over the oil and water legs.

**Water Saturation**

Given the low clay content of the reservoir rock, as seen from wireline logs and core samples, a simple Archie relationship was used to derive formation water saturations where a=1, m=2 and n=2. The calculated water saturation was a good match with the core Dean-Stark water saturations.

Another critical input in the Archie water saturation calculation is the formation water resistivity (Rw). The value calculated is Rw=0.1 @ 25 °C and was determined from the analysis of the water sample recovered by the MDT (Figure 2-34).

Maxxam Analytics Inc

**WATER ANALYSIS**

| Field | Value |
|---|---|
| Laboratory Number | A709313:E61438 |
| Operator Name | HYCAL ENERGY RESEARCH LABS LTD. |
| Well Name | HUSKY AMETHYST |
| Name of Sampler | N/A |
| Company | HYCAL |
| Sample Point | BHS, H2O 2535 MPSR |
| Container Identity | GLASS |
| Temperature °C As Received | 23.0 |
| Date Sampled Start | 2007/03/08 |
| Date Received | 2007/03/09 |
| Date Reported | 2007/03/12 |
| Date Reissued | 2007/03/12 |
| Analyst | BP ,MC3,DT2 |

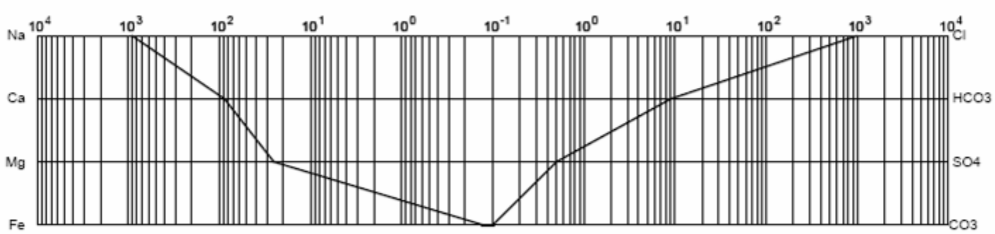
Sample Point I.D. | Client I.D. | Meter Number | LSD | Well ID | Field or Area | Pool or Zone | Percent Full | Test Recovery | Test Type | No. | Multiple Recovery | Interval 1 | Interval 2 | Interval 3 | From: | To: | Elevations (m) | KB | GRD | Sample Gathering Point | Solution Gas | Well Fluid Status | Well Status Mode | Production Rates | Water m3/d | Oil m3/d | Gas 1000m3/d | Gauge Pressures kPa | Source | As Received | Well Status Type | Well Type | Gas or Condensate Project | Licence No. | Date Sampled End

| CATIONS | | | ANIONS | | |
|---|---|---|---|---|---|
| Ion | mg/L | meq/L | Ion | mg/L | meq/L |
| Na | 20800 | 906 | Cl | 35000 | 994 |
| K | 336 | 8.6 | HCO3 | 552 | 9.0 |
| Ca | 1770 | 88.4 | SO4 | 24 | 0.5 |
| Mg | 308 | 25.3 | CO3 | <0.5 | <0.1 |
| Ba | 18.0 | 0.3 | OH | <0.5 | <0.1 |
| Sr | 318 | 7.2 | | | |
| Fe | 3.70 | 0.13 | | | |
| H+ | | | | | |

| Total Dissolved Solids (mg/L) | |
|---|---|
| 58500 | 58800 |
| Measured | Calculated |

| | |
|---|---|
| 1.044 | 1.340 |
| Relative Density | Refractive Index |
| 100000 | 0.10 |
| Conductivity (uS/cm) | Resistivity (ohms) @25°C |
| 5700 | 452 |
| Total Hardness as CaCO3 (mg/L) | Total Alkalinity as CaCO3 (mg/L) |
| 73.9 | 1.63 |
| Total Fe (mg/L) | Total Mn (mg/L) |
| 6.87 | ABSENT |
| Observed pH | H2S Spot Test |

Logarithmic Patterns of Dissolved Ions (meq/L)




** Information not supplied by client – data derived from LSD information

Results relate only to items tested

Remarks:

CALGARY 2021-41 Avenue N.E., Calgary,Canada T2E 6P2 Tel: (403) 291-3077 Fax (403) 291-9468
EDMONTON 9331-48 Street, Edmonton, Canada T6B 2R4 Tel: (780) 468-3500 Fax (780) 468-3560

GRANDE PRAIRIE 9101, 7002 - 98 Street, Clairmont, Canada T8H 0W9 Tel: (780) 532-6227 Fax (780) 532-8288
STETTLER Box 6, 4703 - 42 Street, Stettler, Canada T0C2L0 Tel: (403) 742-1107 Fax (403) 742-6179

2007/03/12 11:47

**Figure 2-34 Water Analysis Report for K-15**

**Permeability**

The permeability values were derived using the equation listed below. This equation is the core porosity/permeability relationship listed in Figure 2-32.

$$K = 10^{\left(-10.23 + 137.76 \phi - 520.82 \phi^2 + 708.79 \phi^3\right)}$$

**Hydrocarbon Net Pay Criteria**

Following are the net reservoir and pay criteria from the core White Rose field:

***Reservoir Cut-offs:***
Porosity cut-off: 10%
Permeability cut-off: 3md
Shale volume cut-off: 30%

***Pay Cut-offs:***
Porosity cut-off: 10%
Permeability cut-off: 3md
Shale volume cut-off: 30%
Water saturation cut-off: 50%

**Reservoir Porosity and K_Air Permeability - Overburden Compaction Factor**

Standard core analysis may incorporate systematic errors in porosity because these values are measured at low pressure (e.g. 2758 Kpa), which leads to an over-estimation of porosity. At surface conditions pore volumes tend to expand with the decrease in confining pressure. Additional core analysis was undertaken to correct for the overburden.

Porosity and permeability measurements were taken on 13 core plugs from White Rose A-17 and N-30 wells. This work was carried out by Hycal Laboratories as a supplement to special core analysis work. Using CMS-300 equipment, measurements were taken using a series of increasing pressures intended to simulate and span reservoir pressures existing in the White Rose field.

The resulting data series have been trended to extract equations. These equations link the decrease in reservoir porosity and permeability to an increase to overburden or reservoir-equivalent pressures, and to the original porosity and permeability of each sample. These equations will provide the basis for adjusting all "as measured" lab porosities and permeabilities to those representing the same rock under reservoir conditions.

Work Method:

Hycal measured the porosity and permeability for each plug at requested overburden pressures of 800, 1740, 3480, 5370 and 7250 psi (Table 2-11). Rock and pore volume varied, plug by plug and acted to reduce this pressure by a small amount. These overburden pressures were converted to kPa. The overburden pressures applied for the permeability calculations are different than those applied for the porosity calculations.

These plugs have previously been measured by Core Laboratories under routine or lab conditions, however Core Lab routinely uses 400 psi seating pressure. The Core Lab values of porosity and permeability were added to the values in Table 2-11 to see whether the values were in the right range, and whether there was any systematic difference between the "routine" values reported by Core Lab and Hycal (Figure 2-35).

These systematic differences in methodology were found to exist. The Hycal porosities and permeabilities measured at 800 psi were higher than the Core Lab values measured on the same plugs at a lower seating pressure of 400 psi.

**Table 2-11 Hycal and Core Lab Measurements**

| Sample I.D. | Depth | Requested Overburden psi | Act. Overbur. During Pore Vol psi | kpa | Pore Volume cc | Porosity 1 % | Act. OverBur. During Perm psi | kpa | Air Perm md |
|---|---|---|---|---|---|---|---|---|---|
| Core Lab Value | 29 | | 400 | 2758 | | 17.7 | 400 | 2758 | 96.8 |
| 880803 | 29 | 800 | 746 | 5143.67 | 12.6111 | 17.78 | 896 | 6177.92 | 117.32 |
| 880803 | 29 | 1740 | 1610 | 11100.95 | 12.4305 | 17.57 | 1756 | 12107.62 | 116.51 |
| 880803 | 29 | 3480 | 3318 | 22877.61 | 12.2852 | 17.4 | 3463 | 23877.385 | 113.83 |
| 880803 | 29 | 5370 | 5153 | 35529.935 | 12.1806 | 17.28 | 5306 | 36584.87 | 111.83 |
| 880803 | 29 | 7250 | 6989 | 48189.155 | 12.112 | 17.2 | 7151 | 49306.145 | 110.41 |

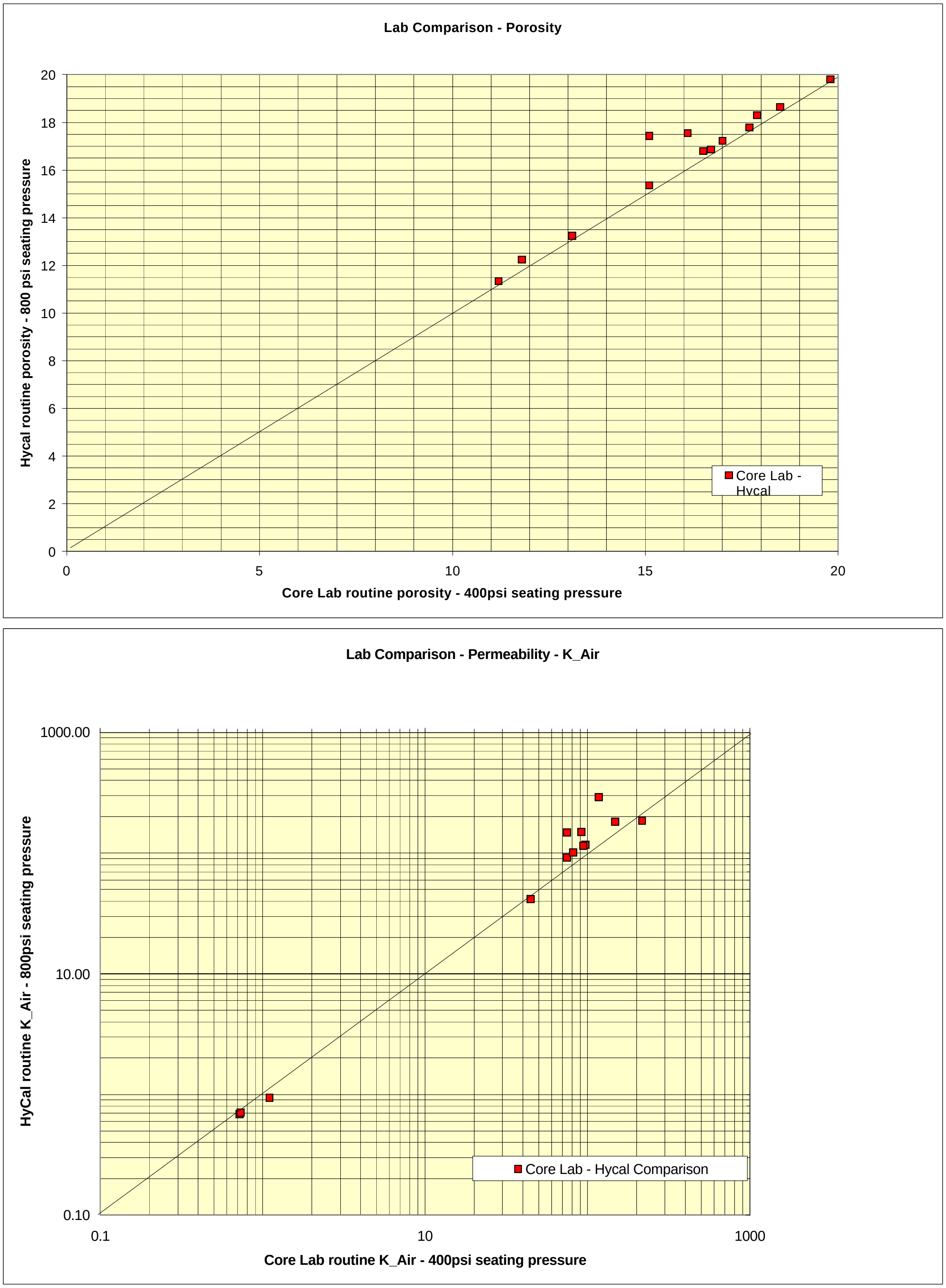



**Figure 2-35 Core Lab - Hycal Comparison**

Overburden Correction:

Core porosity and permeability at low pressure versus core porosity and permeability at simulated overburden pressure is shown in Figures 2-36 and 2-37.

Core porosity measured under laboratory conditions when applying 400 psi or 2758 kPa seating pressure (Core Lab practice) should be adjusted using the following equation:

$$f\ @\ 30.000\ Kpa = 1.0191\left(f\ @\ 2758\ Kpa\right) - 0.8695$$

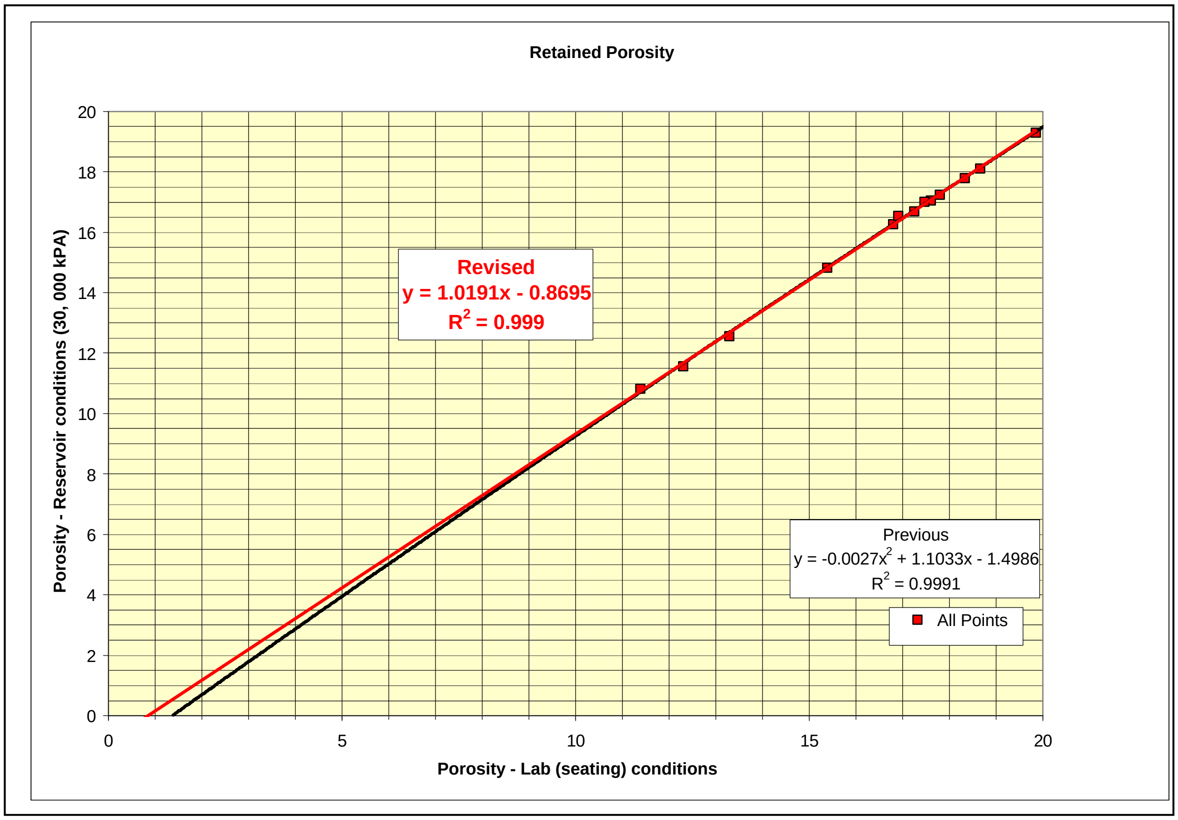



**Figure 2-36 Core Porosity and Permeability at Low Pressure**

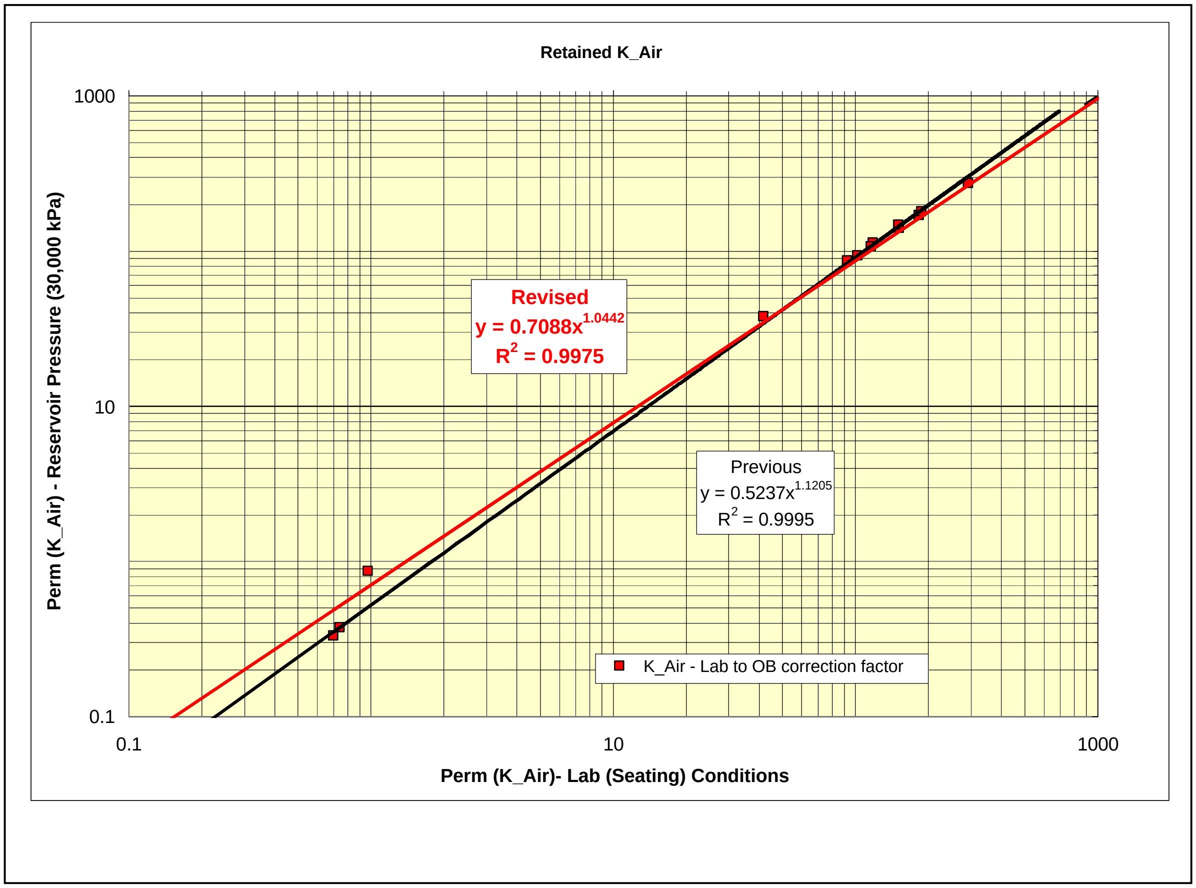



**Figure 2-37 Core Porosity and Permeability at Simulated Overburden Pressure**

For the 13 samples analyzed, the reservoir porosity averaged 96.5% of laboratory values.

Core permeability measured under laboratory conditions when applying 400 psi or 2758 kPa seating pressure (Core Lab practice) should be adjusted using the following equation:

$$K @ 30,000\ Kpa = 0.7088\,(K @ 2758\ Kpa)^{1.0442}$$

For the 13 samples measured, the reservoir permeability averages 87.2% of laboratory values.

**<u>Methods used in the Petrophysics of the WhiteRose Field Permeability Calculation</u>**

Figure 2-38 illustrates the core porosity-permeability relationship for all the wells in the White Rose Field that have a core sample.

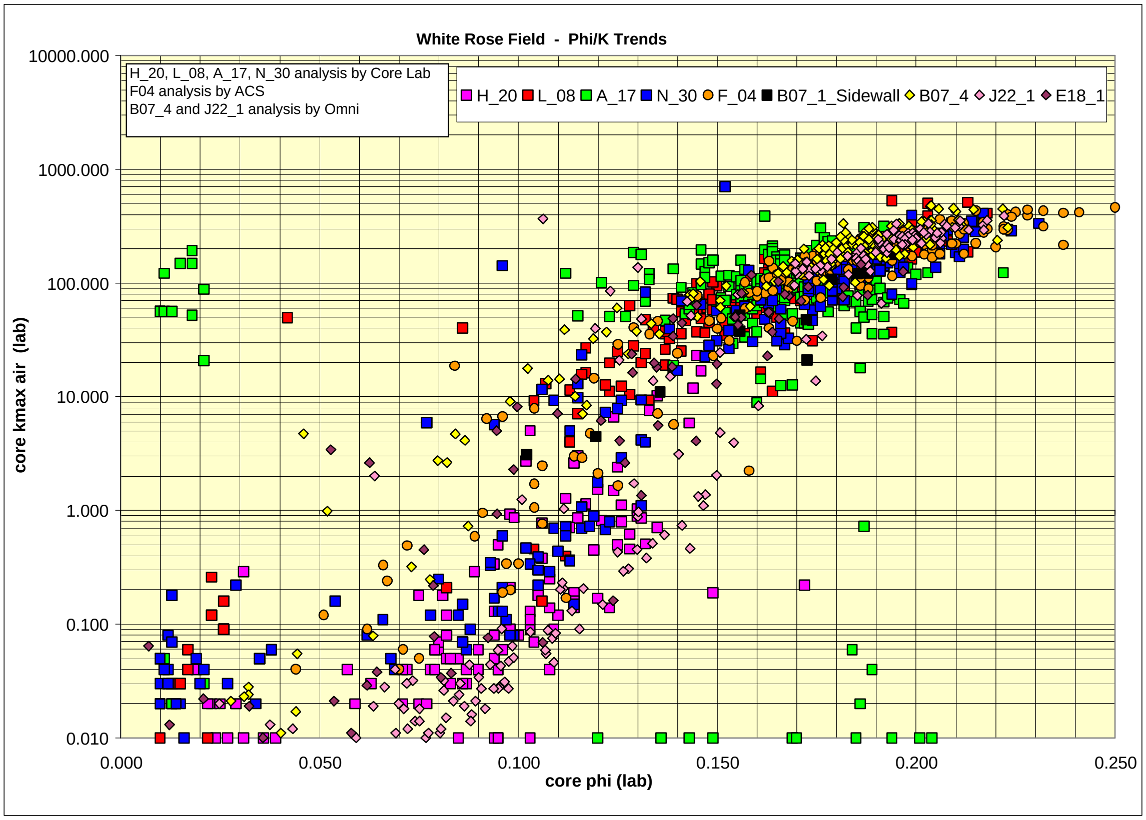



**Figure 2-38 Core Porosity-Permeability Relationship for White Rose Wells**

Husky's standard practice is to correct the core porosity and permeability for the over-burden pressure and link the core permeability with other attributes such as porosity and depositional facies.

In Figure 2-39 the porosity-permeability relationship shows two different trends; one mainly for the better laminated sand (colored in blue) and the second trend for the bioturbated sand facies (colored in green). The generated permeability from the porosity and given deposition facies assignment is illustrated in the following equations:

For shale, bioturbated sand, calcite:

$$k = 10^{\left(-2.1890 + 0.567\phi + 84.1\phi^{2} + 656.31\phi^{3}\right)}$$

For laminated sand:

$$k = 10^{\left(-2.301 + 40.02\phi - 84.056\phi^{2}\right)}$$

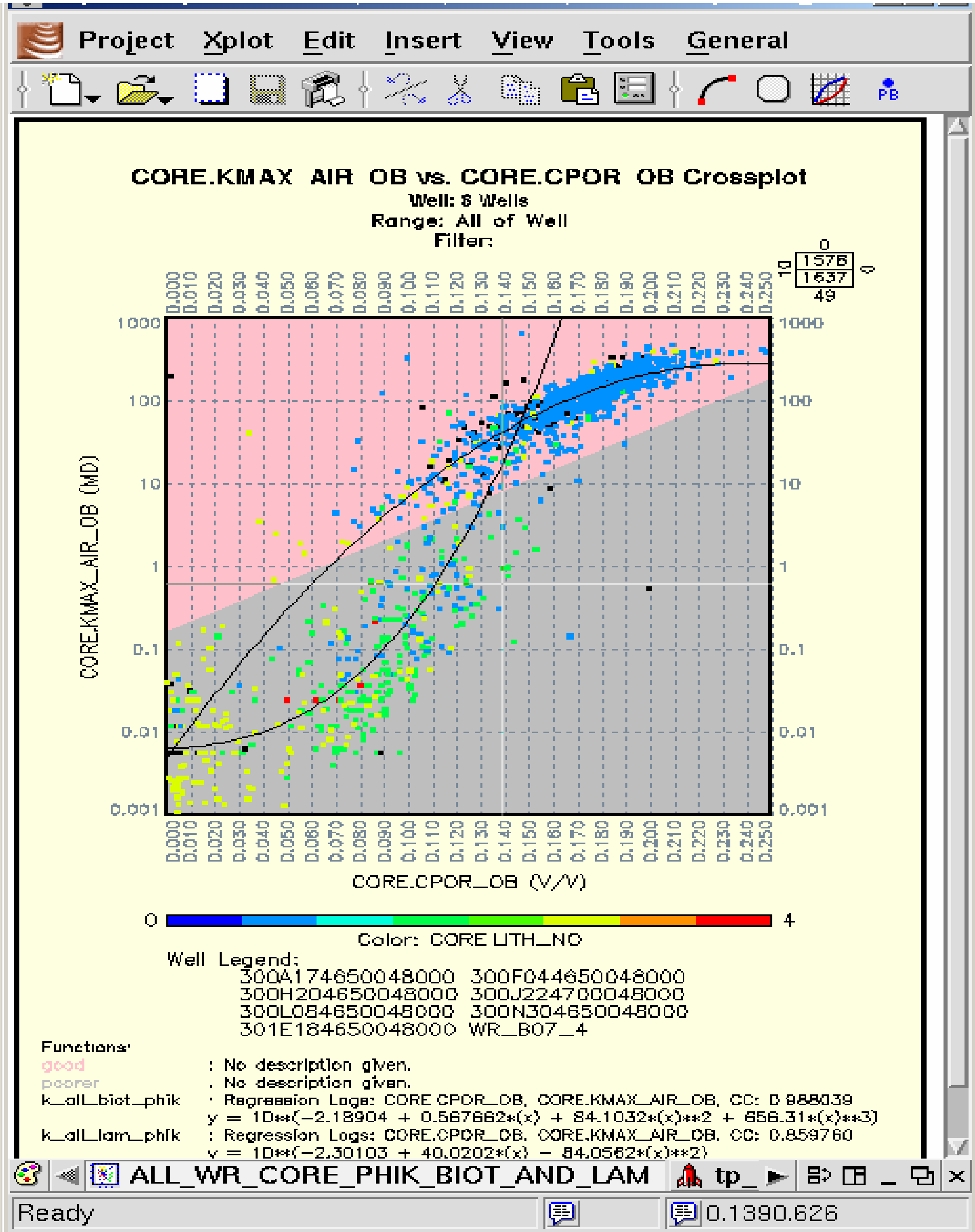



**Figure 2-39 Porosity-Permeability Relationship**

**Formation Water Resistivity**

The water salinity was determined using the modular dynamic tester water samples gathered in the well L-08. The samples were obtained using the optical fluid analyzer and resistivity measurement to minimize the mud filtrate contamination.

Table 2-12 indicates the values obtained for each sample. At 25°C, the resistivities varied from a low of 0.212 to a high of 0.565 ohm-m. Sample number 208 was used because this sample indicated the lowest PH above 7.

**Table 2-12 Values from Formation Water Testing**

| Sample # | Sample Depth | Sample Tritium Conc | Mud Tritium Conc | Sample Tritium Contam | Contam Sample Rw@25 | Contam Sample Conc | Sample pH | Mud Salinity | Corrected Formation Salinity PPM | Corrected Formation Resistivity Rw @ 25 |
|---|---|---|---|---|---|---|---|---|---|---|
| | (m) | (pCi/ml) | (pCi/ml) | (%) | (ohm-m) | (ppm) | | (ppm) | (ppm) | (ohm-m) |
| | | | | | | | | | | |
| 199 | 3047 | 10874 | 42345 | 25.7 | 0.135 | 47,100 | 8 | 133,267 | 17,327 | 0.339 |
| 311 | 3047 | 10294 | 42345 | 24.3 | 0.156 | 39,960 | 8 | 133,267 | 9,992 | 0.565 |
| 315 | 3047 | 9722 | 42345 | 23.0 | 0.144 | 43,746 | 8 | 133,267 | 17,068 | 0.344 |
| 208 | 3094.5 | 2853 | 38058 | 7.5 | 0.171 | 36,000 | 7.7 | 133,267 | 28,118 | 0.218 |
| 233 | 3094.5 | 2870 | 38058 | 7.5 | 0.167 | 36,972 | 7.8 | 133,267 | 29,118 | 0.212 |
| 248 | 3094.5 | 2970 | 38058 | 7.8 | 0.173 | 35,500 | 7.9 | 133,267 | 27,225 | 0.224 |

Note: The Rw used for the Avalon field study was 0.218 @ 25°C, 0.082 @ Formation Temperature of 100°C, which is 28,118 NaCl equivalent.

**Electrical Properties M and N**

Special core analyses were undertaken using core from L-08 to determine the correct cementation exponent "M" and saturation exponent "N" to be used in determining water saturation using the log evaluation software.

The reported average values for M and N, using an 'a'=1 are:

The Cementation exponent M=1.78
The Saturation exponent N=1.86

Knowing the M and N values will allow use of the Pickett Plot in the water leg to determine the formation water resistivity.

# 3.0 Reservoir Engineering

## 3.1 Basic Reservoir Data

### 3.1.1 Reservoir Pressures and Temperatures

A full set of reservoir pressures were obtained using Schlumberger's MDT (modular dynamic formation tester) tool in the North Amethyst K-15 well. The reservoir pressure observed at the K-15 well was 23,800 kPa @ 2,333 mTVDss. The reservoir temperature detected during logging the K-15 well was approximately 88 $^{o}$C. The MDT pressure data indicated gas-oil and oil-water contact depths of 2,333.9 mTVDss and 2,386.39 mTVDss, respectively. The gas-oil and oil-water contacts were also confirmed from logs. Table 3-1 compares the K-15 fluid contacts with the fluid contacts evident in the greater White Rose region.

The gas, oil and water gradients observed at the K-15 well were 1.83 kPa/m, 7.01 kPa/m and 9.90 kPa/m, respectively. These values are similar to the fluid gradients seen elsewhere in the White Rose area as indicated in Table 3-2. The pressure elevation plot for the K-15 well is illustrated in Figure 3-1.

In addition to MDT data, two vertical interference tests and one mini-DST test were performed with the MDT tool in the K-15 well (Appendix A). These tests were designed to assess vertical communication, permeability and skin values in the formation. The results of the tests indicated reservoir permeability in the range of 155 to 450 md. The tests also indicated that the ratio of vertical permeability to horizontal permeability is higher than 0.12. All of the tests conducted indicted almost a zero skin factor. The results of the two vertical interference tests at 2,390 m and 2,415 m are indicated in Tables 3-3 and 3-4, respectively. Table 3-5 shows the results of the dual packer mini-DST test conducted at 2,400 m.

**Table 3-1 Fluid Contacts, White Rose Region**

| Well | Formation | Contact | Log Depth (m TVD) | Subsea Depth (m SS TVD) |
|---|---|---|---|---|
| L-61 | Ben Nevis | Oil/Water | | |
| L-61 | Ben Nevis | Top of Transition | 2986 | 2963.1 |
| L-61 | Ben Nevis | Bottom of Transition | 3007 | 2984.1 |
| | | | | |
| N-22 | Hibernia | Oil/Water | 3631.3 | 3603.6 |
| | | | | |
| J-49 | Ben Nevis | Gas/Oil | 3092.6 | 3069.7 |
| J-49 | Ben Nevis | Oil/Water | 3154 | 3131.1 |
| | | | | |
| N-30 | Ben Nevis | Gas/Oil | 3039.2 | 3014.2 |
| | | | | |
| H-20 | Ben Nevis | Gas/Oil (Estimated) | 2901.3 | 2874.9 |
| H-20 | Ben Nevis | Oil/Water | | |
| H-20 | Ben Nevis | Top of Transition | 3016.7 | 2990.3 |
| H-20 | Ben Nevis | Bottom of Transition | 3027.2 | 3000.8 |
| | | | | |
| E-09 | Ben Nevis | Gas/Oil | 2894.8 | 2871.8 |
| E-09 | Ben Nevis | Oil/Water | | |
| E-09 | Ben Nevis | Top of Transition | 3013 | 2990 |
| E-09 | Ben Nevis | Bottom of Transition | 3032.5 | 3009.5 |
| | | | | |
| L-08 | Ben Nevis | Gas/Oil | 2897 | 2872 |
| L-08 | Ben Nevis | Oil/Water | | |
| L-08 | Ben Nevis | Top of Transition | 3014 | 2989 |
| L-08 | Ben Nevis | Bottom of Transition | 3034.5 | 3009.5 |
| | | | | |
| A-17 | Ben Nevis | Gas/Oil | 2899.7 | 2874.7 |
| A-17 | Ben Nevis | Oil/Water | | |
| A-17 | Ben Nevis | Top of Transition | 3010 | 2985 |
| A-17 | Ben Nevis | Bottom of Transition | 3024.5 | 2999.5 |
| | | | | |
| J-91 | Ben Nevis | Wet | - | - |
| | | | | |
| F-04 | Ben Nevis | Gas/Oil | 2910.5 | 2887.5 |
| F-04 | Ben Nevis | Oil/Water | | |
| F-04 | Ben Nevis | Top of Transition | | |
| F-04 | Ben Nevis | Bottom of Transition | | |
| | | | | |
| F-04Z | Ben Nevis | Gas/Oil | | |
| F-04Z | Ben Nevis | Oil/Water | 2991.3 | 2968.2 |
| F-04Z | Ben Nevis | Top of Transition | | |
| F-04Z | Ben Nevis | Bottom of Transition | | |
| | | | | |
| B07_1 | Ben Nevis | Gas/Oil | 2895 | 2872 |
| B07_1 | Ben Nevis | Oil/Water | | |
| B07_1 | Ben Nevis | Top of Transition | | |
| B07_1 | Ben Nevis | Bottom of Transition | | |

| Well | Formation | Contact | Log Depth (m TVD) | Subsea Depth (m SS TVD) |
|---|---|---|---|---|
| B07_2 | Ben Nevis | Gas/Oil | | |
| B07_2 | Ben Nevis | Oil/Water | horizontal producer | |
| B07_2 | Ben Nevis | Top of Transition | | |
| B07_2 | Ben Nevis | Bottom of Transition | | |
| | | | | |
| B07_4 | Ben Nevis | Gas/Oil | 2882 | 2858.94 |
| B07_4 | Ben Nevis | Oil/Water | | |
| B07_4 | Ben Nevis | Top of Transition | | |
| B07_4 | Ben Nevis | Bottom of Transition | | |
| | | | | |
| B07_6 | Ben Nevis | Gas/Oil | | |
| B07_6 | Ben Nevis | Oil/Water | 3021.5 | 2998.5 |
| B07_6 | Ben Nevis | Top of Transition | | |
| B07_6 | Ben Nevis | Bottom of Transition | | |
| | | | | |
| B07_3 | Ben Nevis | Gas/Oil | | |
| B07_3 | Ben Nevis | Oil/Water | horizontal producer | |
| B07_3 | Ben Nevis | Top of Transition | | |
| B07_3 | Ben Nevis | Bottom of Transition | | |
| | | | | |
| B07_5 | Ben Nevis | Gas/Oil | | |
| B07_5 | Ben Nevis | Oil/Water | horizontal producer | |
| B07_5 | Ben Nevis | Top of Transition | | |
| B07_5 | Ben Nevis | Bottom of Transition | | |
| | | | | |
| B07_8 | Ben Nevis | Gas/Oil | 2894.54 | 2871.54 |
| | Ben Nevis | Oil/Water | 3015.62 | 2992.62 |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of Transition | | |
| | | | | |
| B07_9 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | water injector | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of Transition | | |
| | | | | |
| J22_1 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | | |
| | Ben Nevis | Top of Transition | | |
| | Eastern Shoals | Bottom of Transition | | |
| | | | | |
| | | | | |
| E18_1 | Ben Nevis | Gas/Oil | 2895.6 | 2872.6 |
| | Ben Nevis | Oil/Water | 3032.07 | 3009.07 |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of Transition | | |

| Well | Formation | Contact | Log Depth (m TVD) | Subsea Depth (m SS TVD) |
|---|---|---|---|---|
| E18_2 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | horizontal producer | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of Transition | | |
| | | | | |
| E18_3 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | horizontal injector | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| E18_4 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | horizontal producer | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| E18_5 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | horizontal injector | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| E18_6 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | horizontal producer | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| E18_7 | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | horizontal injector | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| B-19 | Ben Nevis | Gas/Oil | 2871.9 | 2824.9 |
| | Ben Nevis | Oil/Water | 2999.9 | 2952.9 |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| B-19Z | Ben Nevis | Gas/Oil | 2893.56 | 2846.56 |
| | Ben Nevis | Oil/Water | 3004.81 | 2957.81 |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| O-28Y | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | 3217.09 | 3170.09 |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| O-28X | Ben Nevis | Gas/Oil | | |
| | Ben Nevis | Oil/Water | | |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |
| | | | | |
| K-15 | Ben Nevis | Gas/Oil | 2380.9 | 2333.9 |
| | Ben Nevis | Oil/Water | 2433.39 | 2386.39 |
| | Ben Nevis | Top of Transition | | |
| | Ben Nevis | Bottom of | | |

**Table 3-2 White Rose Fluid Gradients**

| Well | Reservoir Gas Gradient (kPa/m) | Reservoir Oil Gradient (kPa/m) | Reservoir Water Gradient (kPa/m) | PVT Live Oil Gradient (kPa/m) |
|---|---|---|---|---|
| A-17 | 1.71 | 6.96 | 9.71 | 7.07 |
| L-08 | 2.11 | 6.98 | 9.69 | 7.06 |
| E-09 | 2.28 | 7.09 | 9.81 | 6.85 |
| H-20 | n/a | 6.15 | 9.67 | n/a |
| B-07 1 | 2.13 | 6.84 | n/a | n/a |
| B-07 4 | 2.06 | 6.92 | n/a | n/a |
| B-07 6 | n/a | 7.18 | 10.22 | n/a |
| N-22 | 1.99 | n/a | n/a | n/a |
| N-30 | 2.26 | 6.70 | n/a | n/a |
| J-22 1 | 2.05 | n/a | n/a | n/a |
| F-04 | 2.06 | 7.23 | n/a | n/a |
| O-28Y | n/a | 6.98 | 9.70 | 7.19 |
| K-15 | 1.83 | 7.01 | 9.90 | 7.10 |

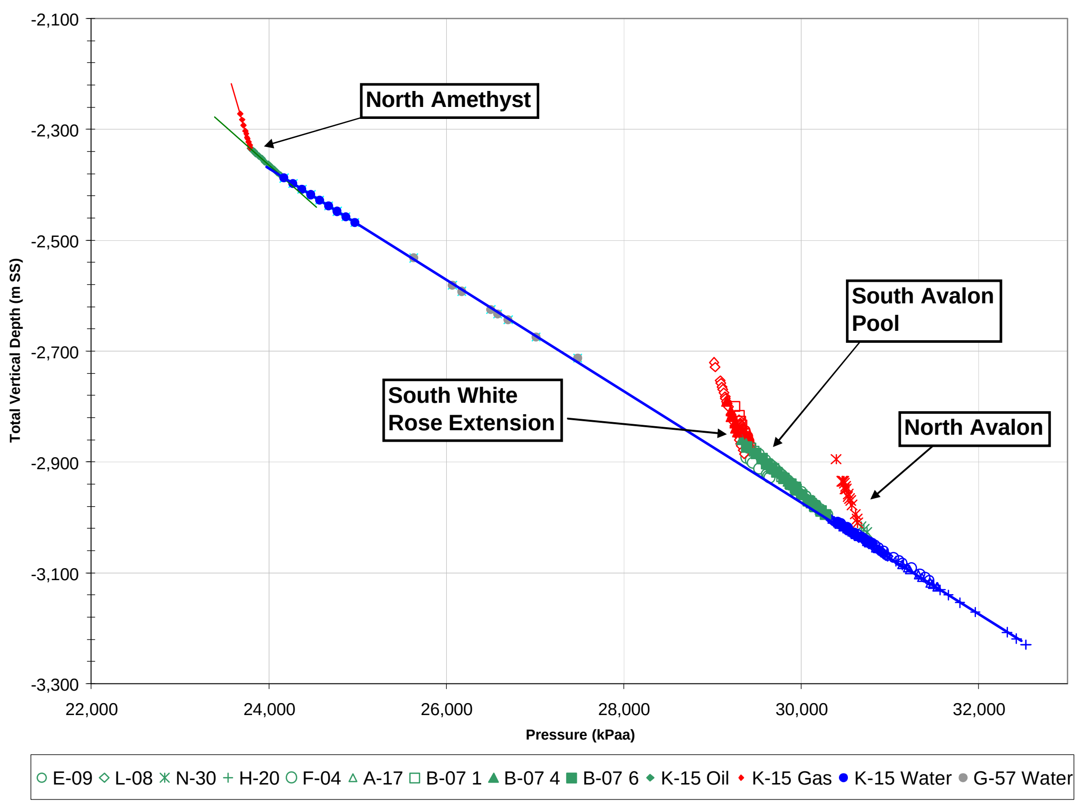



**Figure 3-1 North Amethyst K-15 MDT Pressures**

**Table 3-3 North Amethyst K-15 Vertical Interference Test at 2,390 m**

| kh (md) | kv (md) | kv/kh | Skin | Reservoir pressure at 2,390 m (kPa) |
|---|---|---|---|---|
| 450 | 70 | 0.16 | 0.0 | 23883.57 |

**Table 3-4 North Amethyst K-15 Vertical Interference Test at 2,415 m**

| kh (md) | kv (md) | kv/kh | Skin | Reservoir pressure at 2,415 m (kPa) |
|---|---|---|---|---|
| 302 | 42 | 0.14 | 0.0 | 24036.06 |

**Table 3-5 North Amethyst K-15 Dual Packer Mini DST at 2,400 m**

| kh (md) | kv (md) | kv/kh | Skin | Reservoir pressure at 2,400 m (kPa) |
|---|---|---|---|---|
| 155 | 18 | 0.12 | 0.1 | 23953.35 |

### 3.1.2 Fluid Characterization

A full suite of reservoir fluid samples were obtained in the K-15 well. Six oil samples, three gas samples and three water samples were recovered. Two separator flash tests and one differential liberation test were conducted on the oil samples obtained from the K-15 well (Appendix B). These tests indicated a bubble point pressure between 20,830 and 21,100 kPa. Since the North Amethyst structure is shallower than the South White Rose Pool, the saturation pressure of the oil at North Amethyst is lower than the saturation pressure of 29,400 kPa observed in the South White Rose Pool. Extrapolation of the bubble point pressure observed at the K-15 well, down to the depth of the South White Rose Pool, indicates that the bubble point pressure of the fluids appear to be consistent. A summary of the multi-stage separator and differential liberation analysis conducted on the oil samples are provided in Tables 3-6 and 3-7. Figures 3-2 through 3-5 illustrate the oil formation volume factor, gas-oil ratio, viscosity and density for the K-15 differential liberation fluid study conducted on sample 1365.

**Table 3-6 North Amethyst K-15 Multi-stage Separator Fluid Oil PVT Summary**

| | | |
|---|---|---|
| Sample: | 1364 | 1239 |
| Sample Type: | Bottomhole | Bottomhole |
| Sample Date: | 2-Nov-06 | 2-Nov-06 |
| Sample Depth (mMD): | 2390 | 2415 |
| | | |
| Reservoir Temperature ( °C): | 88.1 | 88.4 |
| Saturation Pressure (kPa): | 20,830 | 21,100 |
| Initial Reservoir Pressure (kPa): | 23,850 | 24,030 |
| Solution Gas-Oil Ratio (m3/m3)*: | 97.65 | 100.97 |
| Oil Formation Volume Factor (res $m^3/m^3$)*: | 1.278 | 1.297 |
| Oil Density ($kg/m^3$)*: | 733.1 | 724.1 |
| API Gravity: | 34.8 | 35.0 |
| Compositional Analysis: | | |
| N2 mole fraction: | 0.0028 | 0.0137 |
| CO2 mole fraction: | 0.0116 | 0.0150 |
| H2S mole fraction: | 0.0000 | 0.0000 |
| C1 | 0.4361 | 0.4307 |
| C2 | 0.0393 | 0.0382 |
| C3 | 0.0271 | 0.0270 |
| i-C4 | 0.0056 | 0.0056 |
| n-C4 | 0.0161 | 0.0162 |
| i-C5 | 0.0068 | 0.0069 |
| n-C5 | 0.0107 | 0.0109 |
| C6 | 0.0165 | 0.0169 |
| C7 | 0.0179 | 0.0179 |

*property at saturation pressure at reservoir temperature.

**Table 3-7 North Amethyst K-15 Differential Liberation Oil PVT Summary**

| | |
|---|---|
| Sample: | 1365 |
| Sample Type: | Bottomhole |
| Sample Date: | 2-Nov-06 |
| Sample Depth (mMD): | 2390 |
| | |
| Reservoir Temperature (°C): | 88.1 |
| Saturation Pressure (kPa): | 20900 |
| Initial Reservoir Pressure (kPa): | 23860 |
| Solution Gas-Oil Ratio (m3/m3)*: | 105.79 |
| Oil Formation Volume Factor (res $m^3/m^3$)*: | 1.3208 |
| Oil Density ($kg/m^3$)*: | 722.6 |
| API Gravity: | 33.8 |
| Compositional Analysis: | |
| N2 mole fraction: | 0.0017 |
| CO2 mole fraction: | 0.0122 |
| H2S mole fraction: | 0 |
| C1 | 0.4349 |
| C2 | 0.0408 |
| C3 | 0.0281 |
| i-C4 | 0.0058 |
| n-C4 | 0.0168 |
| i-C5 | 0.0076 |
| n-C5 | 0.0117 |
| C6 | 0.0174 |
| C7 | 0.0181 |

*property at saturation pressure at reservoir temperature.

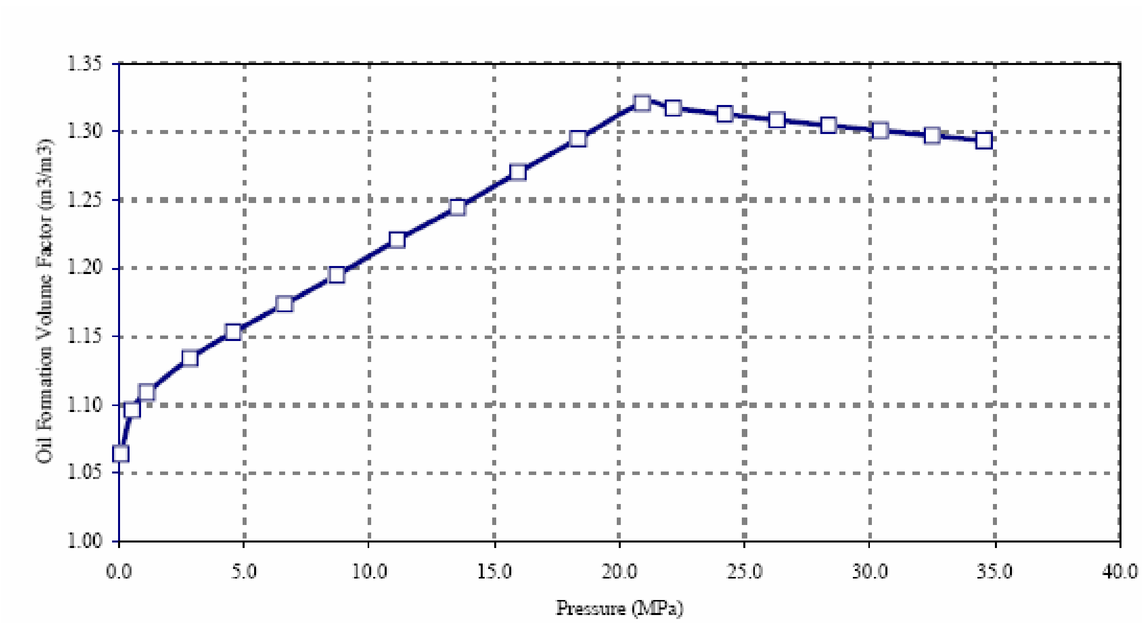



**Figure 3-2 North Amethyst K-15 Differential Liberation Oil Formation Volume Factor @ 88.1 °C**

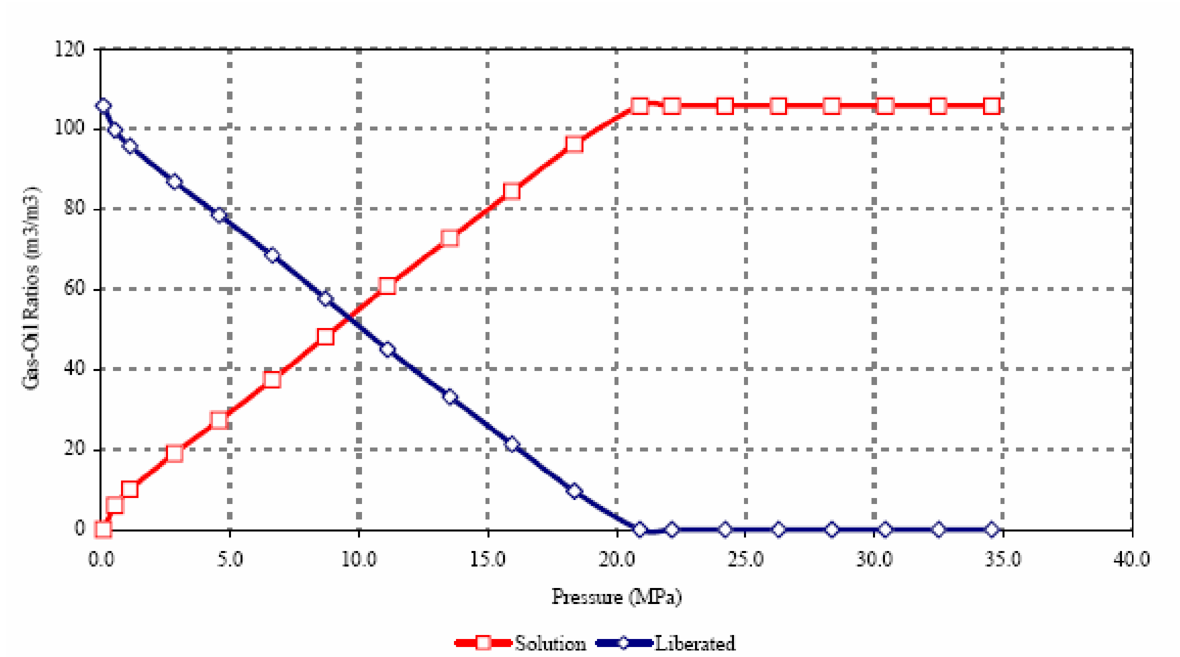



**Figure 3-3 North Amethyst K-15 Differential Liberation Gas-OIl Ratio @ 88.1 $^{0}$C**

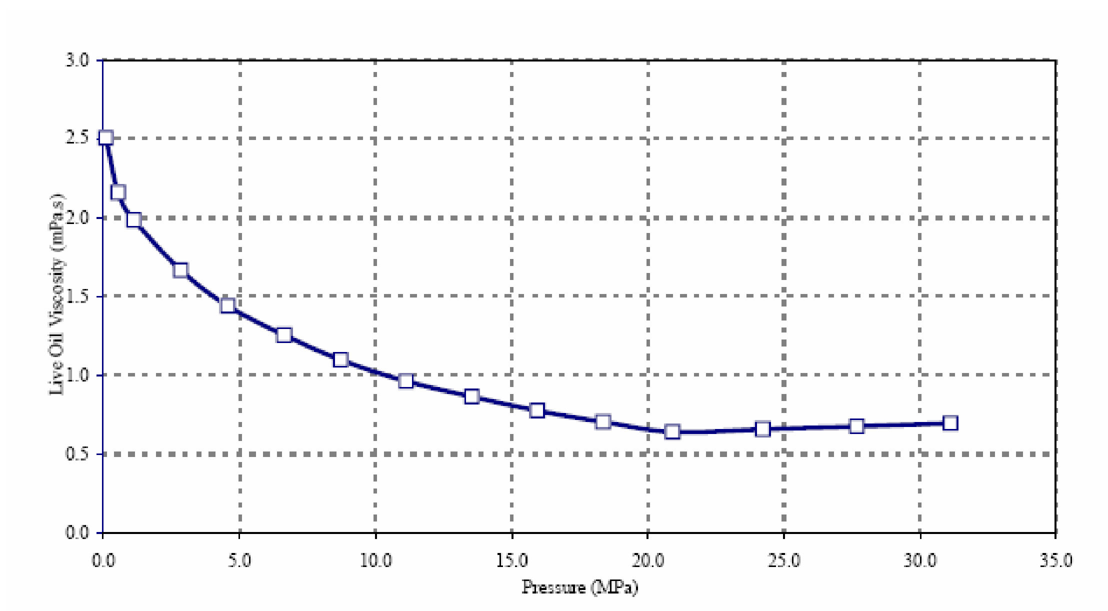



**Figure 3-4 North Amethyst K-15 Differential Liberation Oil Viscosity @ 88.1 $^{0}$C**

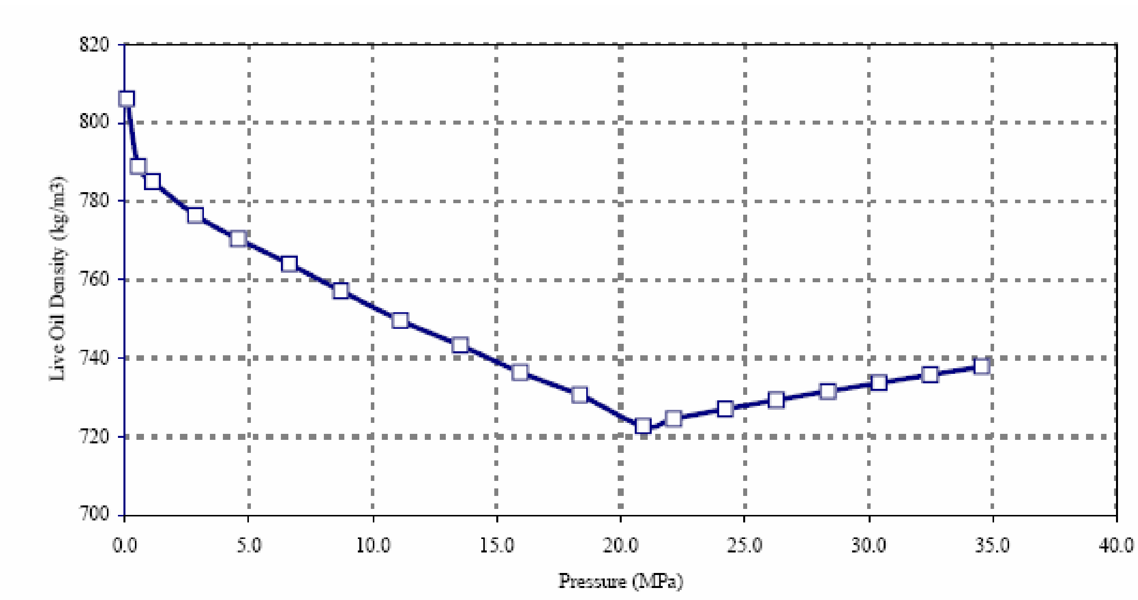



**Figure 3-5 North Amethyst K-15 Differential Liberation Oil Density @ 88.1 $^{0}$C**

PVT analysis was also conducted on a gas sample from the gas cap at the K-15 well. The PVT properties of the gas zone at K-15 are very similar to other gas samples in the White Rose field. The PVT fluid study results for the gas at the K-15 well are summarized and compared to other White Rose wells in Table 3-8.

Water compositional analysis was also conducted on two of the water samples taken from the K-15 well. Table 3-9 summarizes the results of the K-15 water compositional analysis.

**Table 3-8 North Amethyst K-15 Gas PVT**

| | N-30 | J-22 1 | J-22 1 | F-04 | K-15 |
|---|---|---|---|---|---|
| Sample Type | Bottom Hole - MDT | Bottom Hole - MDT | Recombined Sep | Bottom Hole - MDT | Bottom Hole - MDT |
| Sample ID | 248-06 | MPSR 1359 | 1206 / 14002-QA | MPSR 1363 | MPSR 1476 |
| Sample Depth (m MD) | | 2851.3 | Separator | 2826.8 | 2375 |
| Mud System | WBM | SBM | SBM | WBM | SBM |
| Reservoir Temp (°C) | 106 | 106 | 106 | 101 | 88 |
| Dew Point (kPa) | 30,660 | 30,340 | 28,463 | 29,470 | 21,970 |
| Z Factor* | 0.9728 | 0.9131 | 0.9740 | 0.9250 | 0.9044 |
| Viscosity (cP)* | 0.0252 | 0.0240 | n/a | 0.0243 | 0.0201 |
| Density (g/cm3)* | 0.2141 | 0.2256 | 0.1860 | 0.2044 | 0.1641 |
| MW | 21.41 | 21.40 | 20.48 | 20.96 | 20.64 |
| CGR ($m^3$ / $10^6 m^3$) | 182.75 | 183.52 | 159.74 | 150.73 | 102.6 |
| CGR (stb/mmscf) | 32.55 | 32.69 | 28.46 | 26.85 | 18.27 |
| $N_2$ mole fraction | 0.0013 | 0.0037 | 0.0052 | 0.0052 | 0.0052 |
| $CO_2$ mole fraction | 0.0153 | 0.0130 | 0.0108 | 0.0134 | 0.0161 |
| $H_2S$ mole fraction | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| C1 mole fraction | 0.8924 | 0.8787 | 0.8819 | 0.8743 | 0.8813 |
| C2 mole fraction | 0.0389 | 0.0412 | 0.0429 | 0.0431 | 0.0398 |
| C3 mole fraction | 0.0185 | 0.0215 | 0.0230 | 0.0241 | 0.0198 |
| i-C4 mole fraction | 0.0032 | 0.0033 | 0.0035 | 0.0039 | 0.0031 |
| n-C4 mole fraction | 0.0074 | 0.0097 | 0.0087 | 0.0096 | 0.0077 |
| i-C5 mole fraction | 0.0015 | 0.0018 | 0.0024 | 0.0023 | 0.0022 |
| n-C5 mole fraction | 0.0024 | 0.0030 | 0.0034 | 0.0036 | 0.0029 |
| $C6^+$ mole fraction | 0.0191 | 0.0241 | 0.0183 | 0.0205 | 0.0218 |
| $C6^+$ MW | 183.40 | 138.46 | n/a | 127.94 | 117.88 |
| $C6^+$ density ($g/cm^3$) | 0.8417 | 0.7920 | n/a | 0.7700 | 0.7752 |

*property at dew point at reservoir temperature.

**Table 3-9 North Amethyst K-15 Water Compositional Analysis**

| | K-15 | K-15 |
|---|---|---|
| Sample Type | Bottom Hole - MDT | Bottom Hole - MDT |
| Sample ID | 1682 MPSR | 2535 MPSR |
| Sample Depth (m MD) | 2,515 | 2,515 |
| Total Disolved Solids (mg/l): | 57,500 | 58,500 |
| pH: | 6.9 | 6.9 |
| | | |
| Cations / Anions: | mg/l | mg/l |
| Na | 21,200 | 20,800 |
| K | 369 | 336 |
| Ca | 1,760 | 1,770 |
| Mg | 324 | 308 |
| Ba | 15.5 | 18.0 |
| Sr | 233 | 318 |
| Fe | 1.69 | 3.70 |
| Cl | 35,000 | 35,000 |
| HCO3 | 508 | 552 |
| SO4 | 30 | 24 |
| CO3 | <0.5 | <0.5 |
| OH | <0.5 | <0.5 |

At the time when the Eclipse simulation model was constructed for North Amethyst, the final results of the PVT analysis were not available. A table of PVT properties was constructed based on preliminary analysis of the three bottom-hole fluid samples 1364, 1239 and 1365. The PVT correlation package in the MBAL (material balance), software of Petroleum Experts, was used to construct a PVT table which was used in the Eclipse simulation model, as shown in Table 3-10. The PVT properties that were used in the reservoir simulation model were subsequently confirmed with the final PVT analysis results, therefore the initial assumptions were deemed appropriate.

**Table 3-10 North Amethyst K-15 PVT Correlations for Eclipse Reservoir Simulation**

| -- K15 s-stage Test Separator Sample "SN1206" Correlation created | | | | | | |
|---|---|---|---|---|---|---|
| -- Rs | Pressure | Bo | Oil Visc. | -- Pressure | Bg | Gas Visc. |
| -- (sm3/sm3) | (barsa) | (m3/Sm3) | (cp) | -- (bara) | (m3/Sm3) | (cp) |
| -- @ T = 88.4 deg.C. & Pb = 237.9 barsa (MDT Data) | | | | | | |
| -- | | | | | | |
| 0.0000 | 1.0000 | 1.0679 | 1.3419 | 1.0000 | 1.2580 | 0.0137 |
| 4.9257 | 19.2232 | 1.0769 | 1.2675 | 19.2232 | 0.0651 | 0.0138 |
| 11.1256 | 37.4464 | 1.0883 | 1.1830 | 37.4464 | 0.0329 | 0.0141 |
| 17.9406 | 55.6695 | 1.1009 | 1.1000 | 55.6695 | 0.0218 | 0.0144 |
| 25.1933 | 73.8927 | 1.1142 | 1.0213 | 73.8927 | 0.0162 | 0.0147 |
| 32.7917 | 92.1159 | 1.1282 | 0.9479 | 92.1159 | 0.0128 | 0.0152 |
| 40.6780 | 110.3390 | 1.1427 | 0.8800 | 110.3390 | 0.0106 | 0.0156 |
| 48.8128 | 128.5620 | 1.1577 | 0.8175 | 128.5620 | 0.0091 | 0.0161 |
| 57.1667 | 146.7850 | 1.1731 | 0.7603 | 146.7850 | 0.0079 | 0.0167 |
| 65.7178 | 165.0090 | 1.1888 | 0.7081 | 165.0090 | 0.0071 | 0.0172 |
| 74.4471 | 183.2320 | 1.2049 | 0.6604 | 183.2320 | 0.006385 | 0.017819 |
| 83.3406 | 201.4550 | 1.2213 | 0.6170 | 201.4550 | 0.0058 | 0.0184 |
| 92.3860 | 219.6780 | 1.2379 | 0.5776 | 219.6780 | 0.0054 | 0.0191 |
| **100.6410** | **237.9010** | **1.2527** | **0.5462** | **237.9010** | **0.0050** | **0.0197** |
| 100.6410 | 256.1240 | 1.2487 | 0.5558 | 256.1240 | 0.0047 | 0.0203 |
| 100.6410 | 274.3480 | 1.2453 | 0.5653 | 274.3480 | 0.0045 | 0.0210 |
| 100.6410 | 292.5710 | 1.2424 | 0.5749 | 292.5710 | 0.0043 | 0.0216 |
| 100.6410 | 310.7940 | 1.2398 | 0.5844 | 310.7940 | 0.0041 | 0.0223 |
| 100.6410 | 344.3000 | 1.2357 | 0.6020 | 344.3000 | 0.0038 | 0.0234 |

The PVT analysis results from the K-15 well indicate an average initial gas-oil ratio and formation volume factor of approximately 104 $Sm^3/Sm^3$ and 1.27 $Sm^3/Sm^3$, respectively. These results are within the range of the values that were used in the reservoir simulation model therefore the accuracy of the data used has been verified. Both the gas-oil ratio and formation volume factor observed at the K-15 well are lower than those in the remainder of the White Rose field. Average gas-oil-ratios and formation volume factors for the White Rose Field are approximately 137 $Sm^3/Sm^3$ and 1.39 $Sm^3/Sm^3$, respectively.

### 3.1.3 Reservoir Core Data

Significant core has been recovered from the Ben Nevis Avalon formations in the greater White Rose region. Table 3-11 illustrates the amount of conventional core as well as sidewall cores taken in all wells in the greater White Rose region to date.

New core has been recovered in the North Amethyst K-15 and O-28Y delineation wells. The acquisition of this new core has expanded the data set across the Ben Nevis Avalon region in the greater White Rose area.

**Table 3-11 Conventional and Sidewall Cores from the White Rose Region**

| White Rose Cores | | | all depths are measured (metres) | | | |
|---|---|---|---|---|---|---|
| **Well** | **Core Type** | | **Start** | **Finish** | **Recovery** | **Formation** |
| | | | | | | |
| A-17 | Conventional | Core #1 | 2940.8 | 3047.0 | 106.3 | Ben Nevis |
| L-08 | Conventional | Core #1 | 2843.0 | 2866.5 | 23.1 | Ben Nevis |
| L-08 | Conventional | Core #2 | 2866.5 | 2883.5 | 15.5 | Ben Nevis |
| L-08 | Conventional | Core #3 | 2883.5 | 2936.6 | 53.1 | Ben Nevis |
| L-08 | Conventional | Core #4 | 2936.6 | 3043.6 | 107.0 | Ben Nevis |
| L-08 | Conventional | Core #5 | 3043.6 | 3061.9 | 18.3 | Ben Nevis |
| E-09 | Sidewall | 31partial recoveries | | | | Ben Nevis |
| E-09 | Sidewall | 122 recovered | | | | Various |
| H-20 | Conventional | Core #1 | 2916.0 | 2966.0 | 50.0 | Ben Nevis |
| H-20 | Conventional | Core #2 | 2966.0 | 3022.0 | 54.0 | Ben Nevis |
| H-20 | Conventional | Core #3 | 3022.0 | 3038.0 | 12.5 | Ben Nevis |
| N-30 | Conventional | Core #1 | 2954.0 | 3064.0 | 110.6 | Ben Nevis |
| N-30 | Sidewall | 10 recovered | | | | Eastern Shoals |
| N-22 | Conventional | Core #1 | 3378.0 | 3396.0 | 18.0 | Hibernia |
| N-22 | Conventional | Core #2 | 3565.0 | 3570.0 | 5.0 | Hibernia |
| N-22 | Conventional | Core #3 | 3570.0 | 3580.5 | 10.5 | Hibernia |
| N-22 | Sidewall | 22 partial recoveries | | | | Ben Nevis |
| N-22 | Sidewall | 180 recovered | | | | Various |
| J-49 | Conventional | Core #1 | 3096.5 | 3115.1 | 14.9 | Ben Nevis |
| L-61 | Conventional | Core #1 | 3006.3 | 3024.6 | 17.9 | Ben Nevis/E. Shoals |
| L-61 | Conventional | Core #2 | 3257.7 | 3271.8 | 13.4 | Eastern Shoals |
| J-91 | Sidewall | 35 recovered | | | | Nautilus/Ben Nevis |
| F-04 | Conventional | Core #1 | 2764.0 | 2818.0 | 53.3 | Ben Nevis |
| F-04 | Conventional | Core #2 | 2818.0 | 2873.0 | 52.4 | Ben Nevis |
| F-04 | Sidewall | 45 recovered | | | | Various |
| B-07 1 | Sidewall | 32 recovered | | | | Ben Nevis |
| B-07 4 | Conventional | Core #1 | 3844.0 | 3914.0 | 67.6 | Ben Nevis |
| B-07 4 | Conventional | Core #2 | 3914.0 | 3935.7 | 22.0 | Ben Nevis |
| B-07 4 | Conventional | Core #3 | 3935.7 | 3982.9 | 47.2 | Ben Nevis/Hibernia |
| J22-1 | Conventional | Core #1 | 2780.1 | 2883.5 | 103.2 | Ben Nevis |
| E18-1 | Conventional | Core #1 | 4149.0 | 4203.0 | 52.9 | Ben Nevis/E. Shoals |
| O-28Y | Conventional | Core #1 | 3406.4 | 3427.0 | 17.2 | Ben Nevis |
| O-28Y | Sidewall | 25 recovered | 3373.5 | 3449.0 | | Ben Nevis/E. Shoals |
| O-28X | Sidewall | 25 recovered | 3373.5 | 3447.0 | | Ben Nevis/E. Shoals |
| K-15 | Conventional | Core #1 | 2335.3 | 2445.6 | 95.7 | Ben Nevis |
| K-15 | Sidewall | 25 recovered | 2323.0 | 2528.0 | | Ben Nevis/E. Shoals |

Figure 3-6 illustrates a core-based porosity-permeability cross plot including the new data acquired from the K-15 well. This cross plot illustrates how the new data acquired at the K-15 well align very well with the previous data in the South Avalon pool and emphasizes the consistent facies relationship across the White Rose region. Table 3-12 summarizes the total core recovery in wells within the greater White Rose region.

A semi-log porosity-permeability correlation chart of the K-15 conventional core-analysis data was used to predict the air permeabilities at the location of K-15 well. The calculated air permeability was in the range of 200 mD to 800 mD within the oil and water sections. In the gas section, the permeability declines to within 10 mD to 500 mD as more bioturbated intervals are encountered. The distribution of V-shale by depth indicates a cleaner sand, in particular within the oil and water zones, than that observed in the main South Avalon pool. A kv/kh ratio of 0.5 is currently assumed in the Eclipse reservoir simulation model. However, analysis of core data has suggested a kv/kh ratio higher than 0.5.

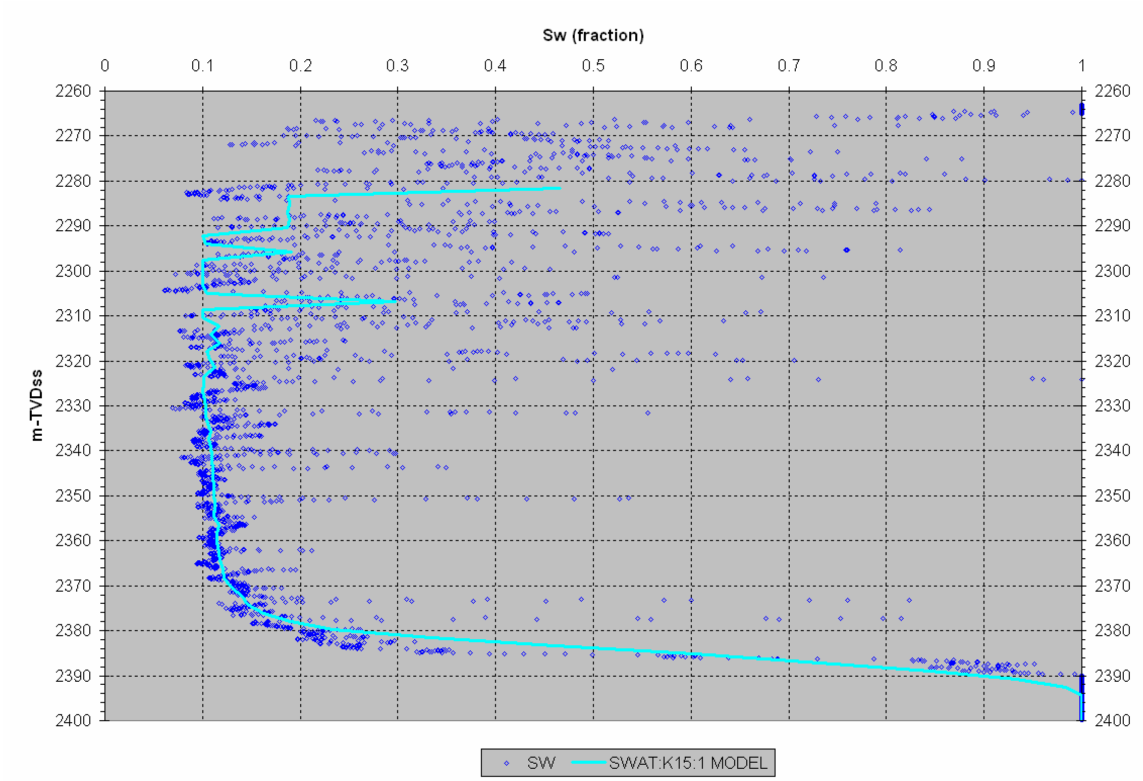
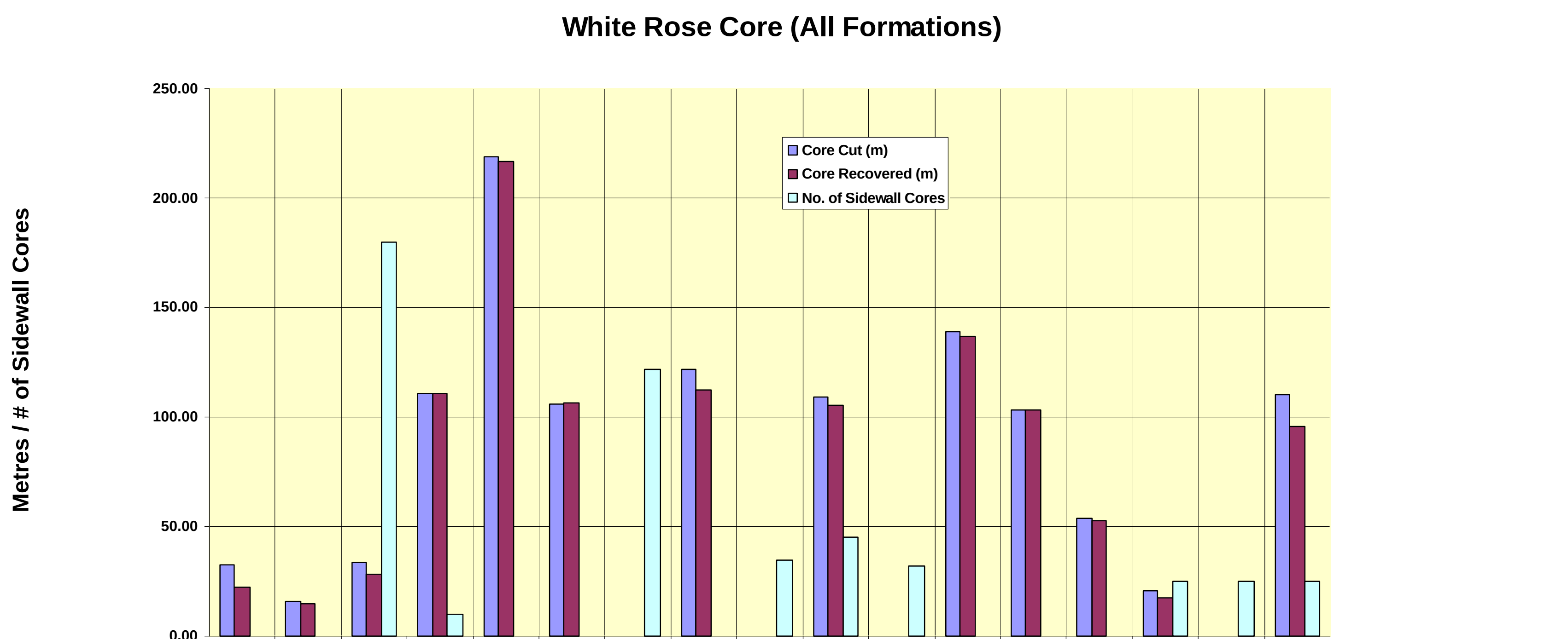



**Figure 3-6 K-15 Sw Versus Depth: Log Data Versus Simulation Model**

**Table 3-12 White Rose Region Cores (All Formations)**




| | L-61 | J-49 | N-22 | N-30 | L-08 | A-17 | E-09 | H-20 | J-91 | F-04 | B-07 1 | B-07 4 | J-22 1 | E-18 1 | O-28Y | O-28X | K-15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Core Cut (m) | 32.40 | 15.70 | 33.50 | 110.60 | 218.90 | 106.20 | | 122.00 | | 109.00 | | 138.90 | 103.40 | 54.00 | 20.60 | | 110.30 |
| Core Recovered (m) | 22.12 | 14.90 | 28.50 | 110.60 | 217.00 | 106.30 | | 112.50 | | 105.70 | | 136.80 | 103.20 | 52.90 | 17.20 | | 95.70 |
| No. of Sidewall Cores | | | 180 | 10 | | | 122 | | 35 | 45 | 32 | | | | 25 | 25 | 25 |

### 3.1.4 J Function Curves

The water saturation (Sw) calculated from J-curves at the location of K-15 was compared to the log Sw in Figure 3-7.

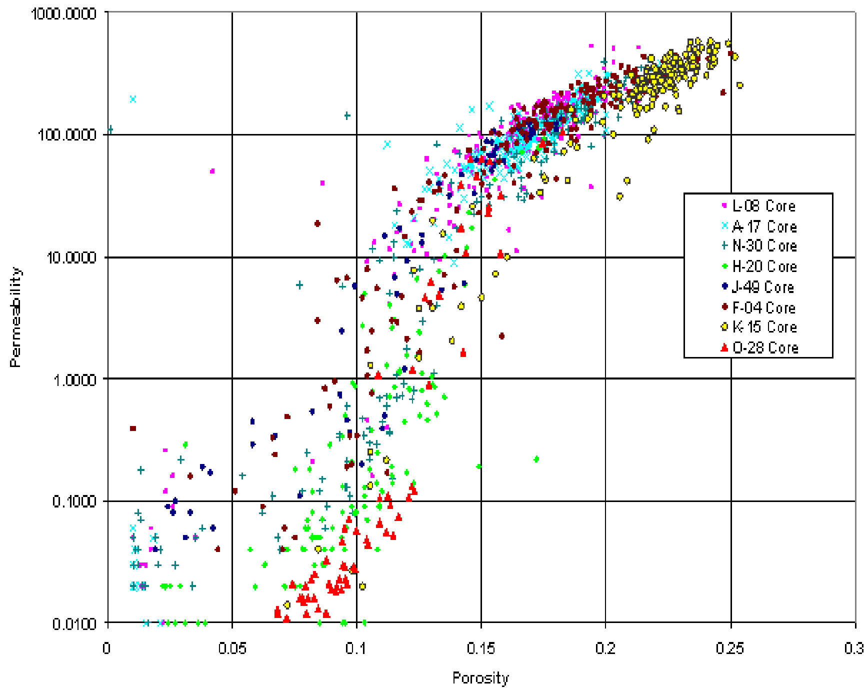



**Figure 3-7 Core Porosity-Permeability Cross Plot, Delineation Wells, Greater White Rose Region**

The "J" values were calculated from the log data of the K-15 well. Figure 3-8 demonstrates the "J" versus Sw plot for the values calculated from the K-15 log. The "J" values (calculated from logs) versus Sw values has suggested two major distinguished rock types: laminated and bioturbated. The following equation was used to generate the J curves:

$$J = P_C \left( \frac{K_{AIR}}{f} \right)^{1/2}$$

No surface tension was used.

$$P_c(at\ depth\ D) = 0.00981\,(OWC\ m - D\ m)\left(\Delta\,\rho_{ow}\ kg/m^3\right) = 0.00981\,(OWC - D)(995.4 - 736.363)$$

These “J” versus “Sw” curves were normalized, using Sw values from 0 to 1, and were used in the Eclipse simulation model. However, some of the data points fall within a transition region on the plot. Most of these transition data points were given a flag of laminated rock-type in the Eclipse coarse model within the sections where these transition data points exist.

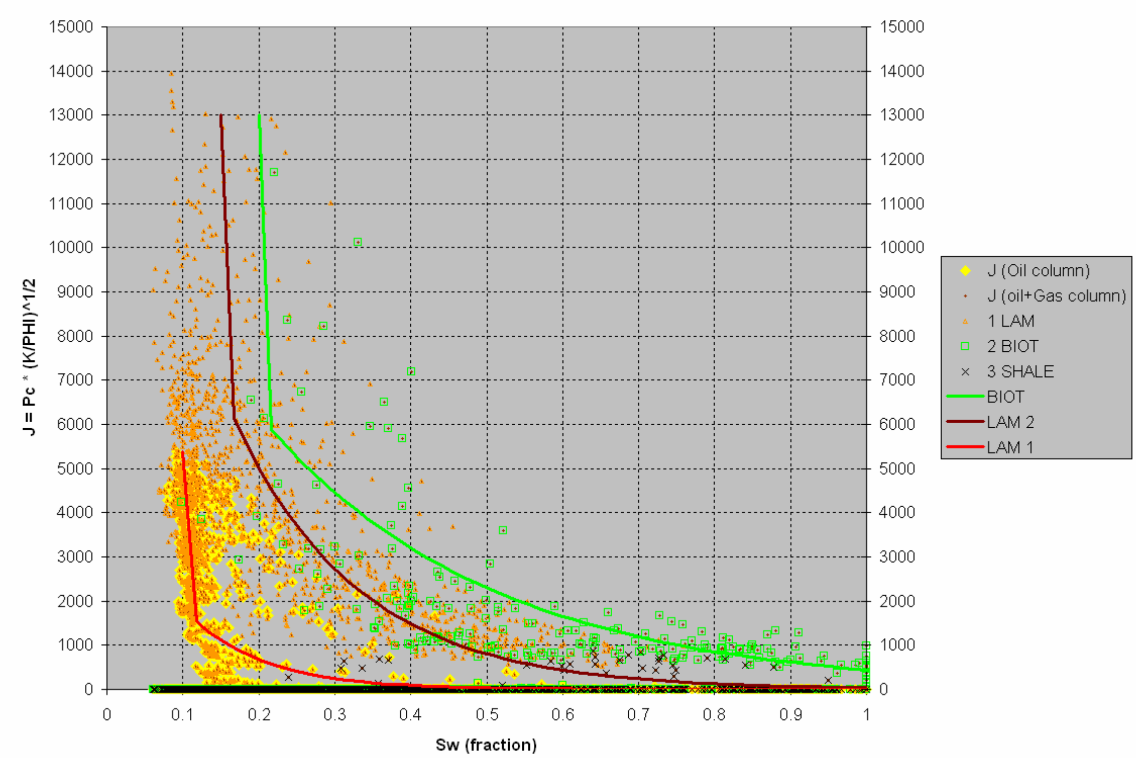



**Figure 3-8 North Amethyst K-15 “J” Values vs. Sw**

### 3.1.5 Special Core Analysis

Nine full diameter core pieces from the North Amethyst K-15 well were reserved for Special Core Analysis (SCAL). SCAL work is currently ongoing. Gas-oil and oil-water relative permeability tests are planned for core taken from within the gas and oil zones at K-15. Amott/USBM wettability tests and capillary pressure tests will also be conducted.

At the time of building the North Amethyst reservoir simulation model, SCAL data was not available for the K-15 well. Therefore, the normalized relative permeability curves for the main South Avalon Pool model were used for the North Amethyst simulation model. The $K_r$ and $S_w$ end points for the North Amethyst distinguished rock types were predicted using correlation plots. Correlation plots for Sor, kro, krg and krw are shown in Figures 3-9, 3-10 and 3-11. The end points that were used in the Eclipse simulation model are summarized in Table 3-13.

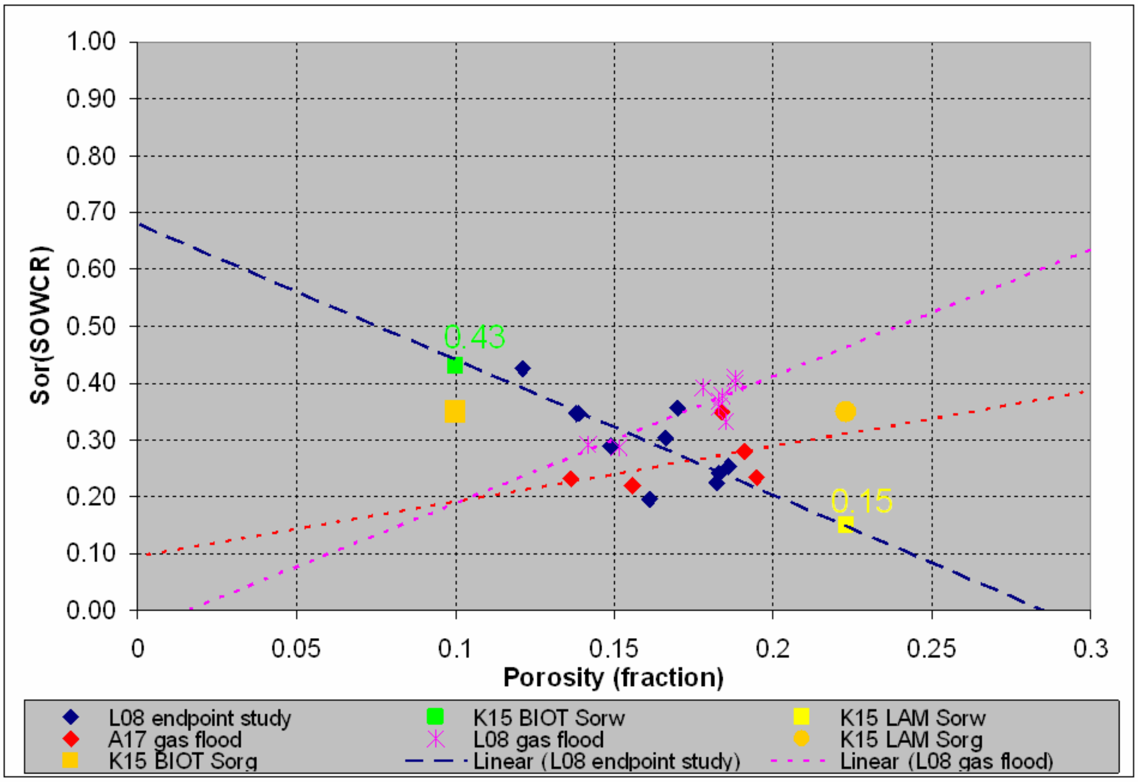



**Figure 3-9 North Amethyst K-15 Sower End Points**

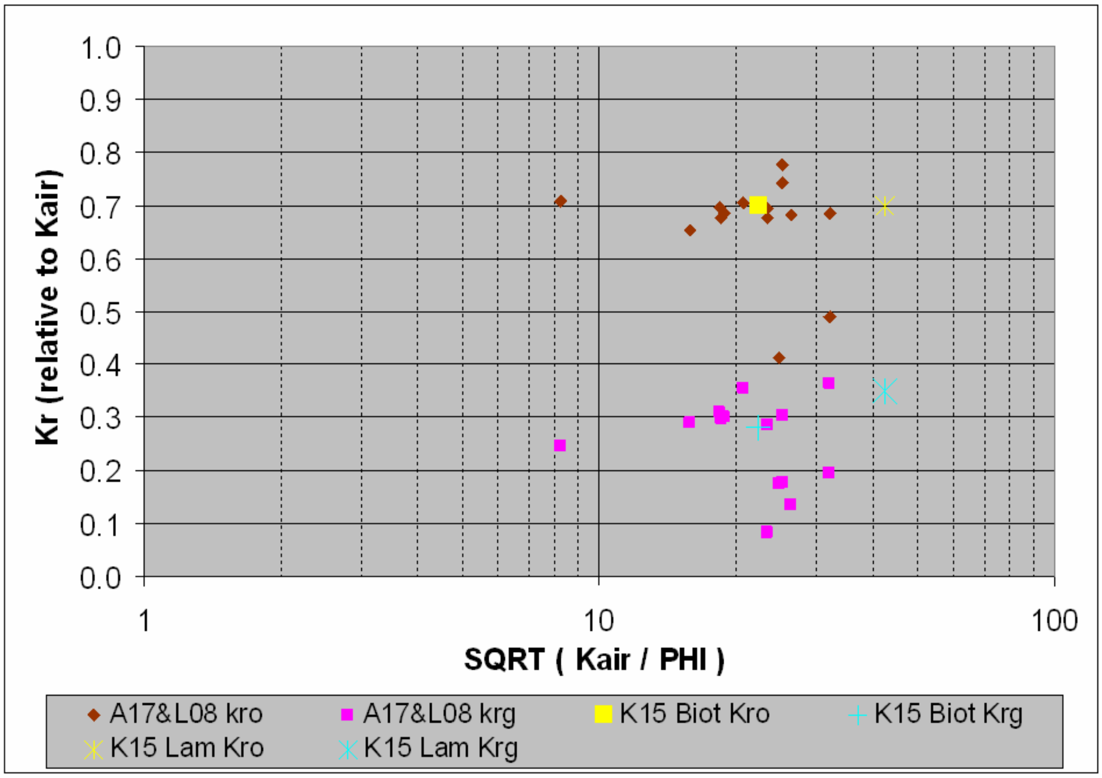



**Figure 3-10 North Amethyst K-15 Kror and Krgr End Points**

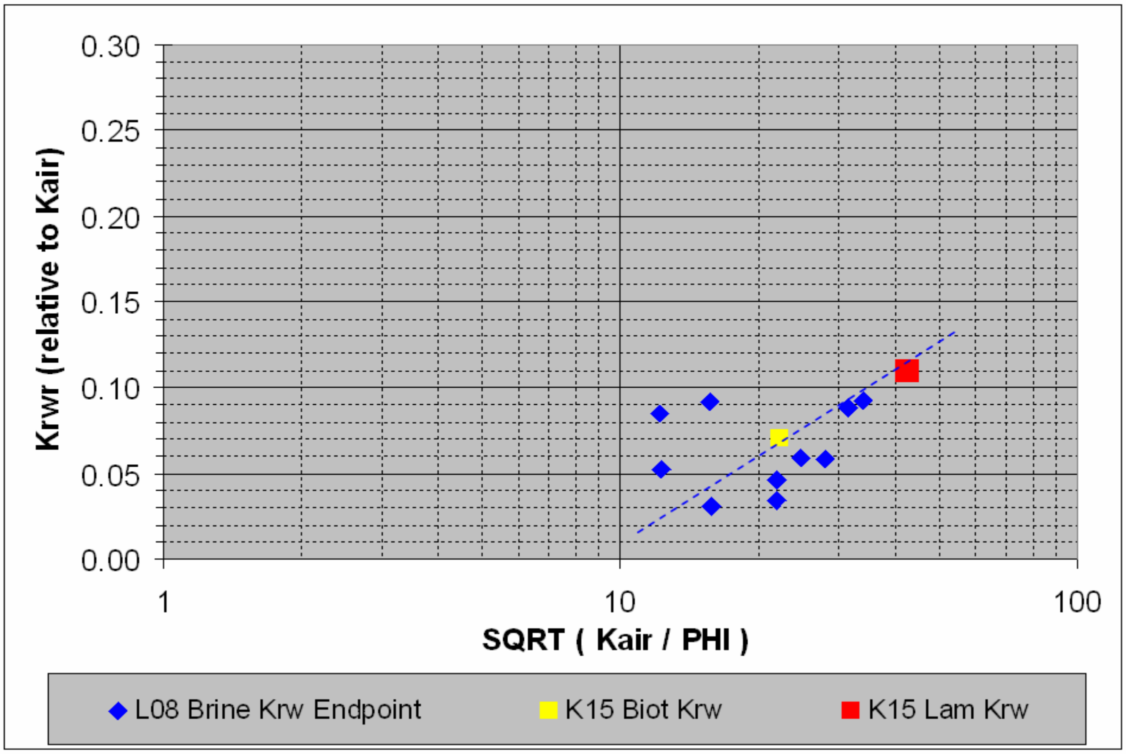



**Figure 3-11 North Amethyst K-15 Krwr End Points**

**Table 3-13 North Amethyst Relative Permeability End Points Correlation**

| | Laminated | Bioturbated |
|---|---|---|
| **Swcr** | **0.1** | **0.25** |
| **Sowcr** | **0.15** | **0.43** |
| **Sogcr** | **0.35** | **0.35** |
| **Kror** | **0.7** | **0.7** |
| **Krgr** | **0.35** | **0.28** |
| **Krwr** | **0.11** | **0.07** |

## 3.2 Development Strategy

### 3.2.1 Displacement Strategy

The displacement strategy for the North Amethyst field will provide water injection for pressure support, however both gas flood and water flood options were considered. In terms of ultimate oil recovery and current *SeaRose* FPSO gas handling capacity, a comparison between the gas flooding and water flooding scenarios has recommended water flooding as the preferred secondary recovery mechanism.

The depletion plan for the North Amethyst field includes secondary recovery by water flood. Seawater will be injected from the *SeaRose* FPSO and will be sourced and treated in the same manner as water that is currently being injected into the South Avalon pool.

### 3.2.2 Development Scenario

A prediction model was run for development of the North Amethyst field. Figure 3-12 shows a top view of the current proposed well locations for the North Amethyst field development. The northwest-southeast oil region of the North Amethyst field was found to be best drained by four horizontal oil producers and five water injectors (1 horizontal and 4 deviated).

Further optimization and well design work scope will be conducted and, as such, well counts and well plans may change. The following details are included as an overview of the current development scenario wells.

**Primary Wells**

The following wells are currently proposed for development of the North Amethyst field. The proposed well designs and locations are based on the current well planning scenario, however further optimization is still ongoing and these plans may be altered as a result of that optimization work.

**Oil Producers:**

- Horizontal producer P1 in the south region. The well is oriented northwest-southeast parallel to the eastern boundary fault. Sensitivity of optimum TVD elevation has recommended approximately 2,355 mTVDss.

- Horizontal producer P2 in the central region. The well is oriented Northwest west-southeast east intersecting two internal faults. Sensitivity of optimum TVD elevation has recommended approximately 2,365 mTVDss for this well.

- Horizontal producer P3 at the northern region. Sensitivity of optimum TVD elevation has recommended approximately 2,360 mTVDss.

- Horizontal producer P4 in the northern region. Sensitivity of optimum TVD elevation has recommended approximately 2,360 mTVDss.

**Water Injectors:**

- Southern horizontal water injector located on both sides of an internal fault.

- Four deviated water injectors located in the north and central regions.

Since the northwest-southeast elongated North Amethyst oil region is isolated from the east by a major eastern boundary fault, all Eclipse model runs discussed in this evaluation have assumed no aquifer exists.

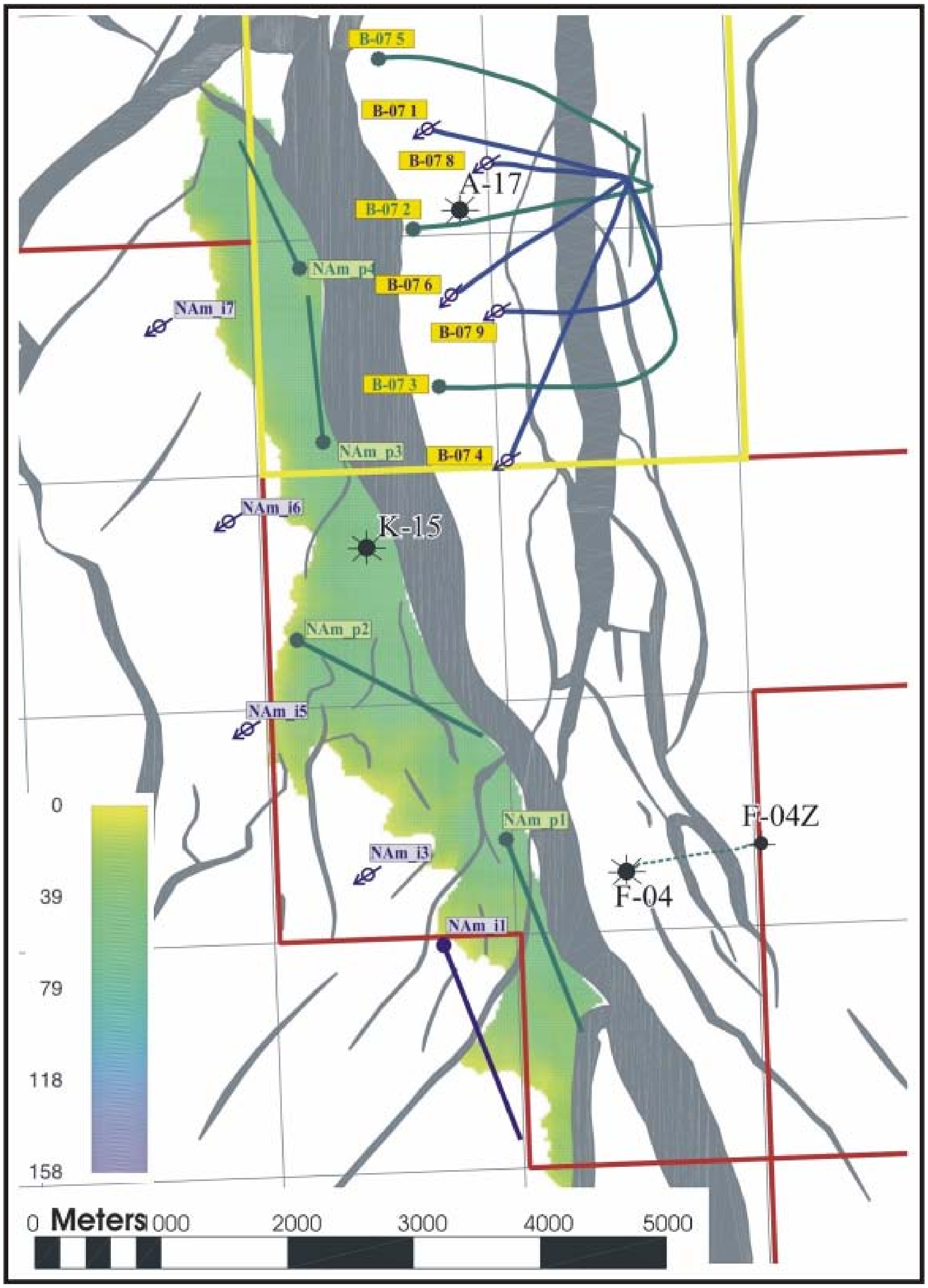



**Figure 3-12 Proposed North Amethyst Well Locations**

### 3.2.3 Reservoir Management Plan

The reservoir management plan for the North Amethyst field will be incorporated into the existing criteria currently being used to manage the White Rose South Avalon pool. Each pool in the White Rose area is at the bubble point pressure with an overlying gas cap and underlying water leg. Therefore, a voidage replacement ratio between 1.0 and

1.2 will continue to be targeted. This will provide for long term pressure support in case of any unforeseen interruptions in water injection.

Produced gas from the North Amethyst field will be re-injected into the North Avalon pool for storage purposes in the same manner that excess produced gas from the South Avalon pool is currently being handled. The gas storage area capacity is currently under evaluation and the Northern Drill Center (NDC) has two spare drilling slots which are available for expansion.

## 3.3 Reservoir Simulation

### 3.3.1 Simulation Model

The North Amethyst Eclipse simulation model was generated from the geological model updated in January 2006 after up-scaling the cell dimensions and petrophysical characteristics. The Eclipse model was initialized having 50 x 114 x 326 cells with aerial dimensions of approximately 100 m x 100 m. The vertical thickness of cells vary from 1.4 m to 2.2 m within the main hydrocarbon region. The thickness coarsens from 2.5 m to 2.0 m as the structure dips west into water. The total number of active cells in the Eclipse model was 342,415.

### 3.3.2 Production / Injection Constraints

The base case North Amethyst simulation model was run together with South Avalon production and is assuming an annualized production rate of 19,081 $m^3$/d (120,000 bopd). The case considered presents one potential scenario but field optimization and management will be conducted on a field by field and on an integrated basis. The following are the assumptions used in conducting the base case North Amethyst simulation model. Any change to these assumptions will impact the results presented in this section.

- North Amethyst is tied back to *SeaRose* FPSO directly;
- First oil from the North Amethyst Satellite Tie-back on December 1, 2010;
- North Amethyst development is based on a 9 well scenario (4 producers and 5 water injectors (1 horizontal and 4 deviated));
- Vertical flow performance (VFP) tables based on 177.8 mm tubing and current White Rose standard production well completion.
- VFP tables were generated (using Prosper software) for production wells using proposed well trajectories and predicted production and pressure performance from Eclipse. In addition, a minimum well head pressure (WHP) of 5,700 kPa and a minimum bottom hole pressure (BHP) of 20,000 kPa were applied for all four North Amethyst oil producers.

- The current *SeaRose* production and injection constraints were considered:
  - Gas compression capacity = 4.2 X $10^6$ $m^3$/d
  - Total water injection capacity = 44,000 $m^3$/d
  - Water injection capacity per glory hole = 30,000 $m^3$/d
  - Produced water = 28,000 $m^3$/d
  - Total liquids = 33,000 $m^3$/d
  - Lift gas = 1.6 X $10^6$ $m^3$/d
  - Lift gas per glory hole = 1.19 X $10^6$ m3/d

### 3.3.3 Production / Injection Performance

The maximum oil production rate is expected to be between 10,000 $m^3$/d (62,900 bopd) and 12,000 $m^3$/d (75,500 bopd) for the North Amethyst group of wells. The maximum oil production rate will be refined based on further modeling, optimization, and actual drilling and production results. The combined North Amethyst and South Avalon base case production profile is shown in Figure 3-13.

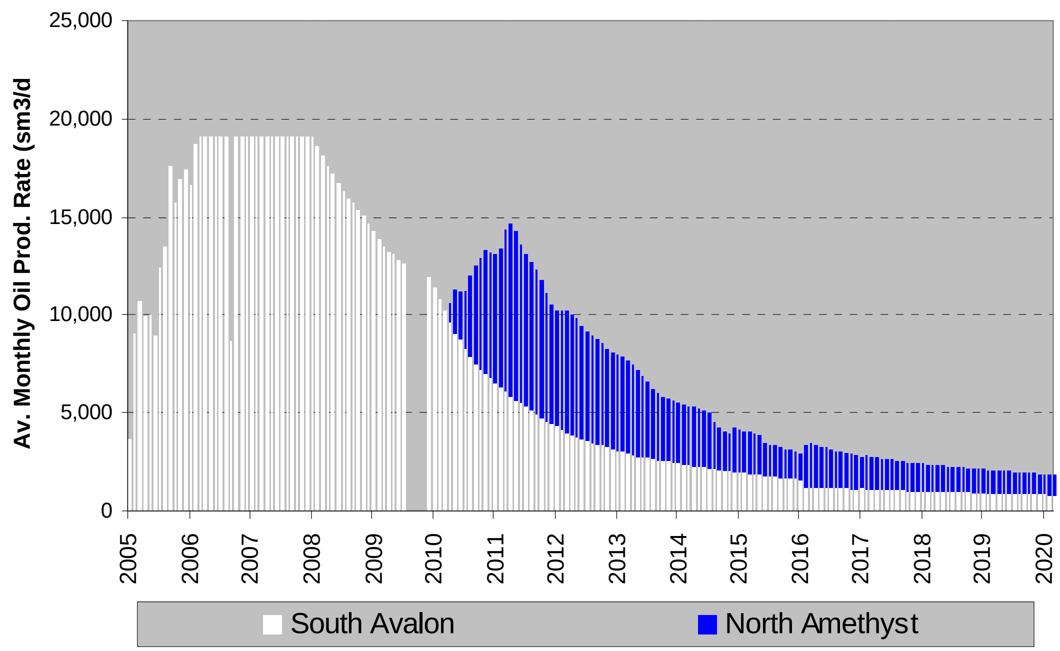



**Figure 3-13 Combined North Amethyst and South Avalon Base Case Production Profile**

The producing water cut versus oil recovery for the North Amethyst field and the South Avalon pool are presented in Figure 3-14. The changes in the producing gas-oil ratio with oil recovery over the predicted life of the field are illustrated in Figure 3-15. The

North Amethyst water-cut and producing gas-oil ratio profiles are much more accelerated than in the South Avalon Pool. The North Amethyst overall performance is predicted to exceed a GOR of 600 $Sm^3$/d and a watercut of 50% before producing 20% of its original oil in place. The GOR is expected to increase dramatically in the North Amethyst region due to the relatively high vertical sand continuity which translates into a high kv/kh ratio. Primary recovery for the North Amethyst base case development scenario is approximately 5.04 million $Sm^3$, at a recovery factor of 12.3%.

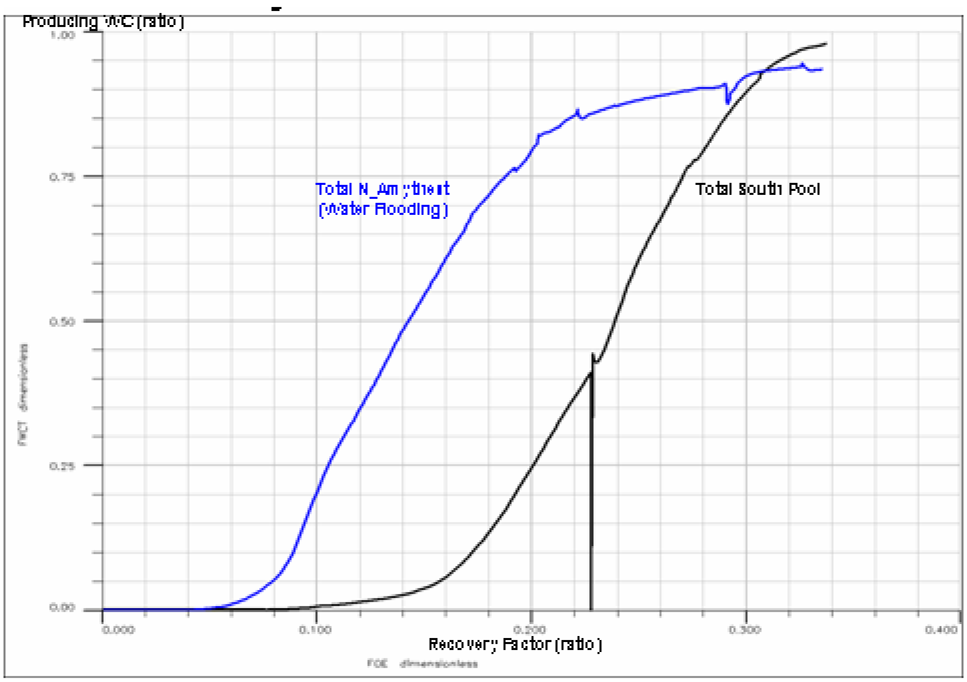



**Figure 3-14 North Amethyst and South Avalon Base Case Watercut versus Recovery Factor**

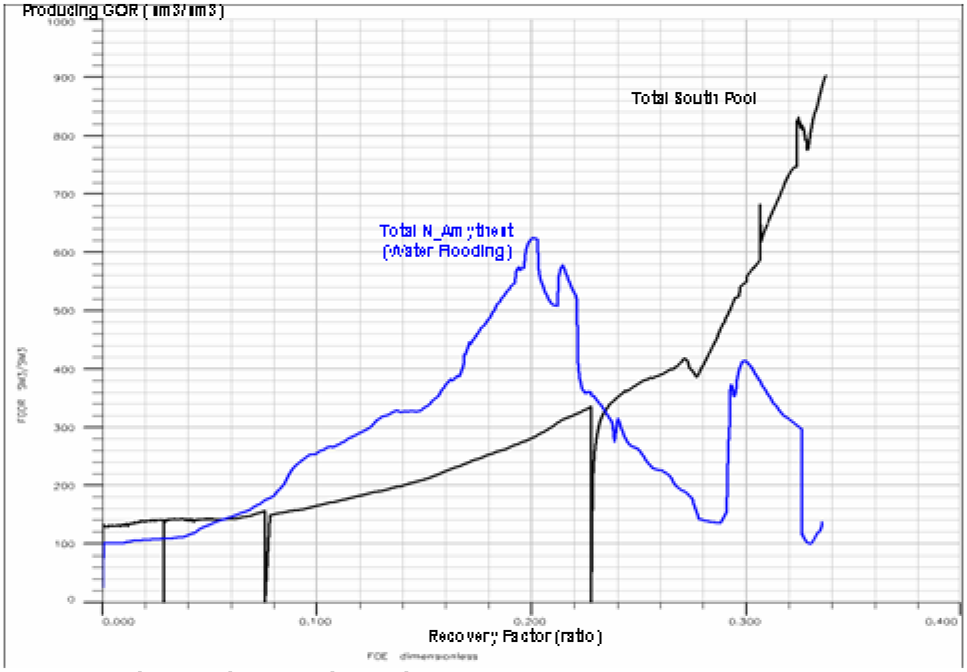



**Figure 3-15 North Amethyst and South Avalon Base Case GOR versus Recovery Factor**

The produced water, water injection, total liquid and gas profiles for the North Amethyst base case are shown in Figures 3-16 through 3-19. Water will be injected into the North Amethyst reservoir to maintain a voidage replacement of 1.0 to 1.2. All peak values are within the current topsides constraints of the *SeaRose* FPSO.

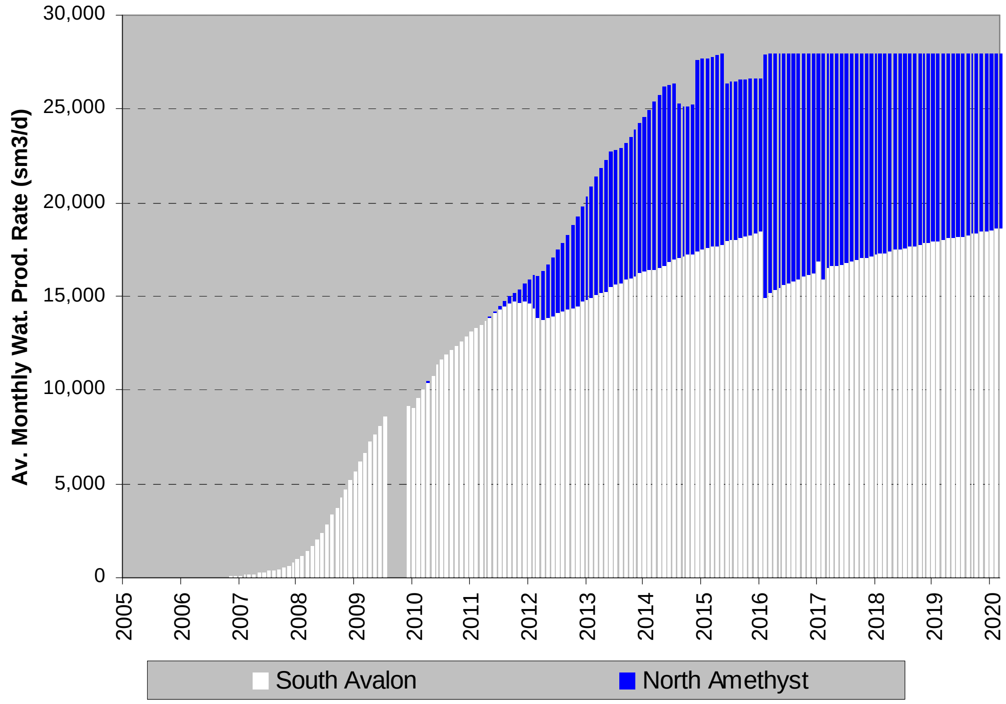



**Figure 3-16 Combined North Amethyst and South Avalon Average Monthly Water Production**

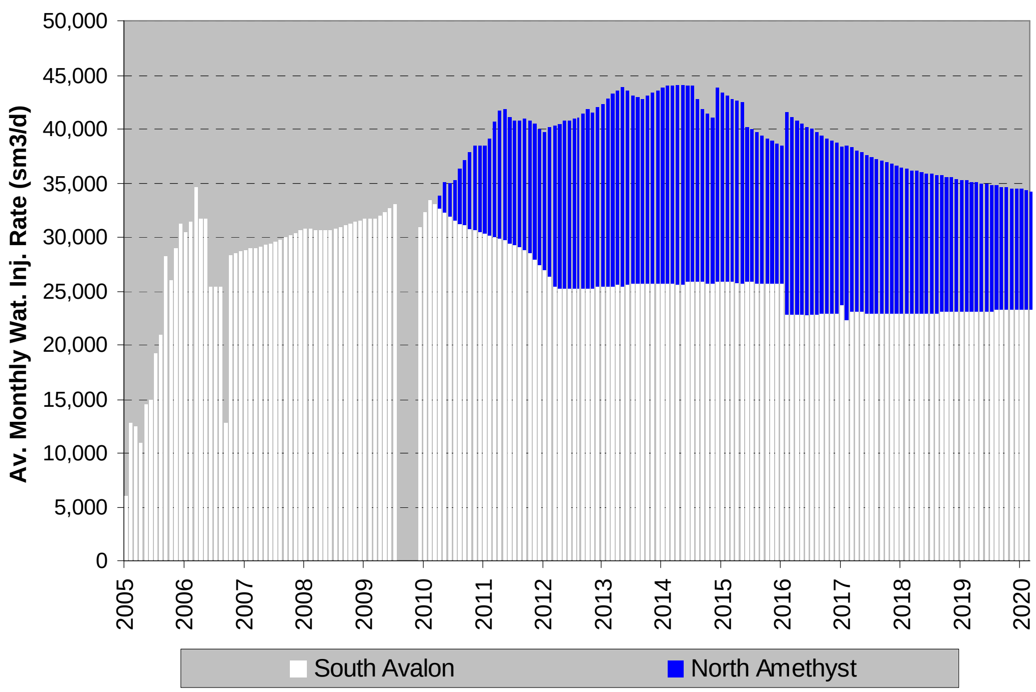



**Figure 3-17 Combined North Amethyst and South Avalon Average Monthly Water Injection**

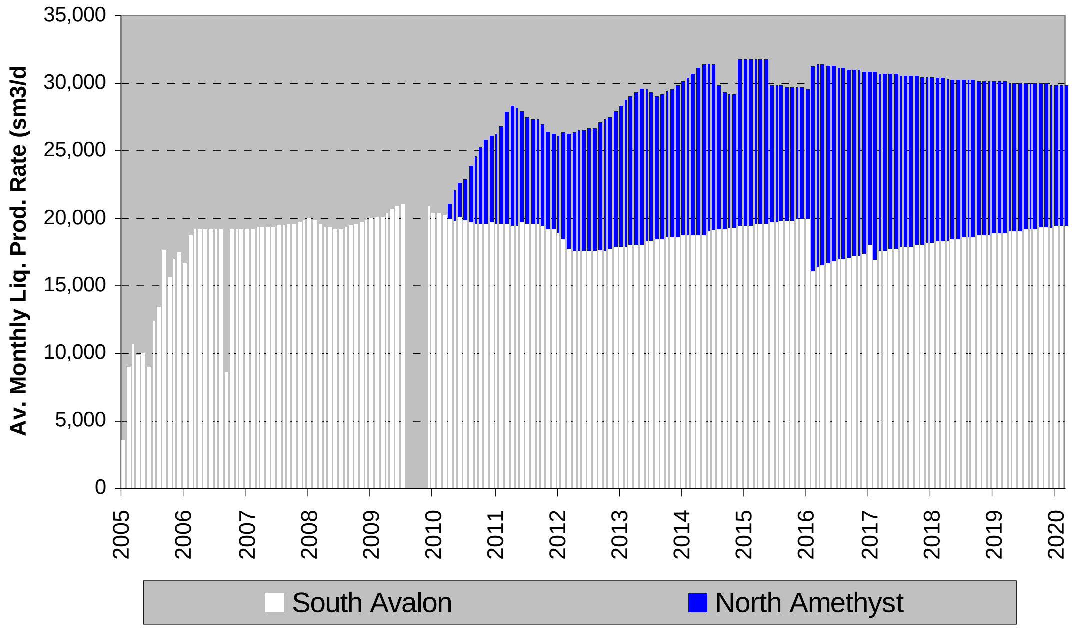



**Figure 3-18 Combined North Amethyst and South Avalon Average Monthly Total Liquid Production**

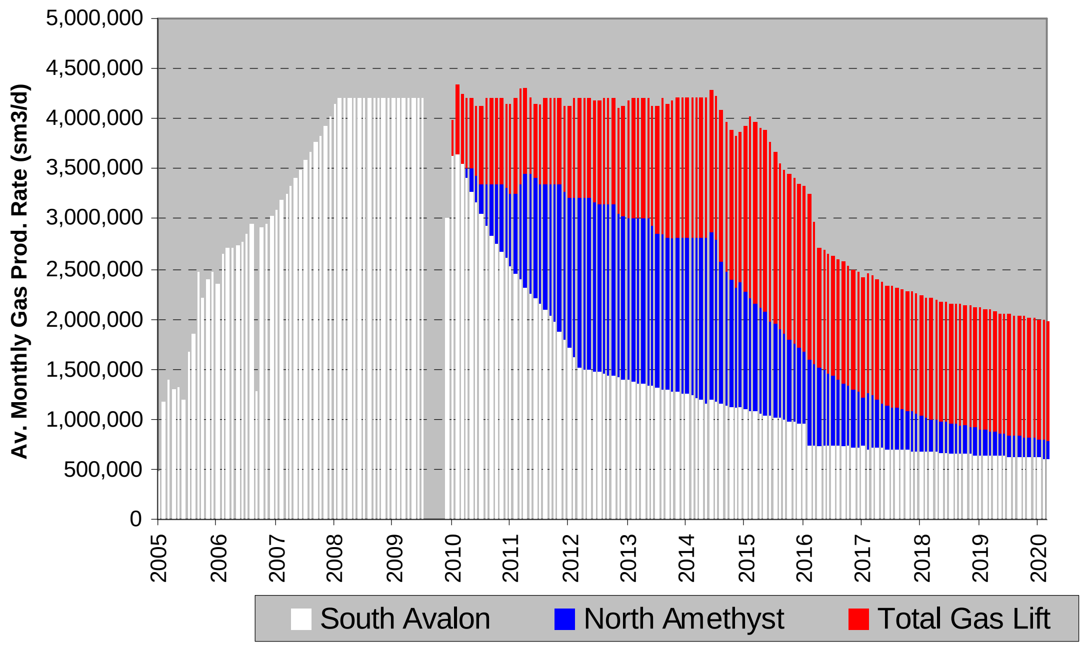



**Figure 3-19 Combined North Amethyst and South Avalon Average Monthly Gas Plot**

## 3.4 Production Forecasts

The base case production profile for the combined North Amethyst and South Avalon is illustrated in Figure 3-13. Table 3-14 presents the oil production forecast in tabular format. The ultimate recovery for the North Amethyst base case development by the end of 2020 is 11.25 million $Sm^3$ (70.7 million bbls).

**Table 3-14 Combined North Amethyst and South Avalon Base Case Production Profile**

| Year | Annual Oil Production | |
|---|---|---|
| | South Avalon $Sm^3$ | North Amethyst $Sm^3$ |
| 2005 | 390,392.6 | 0.0 |
| 2006 | 5,142,242.1 | 0.0 |
| 2007 | 6,639,840.0 | 0.0 |
| 2008 | 6,969,810.4 | 0.0 |
| 2009 | 5,810,110.8 | 0.0 |
| 2010 | 3,017,850.4 | 0.0 |
| 2011 | 2,885,512.8 | 1,530,554.0 |
| 2012 | 1,842,174.7 | 2,694,708.5 |
| 2013 | 1,256,805.4 | 2,001,060.7 |
| 2014 | 963,144.9 | 1,352,688.0 |
| 2015 | 771,245.9 | 905,849.0 |
| 2016 | 622,599.5 | 623,872.6 |
| 2017 | 417,918.2 | 704,404.1 |
| 2018 | 379,781.3 | 556,442.1 |
| 2019 | 345,213.1 | 469,202.6 |
| 2020 | 317,281.8 | 407,439.8 |
| **Total (Sm3):** | **37,771,924** | **11,246,221** |
| **Total (bbl):** | **237,577,847** | **70,736,483** |

## 3.5 Reservoir Simulation Sensitivities

Two sensitivities were also run for the North Amethyst field:

- A rate sensitivity at an average annualized oil production rate of 140,000 bbl/d from the combined North Amethyst and South Avalon.
- Gas flood of the North Amethyst field.

### 3.5.1 140,000 bbl/d Rate Sensitivity

A rate sensitivity was conducted based on an average annualized oil production rate of 140,000 bopd from the combined North Amethyst and South Avalon. There is very little difference between the ultimate recovery for the 19,081 $m^3$/d (120,000 bopd) and 22,261 $m^3$/d (140,000 bopd) simulation runs. Figures 3-20, 3-21 and 3-22 illustrate the production profile, watercut and GOR trends for the 22,261 m$^3$/d (140,000 bopd) sensitivity case.

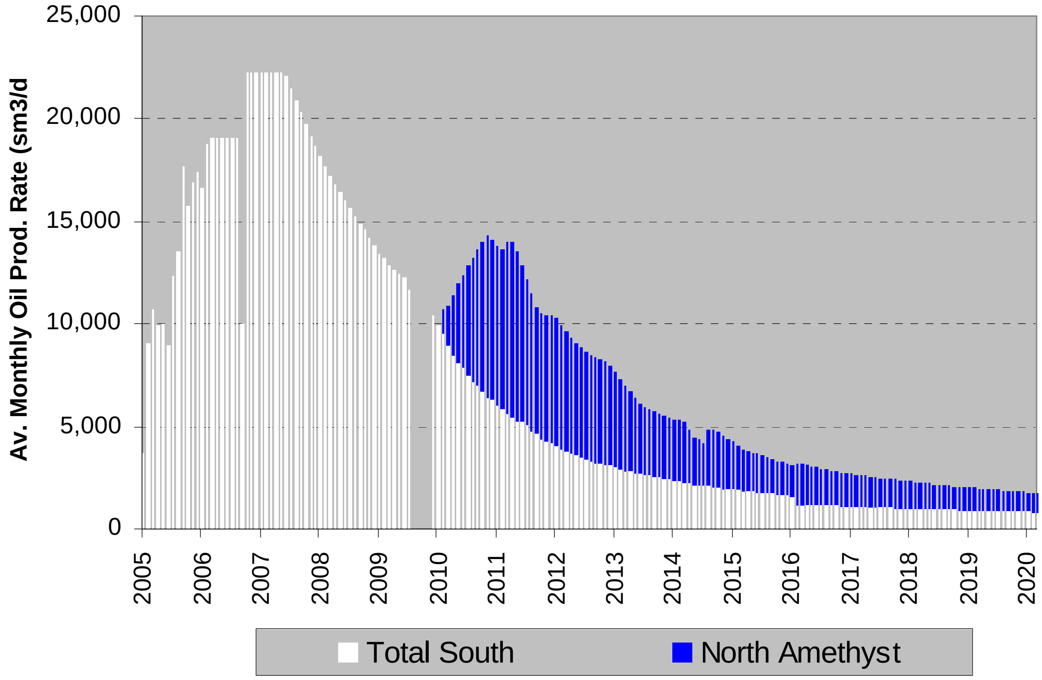



**Figure 3-20 North Amethyst 140,000 bopd Sensitivity Production Profile**

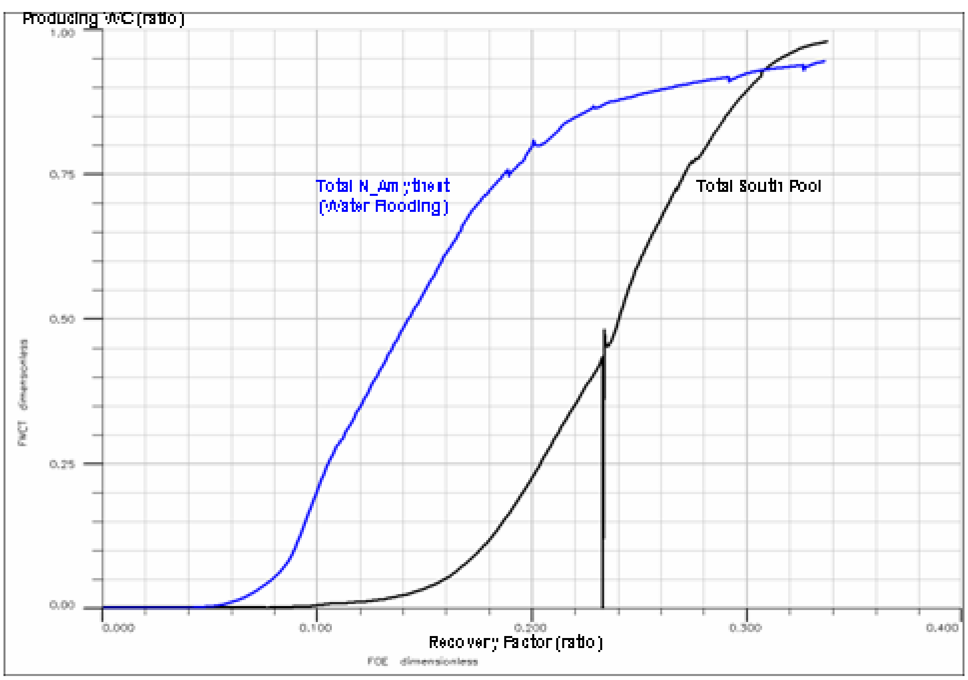



**Figure 3-21 North Amethyst 140,000 bopd Sensitivity Watercut versus Recovery Factor**

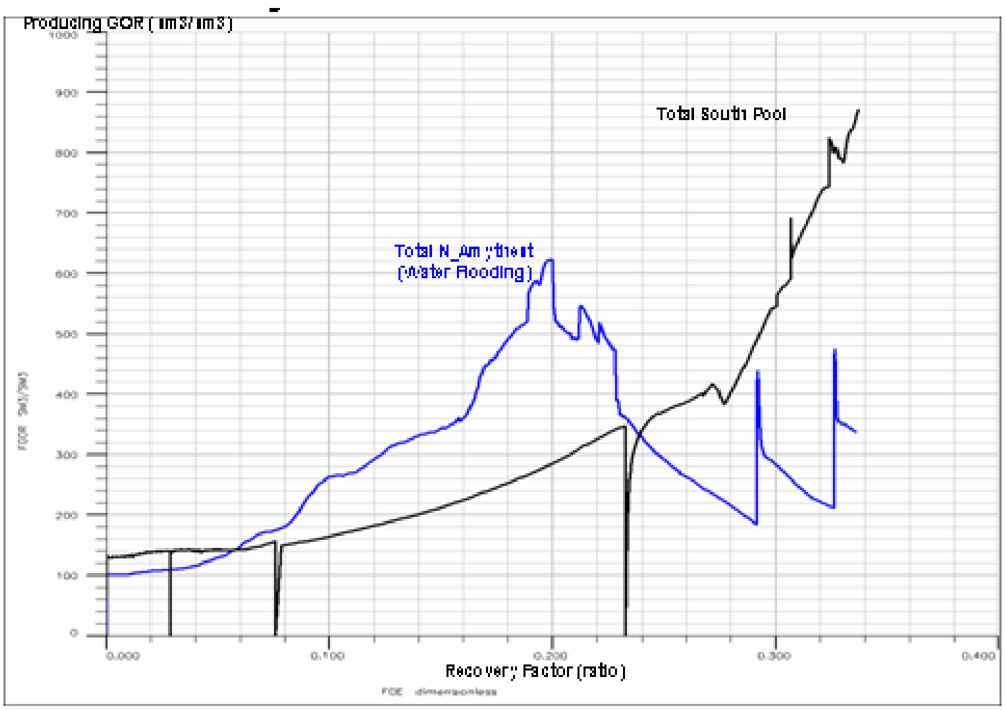



**Figure 3-22 North Amethyst 140,000 bopd Sensitivity GOR versus Recovery Factor**

### 3.5.2 Gasflood Sensitivity

For the gasflood sensitivity, four horizontal producers and three gas injectors were used in the simulation model. Figures 3-23 and 3-24 illustrate the production profile and the GOR trends for the 19,081 $m^3$/d (120,000 bopd) gasflood sensitivity case. A recovery factor for the gasflood scenario considered for the North Amethyst field was 9.8%.

A comparison of the ultimate recovery for the two sensitivity cases as well as the base development case is presented in Table 3-15.

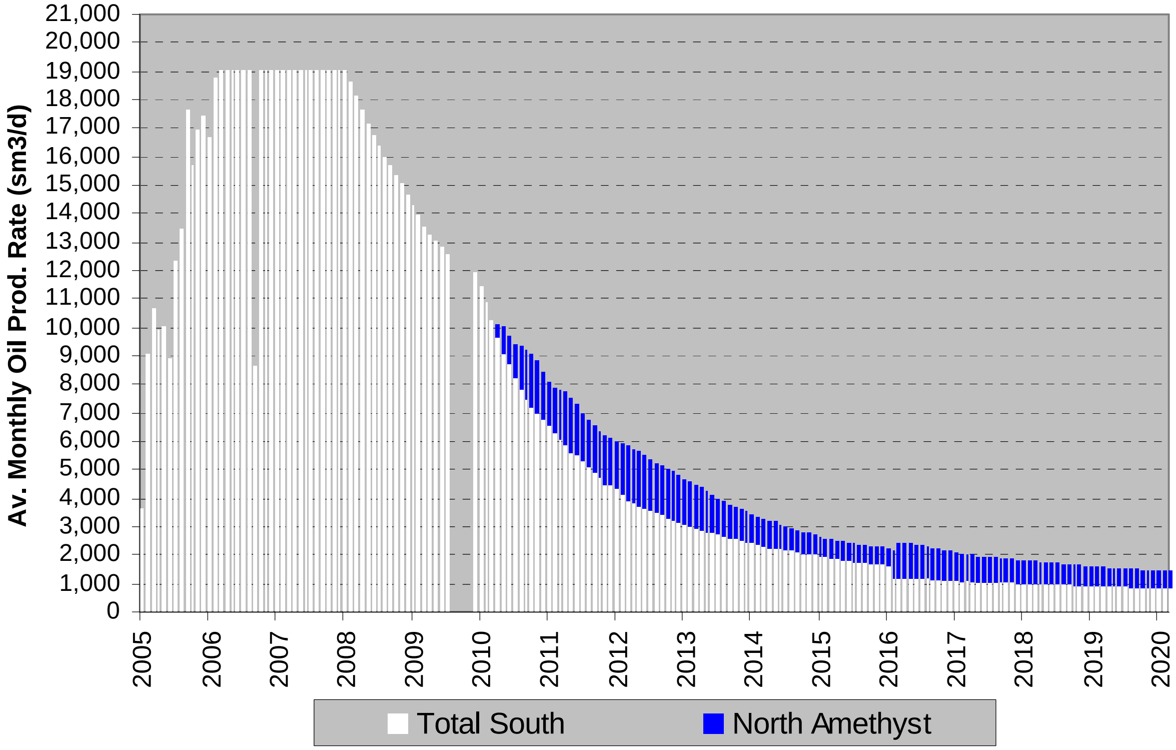



**Figure 3-23 North Amethyst 120,000 bopd Gasflood Sensitivity Production Profile**

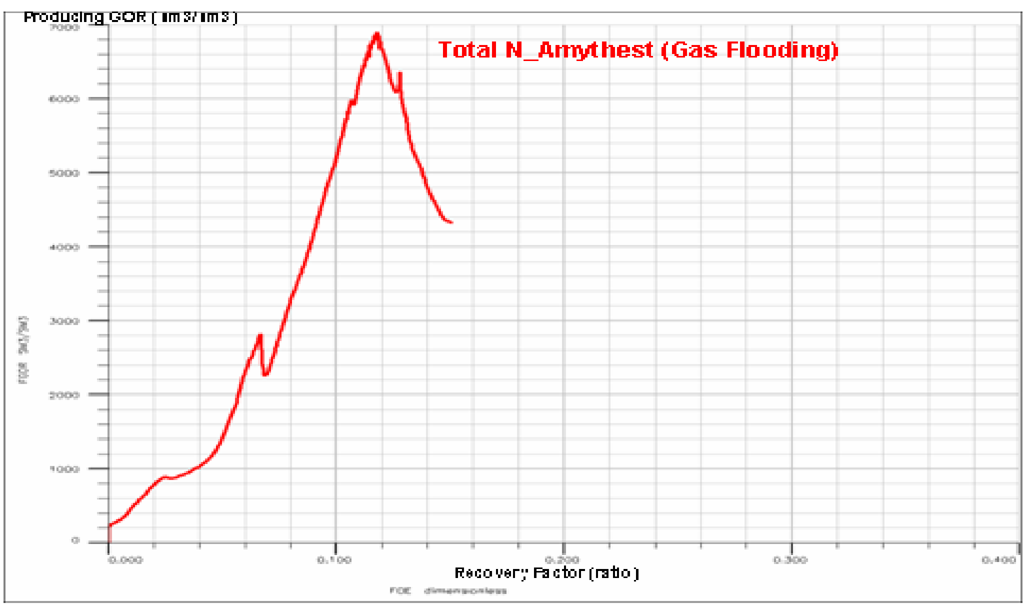



**Figure 3-24 North Amethyst 120,000 bopd Gasflood Sensitivity GOR versus Recovery Factor**

**Table 3-15 Comparison of Simulation Sensitivity Results**

| Case | Ultimate Recovery at 2020 (million $Sm^3$) | Recovery Factor |
|---|---|---|
| North Amethyst Development Base Case<br>Waterflood, Annualized production rate of 120,000 bbl/d | 11.25 | 27.51% |
| Waterflood, Annualized production rate of 140,000 bbl/d | 11.34 | 27.75% |
| Gasflood, Annualized production rate of 120,000 bbl/d | 3.99 | 9.76% |
| Primary Recovery, North Amethyst Development Base Case | 5.04 | 12.33% |

### 3.6 Reserves Estimate

The anticipated recoverable oil from the North Amethyst field is 11.25 million $Sm^3$ (70.7 million bbls). This volume corresponds to a 27.5% recovery factory of the P50 original oil in place of 41 million $Sm^3$ (256 million bbls). This reserve estimate corresponds to the production forecast provided in Figure 3-19 and Table 3-13. A summary of the probabilistic reserves assessment is provided in Section 4.0

## 4.0 Resource and Reserves Estimates

### 4.1 Introduction

The North Amethyst field is directly west of the White Rose South Avalon pool and is separated by one fault. Reservoir modeling of the North Amethyst field indicates that there is between 200 and 300 MMbbls (32 and 48 $e^6m^3$) of oil in place with a most likely estimate being 256 MMbbls (41 $e^6m^3$). The range in gas cap gas in place is between 100 and 200 Bcf (3 and 6 $e^9m^3$) with the most likely estimate being 150 Bcf. (4 e9m3) (Table 4-1). Figures 4-1 and 4-2 illustrate the hydrocarbon thickness and distribution over the structure.

**Table 4-1 Oil and Gas in Place Estimates, North Amethyst**

| | OOIP | Liquids in Gas Cap | | OGIP | Gas in Oil |
|---|---|---|---|---|---|
| MMBbl | 256 | 8 | Bcf | 150 | 150 |
| $e^6m^3$ | 41 | 1 | $e^9m^3$ | 4 | 4 |

Currently Husky is carrying a range of recovery factors for the North Amethyst field of 18-55%. The most likely recovery factor, which is currently used, is 27% which equates to approximately 70 MMBbl (11 $e^6m^3$) of recoverable oil in the North Amethyst field.

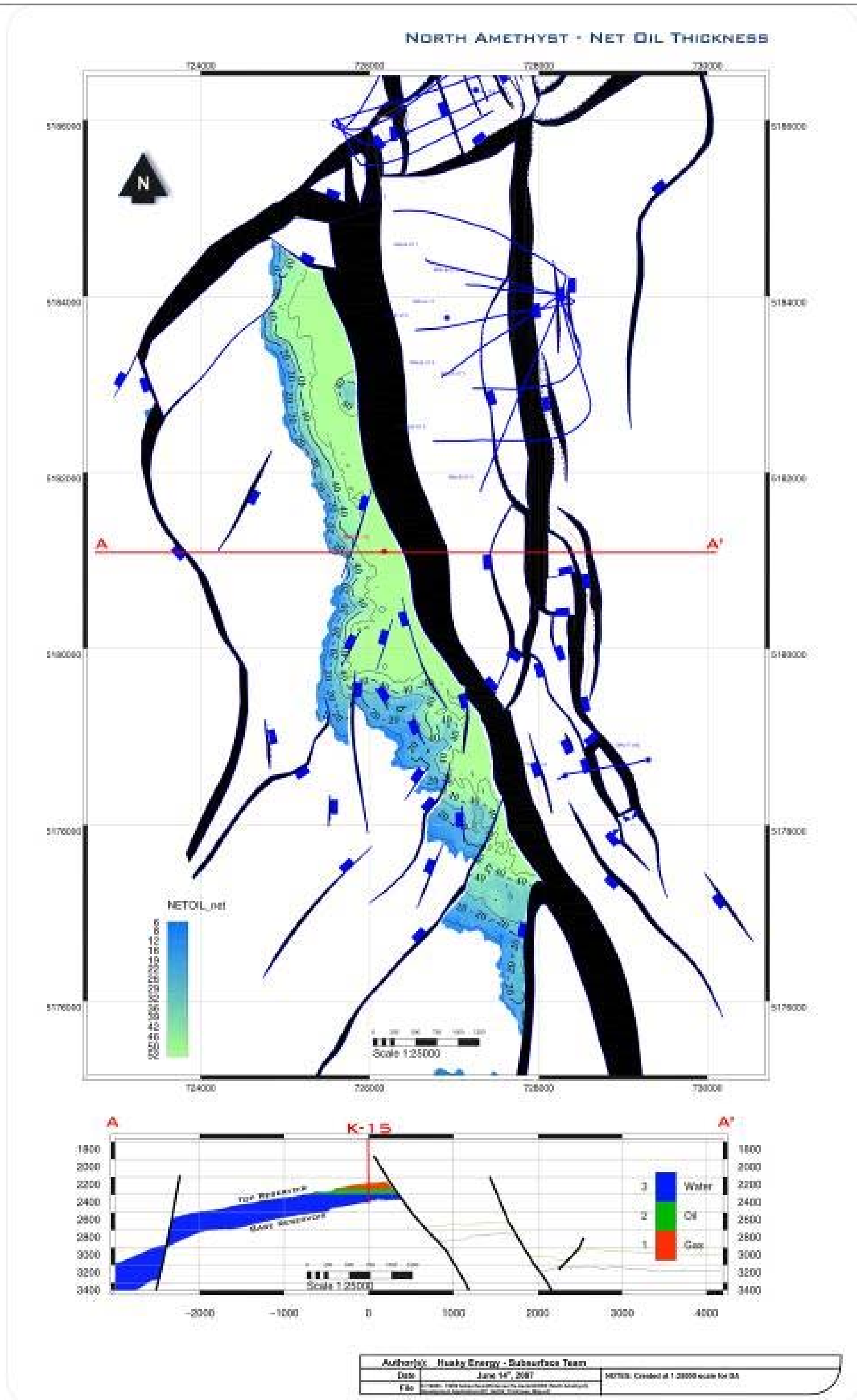



**Figure 4-1 Net oil thickness map of the North Amethyst Field**

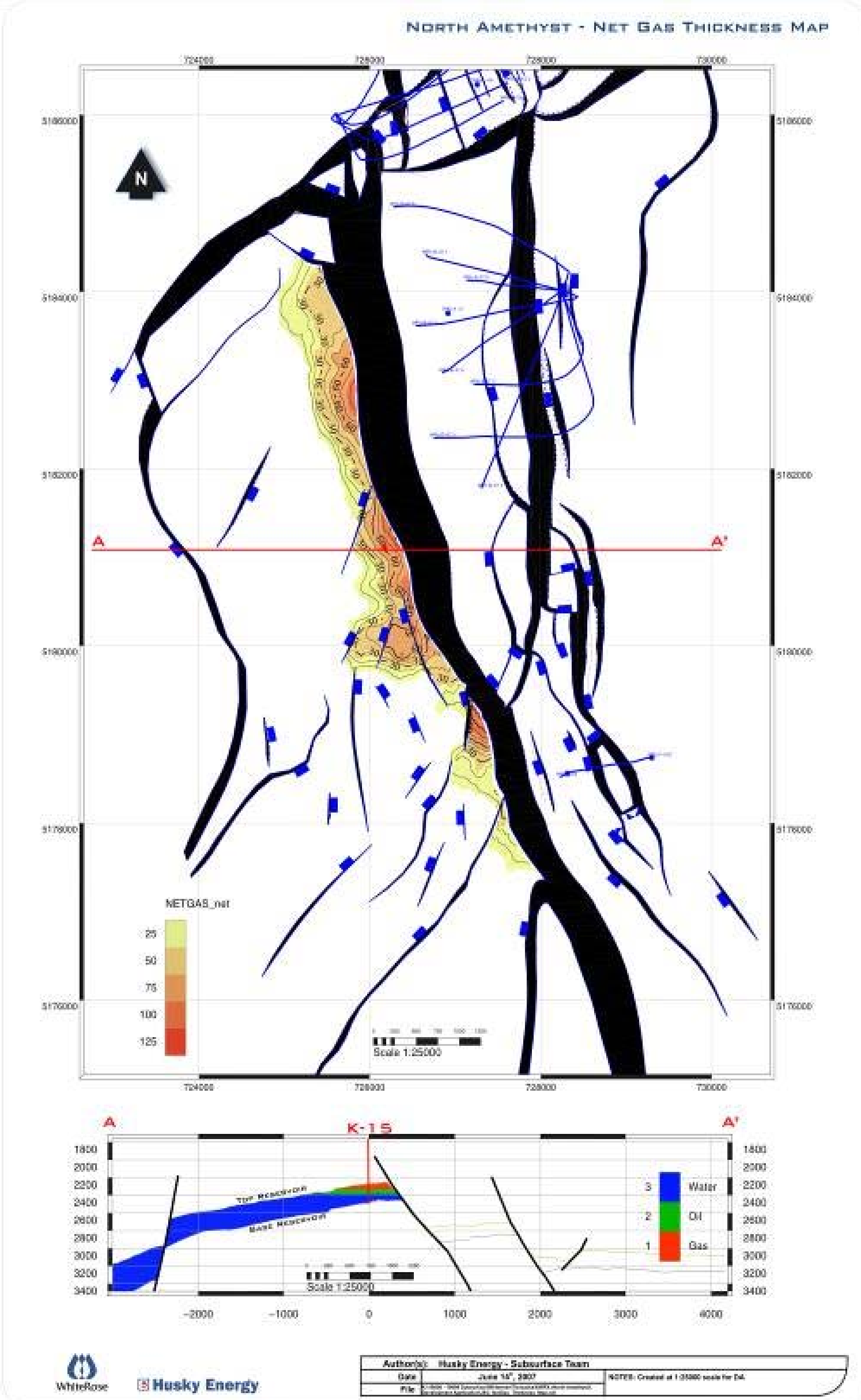



**Figure 4-2 Net Gas Thickness of the North Amethyst**

## 4.2 Probabilistic Resource-In-Place

### 4.2.1 Methodology

The North Amethyst field probabilistic resource estimates were generated using @RISK's (software add-on to Microsoft's Excel) Monte Carlo/Latin Hypercube estimation method. This is the same methodology used in past estimations for the field. Oil and gas volumes were calculated on a single block basis for North Amethyst as a smaller block naming convention is not required for this region. This section will report the North Amethyst field as a single block, which is consistent with past assessments. More defined and smaller areal extent reporting can be conducted on a one-off basis.

In order to generate a probabilistic distribution for the North Amethyst field, ranges of bulk rock volume (BRV), porosity (Phi), net-to-gross (N:G), Formation Volume Factor (FVF), and water saturation (Sw) had to be determined on consistent intervals within the formation. For the purpose of this evaluation, the main intervals of analysis where defined by the fluid contacts such that the gas and oil legs have their own data inputs.

In general, each parameter was assigned a distribution based on a most-likely value, an assigned maximum and minimum, and skew. As in past reviews, BRV was addressed first followed by N:G, Phi, Sw and FVF.

### 4.2.2 Rock Volume Distribution

The bulk rock volume distribution for North Amethyst was generated in much the same way as for the South White Rose pool. In this case, a first pass unstructured grid was built and the surfaces adjusted to produce a low-, high-, and most-likely case. Figure 4-3 illustrates the BRV distribution used in the @RISK simulation

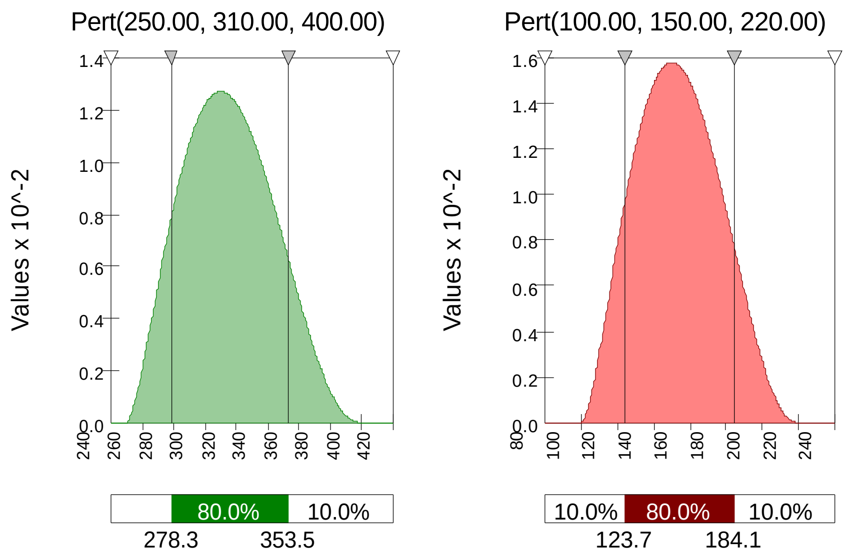



**Figure 4-3 North Amethyst BRV Distributions for Oil (Left) and Gas (right) legs**

Upon penetrating the reservoir with the K-15 well it was found that the top Ben Nevis came in 15 m higher than prognosed in the well basis of design. The base was out by nearly the same amount. The bulk of the difference can be attributed to the well being spudded approximately 20 m south of the original location, and no re-prognosis for the different location was included in the reservoir model. This raises the question of whether the entire surface require a bulk shift of 15 m or is the correction only at the well. Given that there is only a single well in the structure, and that the difference is within the accuracy of the seismic (+/- 30 m) only a local correction is applied to the base case, with the upside case capturing a bulk shift value. Table 4-2 outlines the methodology used to define the high and low cases used in the probabilistic distribution.

**Table 4-2 Bulk Rock Volume (BRV) ranges for North Amethyst**

| Bulk Rock Volume (BRV) Sensitivity ($e^6 m^3$) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Oil | | Gas | | Comments | Actual Inputs to @RISK | |
| | NAm Block 33 | NAm Block 32 | NAm Block 33 | NAm Block 32 | | Oil BRV | Gas BRV |
| Base Case | 311 | 50 | 153 | 3 | Local correction to K15… …block 32 oil leg BRV not used in P50 case as spill point came in 25m deeper than expected suggesting a downward correction may be required in this region | 310 | 150 |
| High Side Max* | 363 | 87 | 204 | 7 | +15 m shift applied to top horizon and tied to well… …base case BRV for block 32 used in upside as the +15m shift fully violates the closure and known OWC encountered in K15.. …also adds uncertainty to the seal separating North Amethyst from the Archer/Amethyst region... ...gas buffered to account for erosional effects at north end of structure | 400 | 220 |
| Low Side Min | 261 | 30 | 113 | 1 | -15m off the top horizon and tied to well… …block 32 was omitted from the BRV input under the assumption that in a true lowside minimum scenario the faults to the north are the seal and this block is wet (i.e. part of the Archer/Amethyst trend… …gas buffered as mentioned above | 250 | 100 |

### 4.2.3 Net to Gross Distribution

The N:G distribution for use in @RISK was generated from the K-15 well. Reservoir quality in this well may not be fully representative of this region and, as a result, N:G is one of the main sensitivities to resource-in-place numbers. In the case of the North Amethyst region, an adjustment was made to account for some poorer quality reservoir encountered in the gas leg of the well entering the oil window down dip of the structure. As a result, the N:G in the well is not used as the most likely outcome. Lateral trends are also considered such that poorer reservoir quality is expected to the west due to the slight movement in the depositional dip direction. Figure 4-4 illustrates both the oil- and gas-leg N:G distributions.

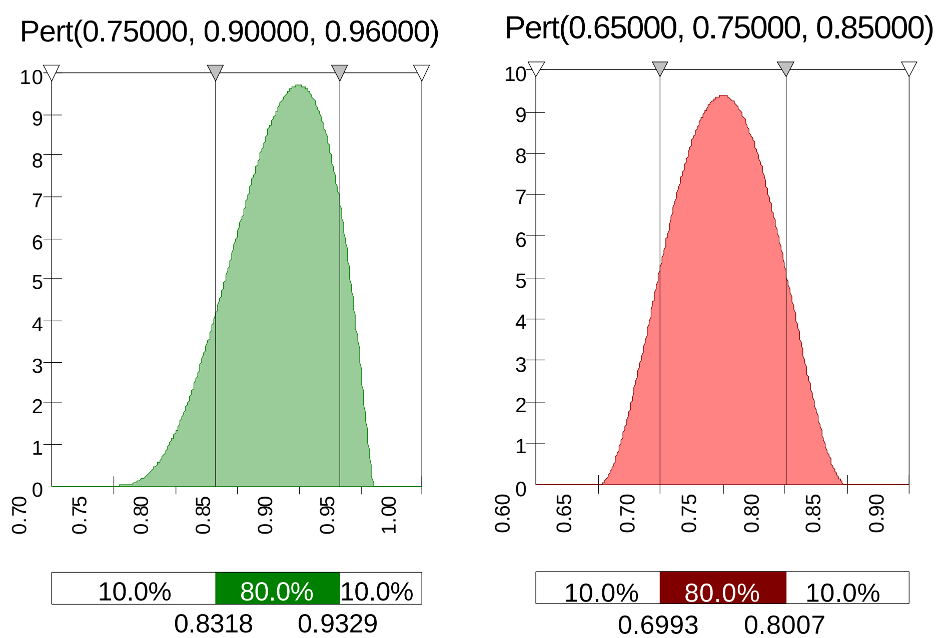



**Figure 4-4 North Amethyst N:G Distributions for Oil (Left) and Gas (Right) Legs**

### 4.2.4 Porosity Distribution

As note previously, porosity ranges are minor due primarily to the homogenous nature of this lower shoreface reservoir. The limited porosity range in the North Amethyst region assumes that where reservoir quality sands are present they exhibit the same characteristics as K-15 proper. Figure 4-5 illustrates the porosity distributions for North Amethyst.

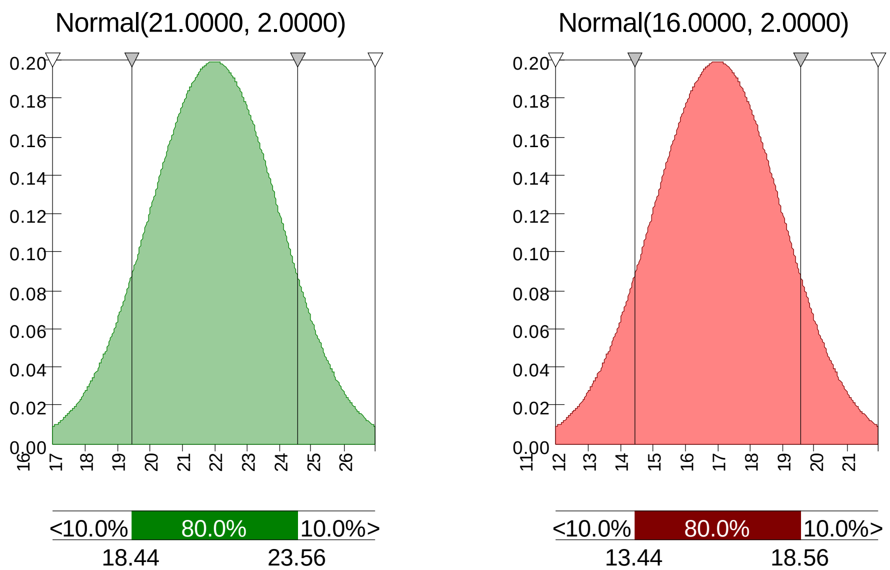



**Figure 4-5 North Amethyst Porosity Distributions for Oil (Left) and Gas (Right) Legs.**

### 4.2.5 Water Saturation Distribution

The water saturation data used to define the distribution was derived from the recently obtained K-15 core plug data. Every fifth core plug sample underwent 'Dean-Stark' analysis for accurate water saturations that were then tied to the petrophysical analysis. Figure 4-6 illustrates the distribution inputs used in the @RISK simulation.

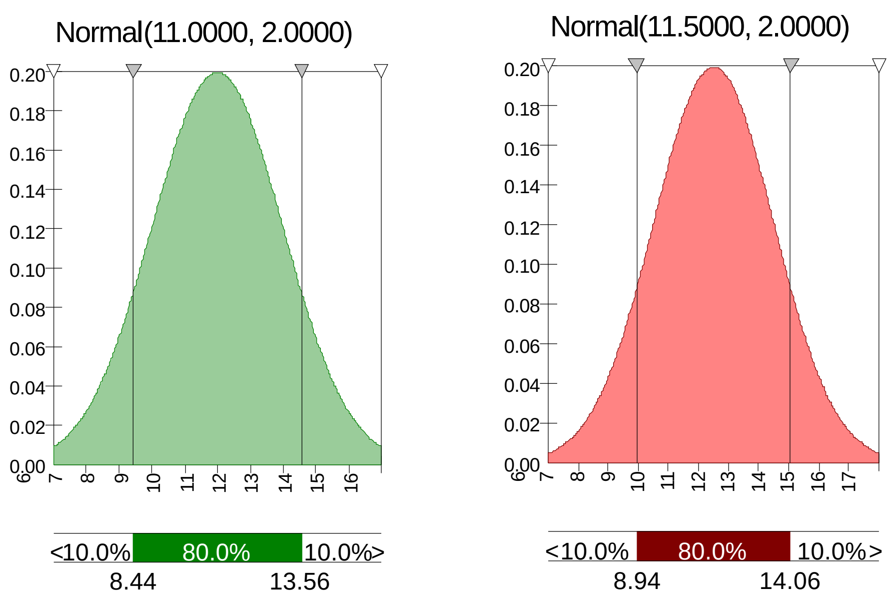



**Figure 4-6 North Amethyst Sw Distributions for Oil (Left) and Gas (Right) Legs**

### 4.2.6 Formation Volume Factor

The FVF distribution used in the North Amethyst @RISK simulation was derived from sample and analyses from K-15 (Figure 4-7). The resultant (final documentation pending) FVF is 1.27.

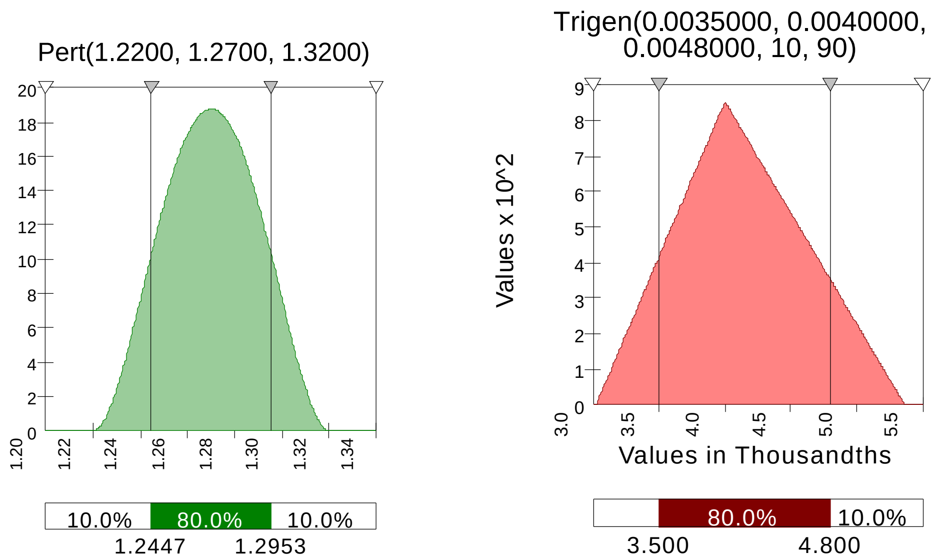



**Figure 4-7 North Amethyst FVF Distributions for Oil (Left) and Gas (Right) legs**

### 4.2.7 Correlations in @RISK Simulation

A negative correlation (-0.55) was applied to porosity and Sw. Since a single fault block was used no correlation was required between different volumetric regions. No other correlations were applied in this assessment.

## 4.3 Oil Resource Estimates

### 4.3.1 Calculated Oil Resources

Using the distributions defined in the previous section, a @RISK simulation was run with 7,000 iterations of the oil-in-place calculation. Figure 4-8 is a cumulative ascending plot illustrating the distribution of North Amethyst oil-in-place.

The probabilistic resource estimate for the main North Amethyst field has a P50 resource number of 40.8 $e^6m^3$ (256.75 MMbbls) of oil-in-place. The base case deterministic oil-in-place (OOIP) is 40.8 $e^6m^3$ (256.8 MMbbls; P50) for the full North Amethyst assessment.

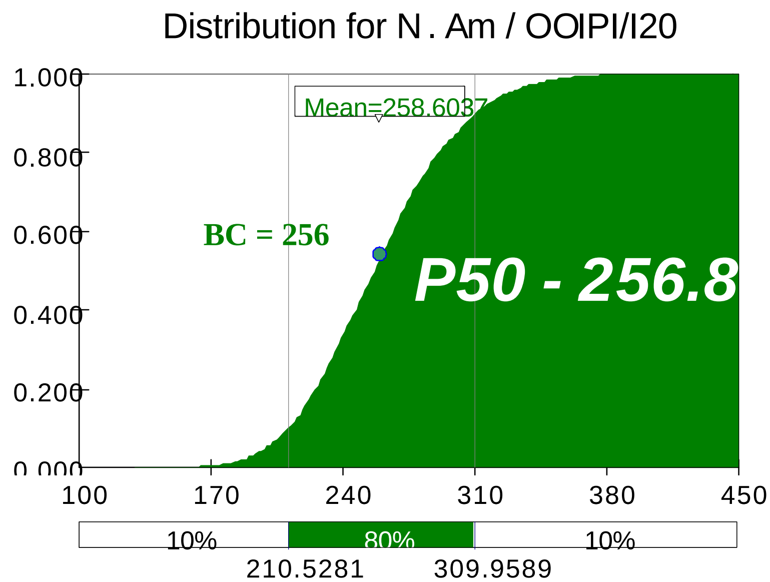



**Figure 4-8 North Amethyst Oil in Place Distribution**

### 4.3.2 Sensitivity Analysis

Given the expected range of rock volume (based on lateral depth changes and no well control) the North Amethyst oil in-place analysis is highly sensitive to this parameter (Figure 4-9). Net-to-gross and porosity are also key sensitivities to the OOIP as the uncertainty ranges for these inputs are variable. Final core plug analyses and further drilling in the region will assist in defining and tightening the ranges for the input data. There is virtually no impact from changes in adjacent blocks in this study, due primarily to a consistent depositional environment for all blocks.

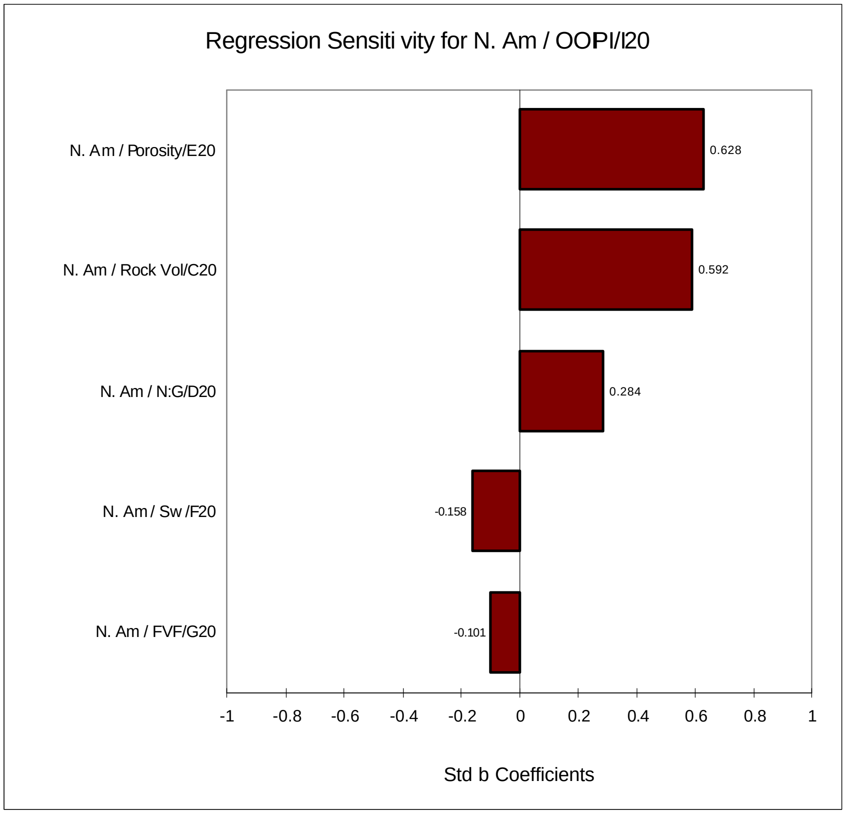



**Figure 4-9 North Amethyst OOIP sensitivity analysis (from @RISK).**

### 4.3.3 Solution Gas

The solution gas-oil ratio (Rs) has been updated for the K-15 results and used to calculate the solution gas resources expected over the North Amethyst field. The Rs ranges from 97 to 111 with a most likely of 104 $m^3$ per standard $m^3$. As with the oil-in-place, the solution gas was probabilistically modeled in @RISK. Figure 4-10 illustrates the solution gas distribution (in bcf).

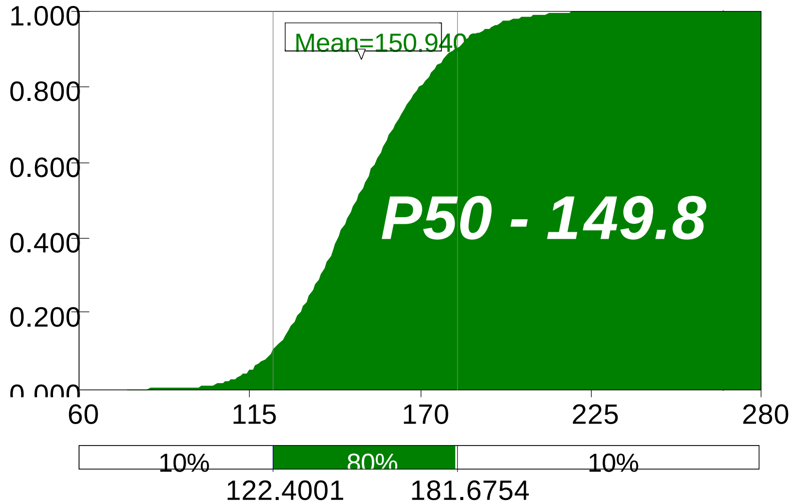



**Figure 4-10 North Amethyst Solution Gas Distribution (bcf)**

## 4.4 Gas Resource Estimates

### 4.4.1 Calculated Gas Resources

The in-place gas (not including solution gas) for the North Amethyst field was simulated in @RISK, with the results illustrated in Figure 4-11. The probabilistic resource estimate for the main North Amethyst field has a P50 resource number of 4.4 $e^9m^3$ (155.0 bcf) of gas-in-place. The base case deterministic gas-in-place (OGIP) is 4.2 $e^9m^3$ (149 bcf - P43) for the full North Amethyst assessment.

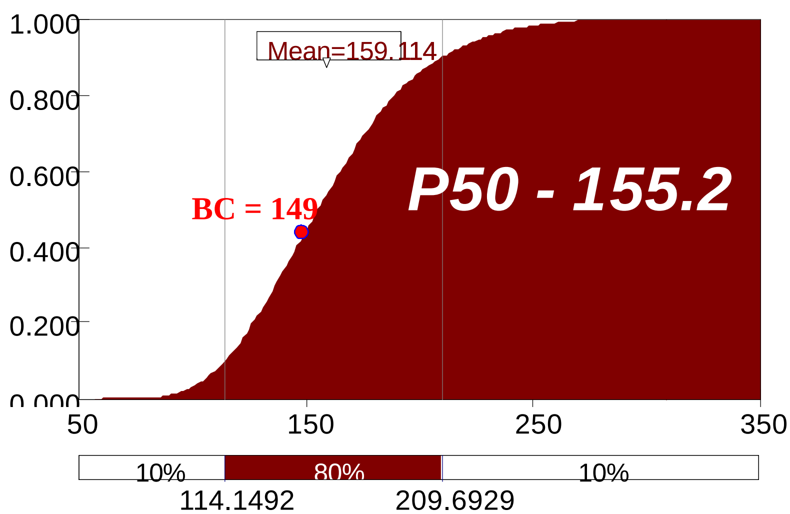



**Figure 4-11 North Amethyst Gas in Place Distribution (bcf)**

### 4.4.2 Sensitivity Analysis

Given the expected range of rock volume (based on lateral depth changes and no well control) the North Amethyst gas in-place analysis is highly sensitive to this parameter (Figure 4-12). Net-to-gross and porosity are also key sensitivities to the OGIP as the uncertainty ranges for these inputs are variable. Final core plug analyses and further drilling in the region will assist in defining and tightening the ranges for the input data. There is virtually no impact from adjacent blocks in this study, due primarily to a consistent depositional environment for all blocks.

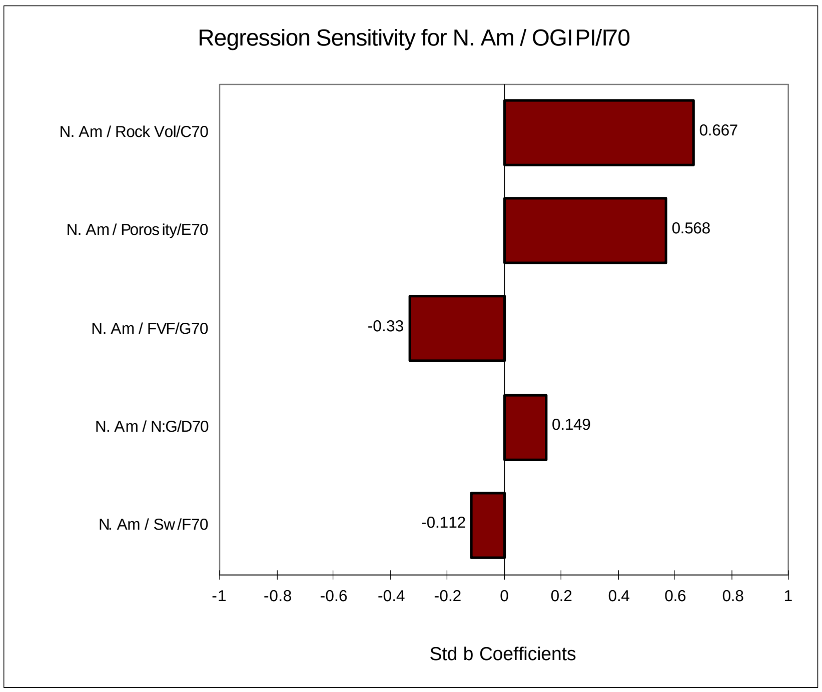



**Figure 4-12 North Amethyst OGIP Sensitivity Analysis**

### 4.4.3 Associated Liquids

The associated liquids for the North Amethyst field are based on the main White Rose development liquids ratio. The probabilistic distribution for the in-place associated liquids in the gas cap is illustrated in Figure 4-13.

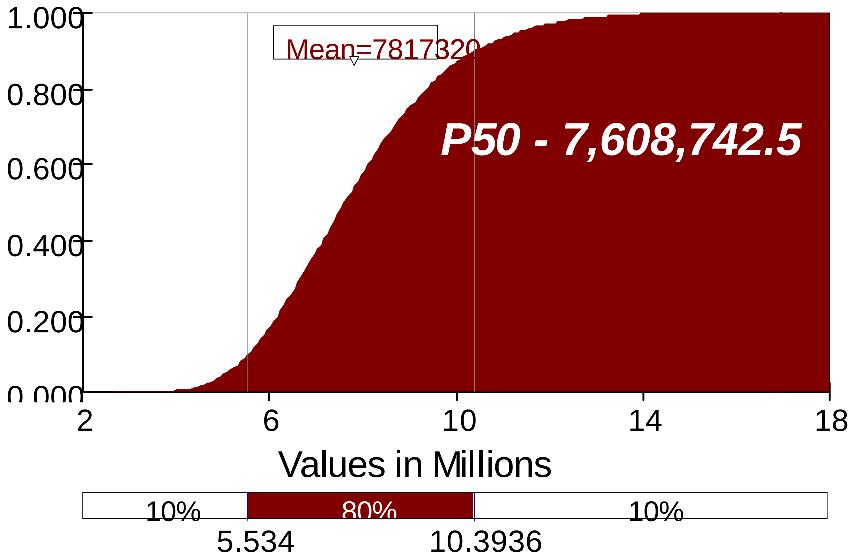



**Figure 4-13 North Amethyst Associated Liquids in the Gas Leg (bbls).**

## 4.5 Probabilistic Reserves, North Amethyst Field

### 4.5.1 Base Recovery Factor

Base recovery factors have been derived from simulation results. In past studies, recovery factors were assigned, in some cases, on a block-by-block basis. Current understanding of the reservoir supports a single distribution to represent the entire North Amethyst recovery factor range.

## 4.6 Reserve Estimates

### 4.6.1 Reserve Calculations

Using the updated recovery factors for oil and gas for the North Amethyst region, the recoverable portion of the in-place volumes was defined as a distribution. Given the delineation nature of the North Amethyst field, it was treated as one large macro-block, with no meso-scale fault blocks defined. The P50 recoverable oil is 70 MMbbls.

### 4.6.2 Sensitivity Analysis

As indicated in Figure 4-14, the key parameters affecting the recoverable oil recovery for North Amethyst are recovery factor (RF), porosity, BRV, and net-to-gross in decreasing order of impact. Given that the well control over this region is sparse and there are no dynamic data, the wide ranges on RF have a strong effect on recoverable volumes.

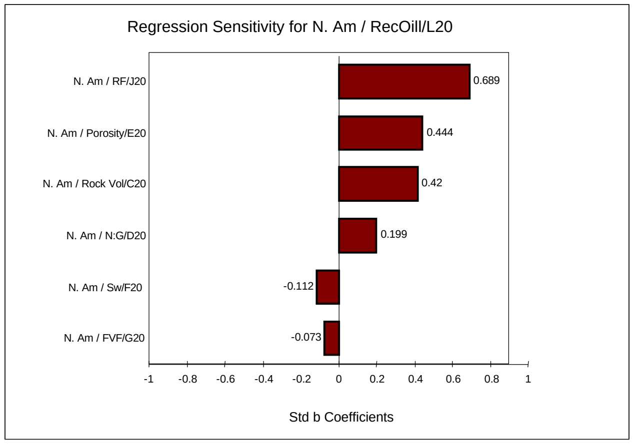



**Figure 4-14 Sensitivity Analysis for North Amethyst Recoverable Oil**

# 5.0 Facilities Design Criteria

## 5.1 Regulations, Codes and Standards

The facilities will be designed such that they comply with codes and standards, and regulatory requirements outlined in the following sub-sections.

### 5.1.1 Codes and Standards

Engineering and design practices will be common across the existing White Rose Development and all designs will conform to the codes and standards referenced in the legislation and/or appropriate Canadian standards. Generally accepted international standards, such as ANSI / ASME specifications, International Standards Organization (ISO) standards and American Petroleum Institute (API) recommended practices, will be applied as appropriate and in cases where they are considered equal to or exceed the requirements of the Canadian equivalent.

### 5.1.2 Regulatory Requirements

The installations will conform to the requirements of the following Canadian Federal and Provincial regulations that include, but are not limited to:

- Canada-Newfoundland Atlantic Accord Implementation Act (S.C. 1987, c.3);
- Canada-Newfoundland and Labrador Accord Implementation Newfoundland and Labrador Act (R.S.N.L. 1990, c. C-2).
- Newfoundland Offshore Certificate of Fitness Regulations 1995 (SOR/95-100);

- Newfoundland Offshore Area Petroleum Production and Conservation Regulations 1995 (SOR/95-103);
- Newfoundland Offshore Petroleum Installations Regulations 1995 (SOR/95-104);
- Draft Newfoundland Petroleum Occupational Safety and Health Regulations (posted on CNLOPB website on May 3, 2004);
- Newfoundland Offshore Petroleum Drilling Regulations 1993 (SOR/93-23);
- Canada Shipping Act (R.S., 1985, c. S-9);
- Offshore Waste Treatment Guidelines (August 2002); and
- Newfoundland Offshore Area Guidelines for Drilling Equipment (March 1993).

## 5.2 Overall Design Requirements

The facilities design will meet the following additional requirements:

### 5.2.1 Fatigue

Target fatigue life for subsea equipment will be in accordance with the regulations listed in Section 5.1.2 and the requirements of the American Society of Mechanical Engineers (ASME), API, Det Norkse Veritas (DNV) and Canadian Standards Association (CSA) guidelines and practices.

### 5.2.2 Design Life Requirements

The subsea installations will be designed for a 20-year minimum service life.

### 5.2.3 Cathodic Protection

Cathodic protection systems will be sourced and used for protection of subsea equipment.

### 5.2.4 Production Testing

Husky intends to conduct a design review of the use of subsea multi-phase flow meters in the design of the NADC. This technology will be considered for use in conjunction with the existing test separation facilities as a means of conducting well testing and allocation on a well/ drill centre basis. Whenever well testing is not ongoing, it is anticipated that the second line will continue to be used for production to optimize production flow and mitigate wax formation in the line.

#### 5.2.5 Hydrogen Sulfide Potential

The subsea system surfaces exposed to produced fluids will be designed for sour service according to NACE, MR-01-75, consistent with the present White Rose design and operating philosophies.

### 5.3 Environmental Criteria

The facilities design will utilize the same environmental criteria developed during the initial White Rose Development including data on wind, waves, currents, ice, seismic, and seawater properties and ambient temperatures.

As part of the current environmental effects monitoring (EEM) program, baseline environmental data for the North Amethyst area will be collected prior to drilling activities in 2008. The EEM program will be reviewed to determine required changes to design as a result of development of an additional drill centre.

Development of the North Amethyst Satellite Tie-back will comply with all applicable government legislation, corporate policy, industry standards, existing Husky procedures, and best practices. Appropriate plans/work will be completed to address any specific environmental concerns. The environmental effects of developing the North Amethyst Satellite Tie-back were assessed in the *Husky White Rose Development Project: New Drill Centre Construction and Operations Program Environmental Assessment* (Husky Document No. WR-HSE-RP-4003) and the *Husky White Rose Development Project: New Drill Centre Construction and Operations Program Environmental Assessment Addendum* (Husky Document No. WR-HSE-RP-0167), approved April 19, 2007.

### 5.4 Quality Assurance and Quality Control

Quality assurance and quality control will be achieved utilizing existing processes for similar White Rose activities.

### 5.5 Certification

Certifying Authority (CA) services will include activities during design, fabrication, installation, and commissioning as required for activities related to the North Amethyst Satellite Tie-back.

### 5.6 Decommissioning and Abandonment

The decommissioning and abandonment of the North Amethyst facilities will be in accordance with the established White Rose Decommissioning and Abandonment Plan.

# 6.0 Alternative Modes of Development

The following sections outline Husky's examination of the feasibility of alternative production and export systems for the North Amethyst field.

## 6.1 Concept Selection

An investigation was carried out by Husky to identify the alternatives and preferred options for development of the North Amethyst field. The first stage of the alternatives investigation reviewed previous work related to selection of the *SeaRose FPSO* for the White Rose Development.

For the initial White Rose Development concept selection, eight production concepts were evaluated based on economics, flexibility, feasibility, deliverability and Canada-Newfoundland and Labrador Benefits:

- steel FPSO facility;
- concrete FPSO facility;
- steel floating, production, drilling, storage, offloading (FPDSO) facility;
- concrete gravity-base structure (GBS);
- steel semi-submersible facility with and without integral storage;
- concrete semi-submersible facility;
- disconnectable concrete tension leg platform (TLP); and
- concrete barrier wall with floating production unit (FPU).

This process eliminated options that were not technically or economically feasible. Although the work was completed five years ago, the fundamental drivers for the decisions have not changed. These drivers relate to relative levels of cost and effort, and although absolute values have altered, the relative rankings remain the same.

Taking into account this previous work, Husky examined two alternative concepts for development of the North Amethyst field:

- A subsea tie-back system to the existing *SeaRose FPSO* facility
- A subsea system to a greenfield steel ship-shaped FPSO facility.

## 6.2 Production System Alternatives Considered

### 6.2.1 Subsea Tie-Back to *SeaRose FPSO*

The subsea tie-back to the *SeaRose* will consist of templates, manifolds, flowlines, umbilicals and risers tied directly back to the facility or back to the facility via existing infrastructure (i.e., existing White Rose drill centres). The main method of iceberg scour protection for wellhead equipment, trees and manifolds will be a dredged glory hole at a strategic location to optimize well placement for production.

### 6.2.2 Subsea System to Greenfield FPSO Facility

The alternative method of developing North Amethyst that was considered comprised a tie-back to a standalone greenfield FPSO facility. This alternative would be very similar to the existing White Rose Development although the vessel would likely be smaller than the *SeaRose* with one drill centre for production and tied into the existing Northern Drill Centre (NDC) for gas injection.

Similar to the *SeaRose*, the new FPSO would be moored using a geo-stationary turret, which is anchored to the seabed. The turret mooring would be disconnectable so that the FPSO could move from station to avoid icebergs. The functional characteristics of the turret would be similar to the *SeaRose* vessel.

The subsea solution for the floating production facility would be the same as for the existing White Rose Development, consisting of templates, manifolds, flowlines, umbilicals and risers. A glory hole would protect the subsea wellhead components.

Also similar to the *SeaRose*, production facilities would be mounted on raised supports above the vessel deck. Reservoir fluids pass from subsea production wells, via flowlines and risers up into the turret and then to the production facilities. Produced oil would be stored in the vessel cargo tanks and periodically offloaded on to a shuttle tanker via an offloading hose.

The processing requirements would likely be based upon a single train and not require any unconventional facilities. The oil would be stabilized in a conventional separation train and de-watered prior to rundown. Produced gas would be compressed for re-injection using a multi-stage compression train.

If the NDC was used for gas injection, a subsea structure would be installed to accommodate tie in of a new flowline and umbilical to the existing NDC flowline and control systems, currently controlled from the *SeaRose*.

## 6.3 Investigations into the Greenfield FPSO Alternative

To better understand the feasibility of the new FPSO alternative, an investigation was conducted to review procurement options. Consideration was given to current market conditions for shipyard construction, and for the design, construction and installation of topsides and turret mooring systems. The following sections outline the results of that investigation.

### 6.3.1 FPSO Options

Two potential FPSO facility options exist:

a) Near sister ship to *SeaRos*e, using similar production throughputs, and with enhancements based on lessons learned from *SeaRose* operation.

b) Smaller facility to address lower production scenarios i.e., 60,000 to 80,000 bbl/day production and possibly a reduced storage capacity (circa 600,000 bbls).

Both options could utilize either a new build or a converted tanker for the hull. The most likely scenario is that the larger facility would utilize a new build hull, as it would prove difficult to find an existing hull of sufficient size, quality, strength and design life to meet project needs. For the smaller facility, conversion candidates that meet the required specifications are more readily available. Table 6-1 outlines the relative positive and negative aspects of a new build FPSO versus a tanker conversion.

**Table 6-1 New Build vs. Tanker Conversion**

| New Build | | Tanker Conversion | |
|---|---|---|---|
| **Positive Aspects** | **Negative Aspects** | **Positive Aspects** | **Negative Aspects** |
| Design flexibility | Longer procurement (design/build cycle) | Shorter procurement cycle | Fixed hull configuration |
| Wider range of configuration options | Relatively high cost | Lower cost | Unknowns with respect to start point/condition |
| Material selection options | | | Challenging upgrade requirements (structure and systems) |
| Clear compliance requirements | | | Challenging compliance requirements |
| Incorporate structural enhancements | | | Scope definition will be |

| | | | |
|---|---|---|---|
| /integration | | | high risk |
| Optimisation of marine systems | | | Steel quality/grade issues |
| Pre-planned interface systems | | | |
| Enhancements for access, inspection & maintenance | | | |

Another option for the smaller unit would be to consider redeployment of an existing unit on either a lease or a purchase basis. There were a small number of existing units identified which could be available for redeployment from areas such as the North Sea (UK and Norway). These units would require varying levels of upgrade and refurbishment. The availability and suitability of such units would depend on:

- near proximity of the vessel's specification with required functional requirements;
- suitability of the vessel hull to meet the low design temperature requirements for Atlantic Canada which demands a very high grade of steel construction;
- suitability of the vessel to meet requirements related to green water protection and survival conditions under the 100 year storm criteria on the Grand Banks;
- suitability of the vessel to meet disconnection for ice avoidance requirements;
- suitability of the vessel to meet Canadian legislative regulations (i.e., double hull, etc);
- extent of modifications required to topsides processing and utilities equipment;
- availability of deck space and load capacity for additional equipment;
- degree to which the CoP (Cessation of Production) dates can be accurately forecast by the owners and existing charter holders; and
- current level of extension options available to existing charter holders.

### 6.3.2 Current FPSO Market Conditions

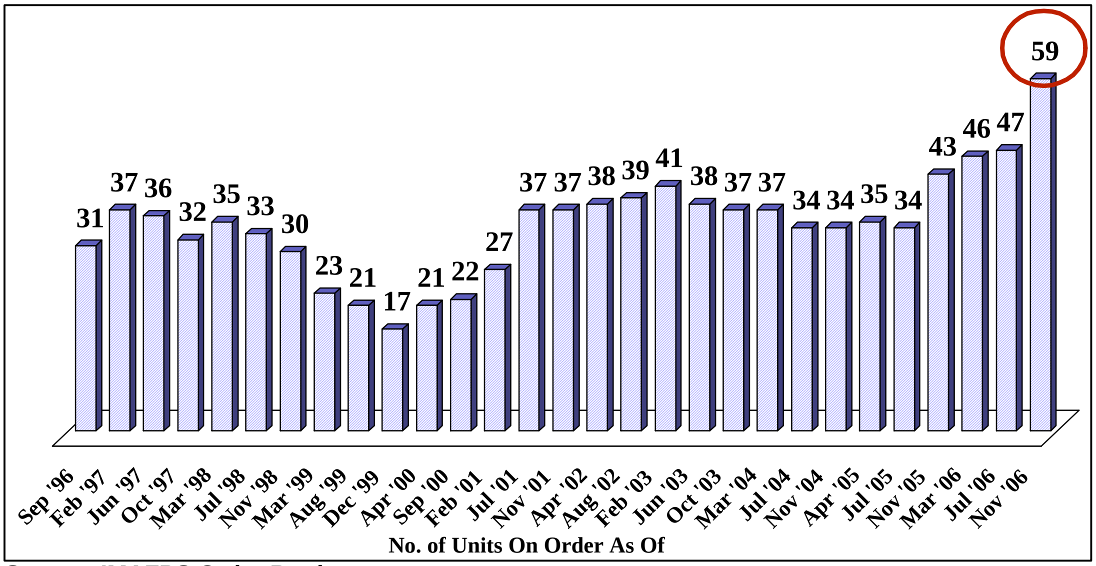
The offshore engineering and construction market has experienced a significant up-turn in activity over the last few years, driven by a combination of sustained high oil prices and resulting increased investor confidence.

Within the overall engineering and construction market, floating production systems have also seen an up-turn in activity, which has generated an all time record high level of activity and order backlogs.

The current order book for production and storage systems as of November 2006, based on data from International Maritime Associates Inc. (IMA) in Washington, DC, has the following floating production systems registered for order:

- two Tension Leg Platforms (new build);
- forty-three Floating Production Storage Offloading (FPSO) (14 new, 27 conversions, two redeployments);
- eight production semi-submersibles (new build);
- four production spars (new build);
- one production barge (new build);
- one floating production unit (conversion);
- one Mobile Offshore Production Unit (conversion); and
- five Floating Storage Offloading (FSO) vessels (one new build, four conversions).

Figure 6-1 shows the current and historical Floating, Production, Storage (FPS) Order Book.



**Source: IMAFPS Order Book**

**Figure 6-1 Current and Historical FPS Orders**

The consequences of these general market conditions include:

- the FPSO order backlog is at an all time high at 70% above the 10 year average (1996-2006);
- the supply side for equipment and services is currently operating at overcapacity with lead times in many cases doubling or tripling so that even stock items are now wait listed
- long lead times for new hull construction slots (currently circa three to four years from the time of order, depending on hull type and specification);
- longer lead times for key equipment items (e.g. valves, high specification materials, power generators, pumps);
- an industry-wide shortage of experienced people in engineering, project management and construction;
- competition with other industries and infrastructure projects for resources (e.g. onshore petrochemicals, oil sands projects); and
- contractor focus on lowering their commercial project execution risk.

The impact of these conditions on the specific FPSO market includes:

- Established FPSO contractors have solid order backlogs and can afford to be selective about the contracts they pursue to ensure best risk/return opportunities.

- If a new hull is required then early commitment to a hull construction slot is required to meet hull delivery within a three to four year window.

- There are many new market entrants into the sector (particularly for contractor owned units) and many units are being built speculatively. The specifications of these units are not generally suited to Atlantic Canada and ice presence.

- Topsides Engineering, Procurement and Construction (EPC) contractors have high workloads in most areas and are looking for contracts with no risk (i.e. most will only take on reimbursable or target price contracts rather than lump sum risk for EPC contracts).

- Most Korean shipyards are willing to take on full EPC responsibility using traditional Engineering and Construction contractors as sub-contractors.

Currently shipyards are also enjoying a market which is at or near all time record levels of activity. This is being driven mainly by a dramatic upturn in demand in LNG vessels, oil tankers and bulk carriers. This, in turn, has lead to a dramatic increase in shipyard prices and a shortage of hull slots leading to long lead times for construction.

The reasons for these high prices include:

- increase in the cost of Asian steel to that of European levels;

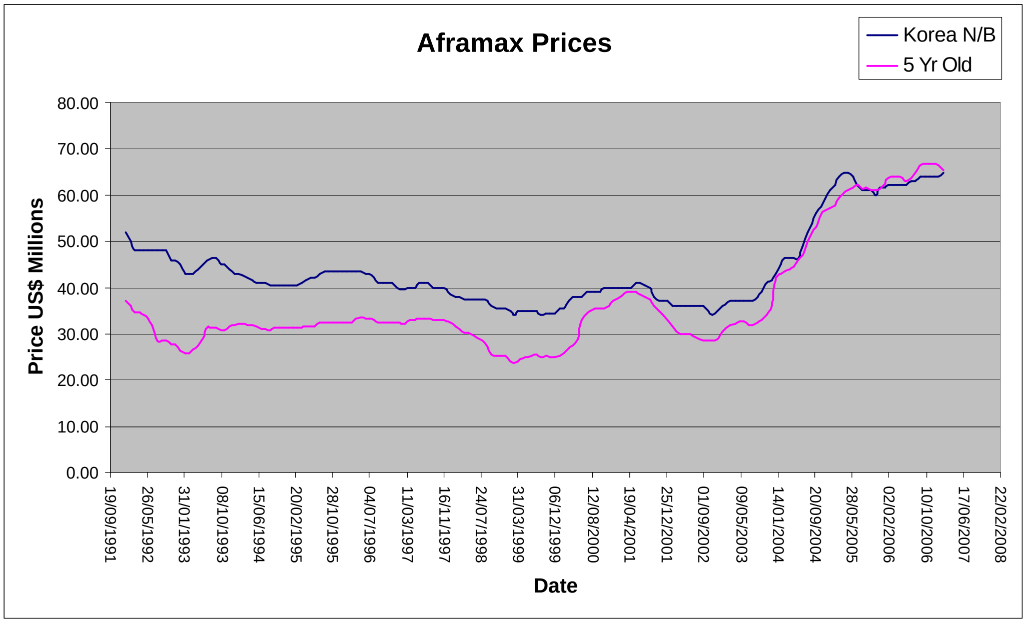
- increase in the cost of main vessel equipment such as pumps and generators;

- changes in currency exchange rates (Won to Euro and $US ); and

- increases in shipyard margins as the owners are able to increase their profit margins in line with the high market activity.

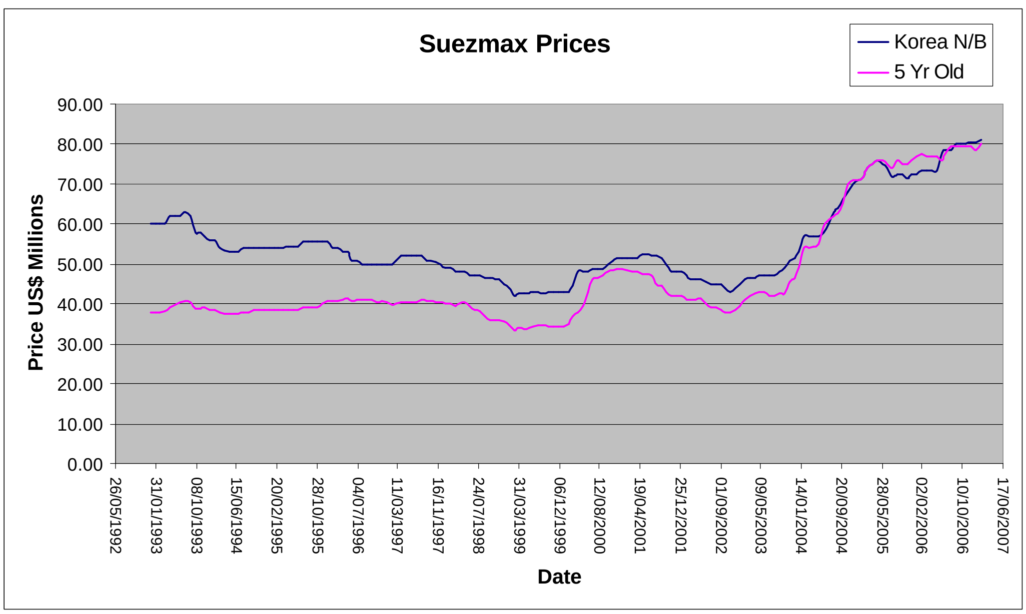
Price comparisons for Aframax and SuezMax tankers over time are shown in Figures 6-2 and 6-3, respectively.

The increase in demand since early 2005 has driven the price of the new build hulls up by 100% and reduced the margin between a new build and a five year old unit to close to nothing. This demonstrates that demand has far outstripped supply capacity and that factors such as condition or specification have very little influence in the out turn cost.




**Source SSY London**

**Figure 6-2 AfraMax Tanker Prices - Korean New Build & Five Year Old**




**Source SSY London**

**Figure 6-3 SuezMax Prices - Korean New Build & Five Year Old**

### 6.3.3 Base Case FPSO Alternative

Taking into account current market conditions and expected functional requirements, the FPSO alternative investigated for the North Amethyst field was redeployment of an existing unit with circa 600,000 bbls storage capacity as described below. These specifications represent generic facilities expected to match development requirements. However, it should be noted that any vessel redeployed to Newfoundland and Labrador would require re-fitting to meet all regulatory and Husky standards.

**Hull**

- Aframax sized – Double hull – fully segregated cargo and ballast
- Ice strengthened (structure to Ice Class)
- Accommodation for 100 persons (maximum)
- 300,000 - 600,000 bbls storage
- Self propelled with heading control facility – possibly multiple azimuth thrusters

**Turret/Mooring System**

- Moored by internal disconnectable turret mooring system
- 8 to10 risers

**Topsides**

- Oil production capacity of 60,000 to 80,000 bbl/day
- Liquids handling capacity of 125,000 to 165,000 bbl/day
- Water injection capacity of 165,000 to 220,000 bbl/day
- Gas compression capacity of 80 to 105 mmscf/day
- Tanker export @ <0.5%BS&W <12RVP

This alternative was further investigated as the option would be less capital intensive and therefore more acceptable to potential contractors.

Based on the foregoing analysis, the alternative that was considered for development of North Amethyst was a converted tanker with new turret and topsides or a modified/upgraded existing unit. For the above alternative, it would be likely that the vessel would be procured on a lease (bare boat charter) basis.

### 6.3.4 Key Risks Identified

The following were identified as key issues in today's FPSO contractor market:

- Market activity in the FPSO sector is at an all time high with a record number of new units on order (i.e., Lloyds List 28-03-07 states "More than 60 floating production systems are currently on order and over 100 could be booked over the next five years").
- Long lead times for new hull construction exist because of high levels of activity within the shipbuilding market sector.
- Long lead times exist for many items of oilfield equipment because of high levels of development activity.
- There is a general shortage of suitably qualified and experienced project, engineering and construction resources throughout the oil and gas industry.
- Only a limited number of suitably experienced full service engineering and construction contractors are able to deliver a complete FPSO which significantly reduces the competition.
- There is a general shift away from lump sum EPC work (particularly in the area of topsides design and fabrication) and a move towards project execution based on a more segmented contracting strategy which reflects a fundamental shift of risk away from contractors to Operators/Owners.
- Competition between suitably qualified turret/mooring system vendors exists, although the number of independent turret vendors is declining due to mergers and acquisitions.

## 6.4 Development Alternatives Costs

Incremental capital and operating cost estimates on an annual basis for the two alternatives are presented in Table 6-2. Operating costs do not include crude transportation or decommissioning and abandonment.

**Table 6-2 Incremental Capital and Operating Cost**

| Year | Subsea Tie-Back to *SeaRose* (CAD $MM) | | | | Subsea System to Greenfield FPSO (CAD $MM) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | DRILLEX | CAPEX | OPEX | Total | DRILLEX | CAPEX | OPEX | Lease Payment | Total |
| 1 | 2 | 60 | | 62 | 2 | 26 | | | 29 |
| 2 | 245 | 115 | | 360 | 245 | 149 | | | 394 |
| 3 | 238 | 166 | | 404 | 238 | 176 | | | 414 |
| 4 | 259 | 201 | | 460 | 259 | 138 | | | 396 |
| 5 | | 1 | 10 | 11 | | 1 | 120 | 142 | 263 |
| 6 | | | 10 | 10 | | | 120 | 142 | 262 |
| 7 | | | 10 | 10 | | | 120 | 142 | 262 |
| 8 | | | 10 | 10 | | | 120 | 142 | 262 |
| 9 | | | 10 | 10 | | | 120 | 142 | 262 |
| 10 | | | 10 | 10 | | | 120 | 142 | 262 |
| **Total** | 744 | 544 | 60 | 1,347 | 744 | 491 | 720 | 852 | 2,806 |

Assumptions:

1. All CAPEX for the greenfield FPSO is absorbed in lease payment
2. Excludes transportation, decommissioning and abandonment costs, includes Insurance.
3. Tie-back to *SeaRose* costs include estimate for modifications to the FPSO.
4. OPEX related to subsea infrastructure remains constant as new equipment replaces abandoned items.
5. All costs in 2007 dollars
6. Assumes first five years of production only. Relative differences in cost would be maintained throughout the life of project.

The alternative of development of North Amethyst to a greenfield FPSO increases overall capital cost exposure due to the cost of building or acquiring an FPSO. If an FPSO is leased rather than owned than this financial arrangement would reduce CAPEX (any costs associated with the FPSO being absorbed in the lease payments). However, it would add OPEX due to the significant lease payments. The greenfield FPSO alternative does not increase recoverable reserves and therefore the additional cost must be justified on the time value of accelerated production. The greenfield FPSO alternative is not economic as it erodes Net Present Value (NPV) of the project.

## 6.5 Schedule for Development of Alternatives

The delivery times for the development alternatives considered are shown in Figures 6-4 and 6-5. Although the approval timeline shown is common for all alternatives under consideration, it is anticipated that a Greenfield FPSO would require substantial regulatory review which may add as much as another year to the schedule.

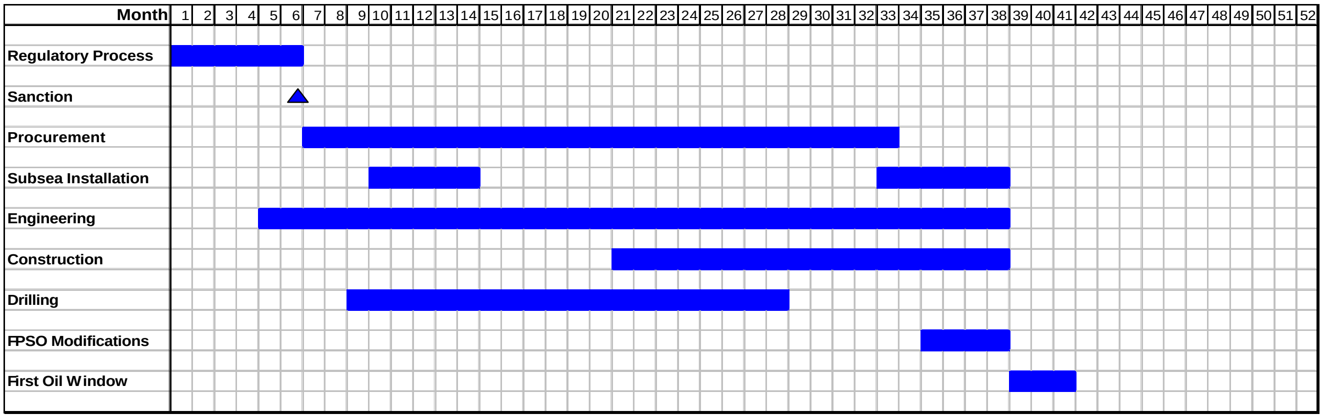



**Figure 6-4 Subsea Tie-Back to *SeaRose* FPSO Notional Timeline**

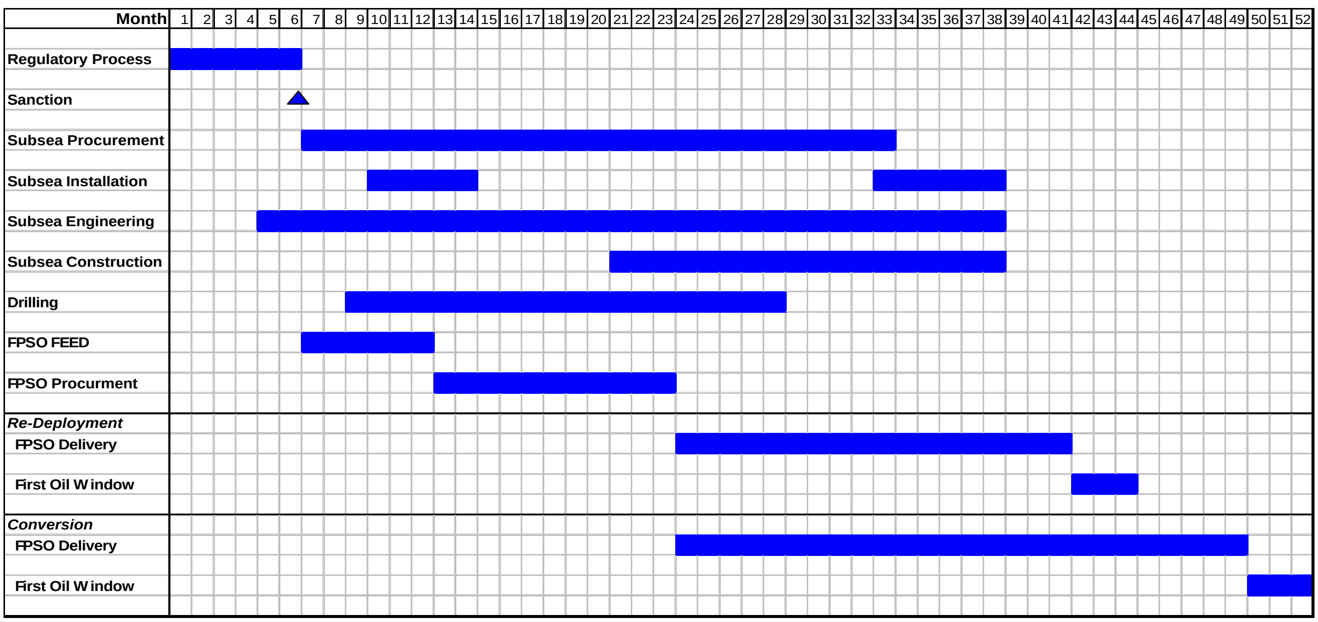



**Figure 6-5 Subsea System to Greenfield FPSO Notional Timeline**

Since much of the infrastructure is already in place, the subsea tie-back to the *SeaRose* can be brought into production more quickly.

## 6.6 Preferred Development Option

The investigation of the various production systems concluded that the preferred option for the North Amethyst field development should be based on a subsea tie-back system to the existing *SeaRose FPSO*. A greenfield FPSO for the North Amethyst field is not economically attractive, as all economic reserves can be developed through *SeaRose* with lower cost.

As is the practice in areas such as the North Sea and Gulf of Mexico (also West Africa, Brazil, Australia, and Indonesia), the use of a subsea tie-back system to an existing facility for processing capability is a cost effective way to develop small offshore oil and gas fields and it can extend the field life of existing production infrastructure. Historically, the largest fields have been developed first, mostly using steel and concrete platforms (mobile or fixed). However, to profitably exploit smaller fields, the trend is now towards subsea tie-back systems to the existing infrastructure of these larger fields. This is even more apparent in today's market conditions for new production facilities.

With the current base production profile for the White Rose Development, production on the *SeaRose* is expected to reach the end of plateau in 2008. As spare production capacity becomes available in *SeaRose*, a subsea tie-back will make use of this future capacity, thereby maximizing utilization of the existing infrastructure and lowering the threshold for small field developments. This development option is the more feasible alternative for North Amethyst.

# 7.0 Production and Export Systems

The production and transportation system that will be used for the North Amethyst Satellite Tie-back project will be the same as that employed for the existing White Rose Development. Specifically, oil produced from the new North Amethyst wells will be transferred through flowlines back to the *SeaRose* for processing and storage. The oil will be offloaded from the *SeaRose* to tankers for transport to market as is currently done with White Rose oil.

# 8.0 Construction and Installation

The North Amethyst Satellite Tie-back will be developed by excavating a new glory hole. Within the glory hole, one new drill centre, the NADC, is being considered with wells either tied back from the glory hole directly via new flow lines and new dedicated riser systems (Option A) (Figure 8-1) or via new flow lines to the existing subsea infrastructure (Option B) (Figures 8-2 and 8-3).

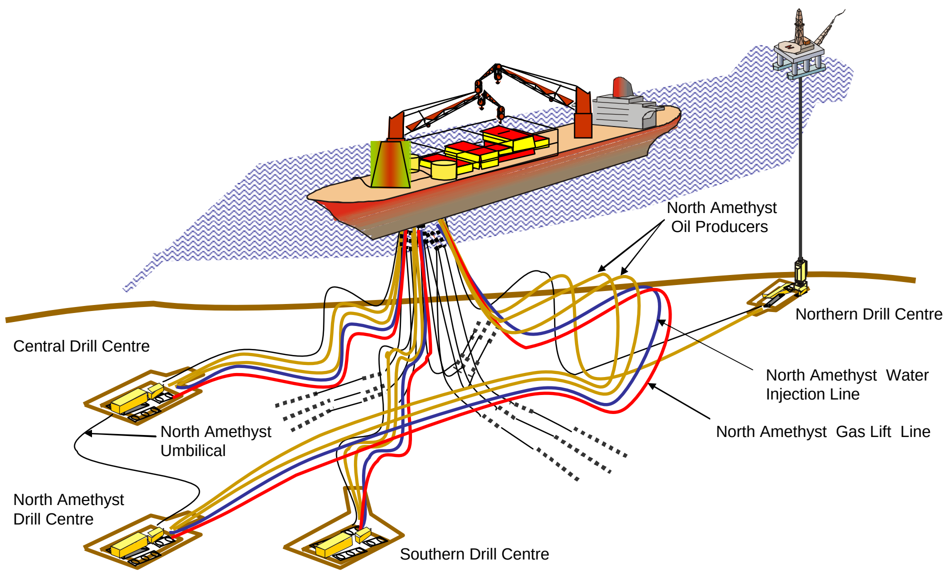



**Figure 8-1 Option A North Amethyst Satellite Tie-back (Directly to FPSO)**

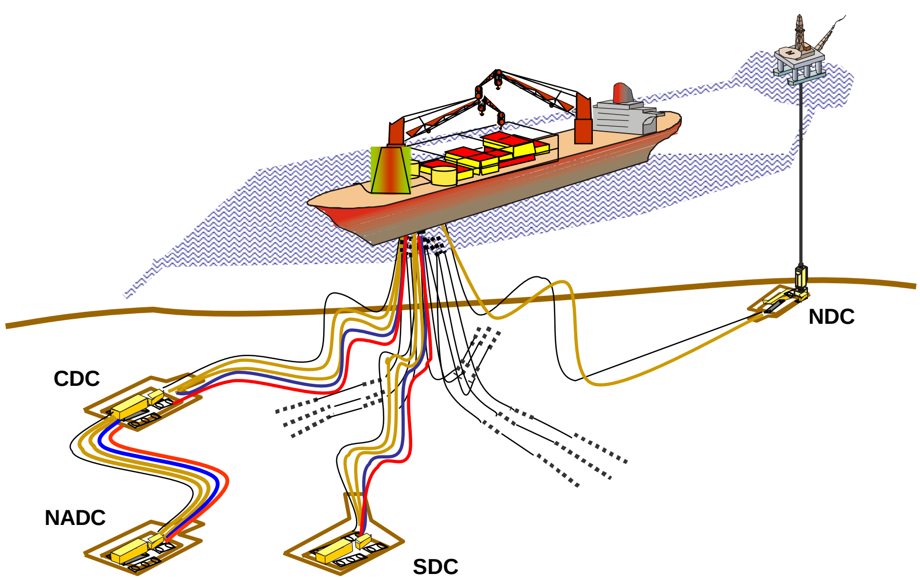



**Figure 8-2 Option B North Amethyst Satellite Tie-back Via Central Drill Centre**

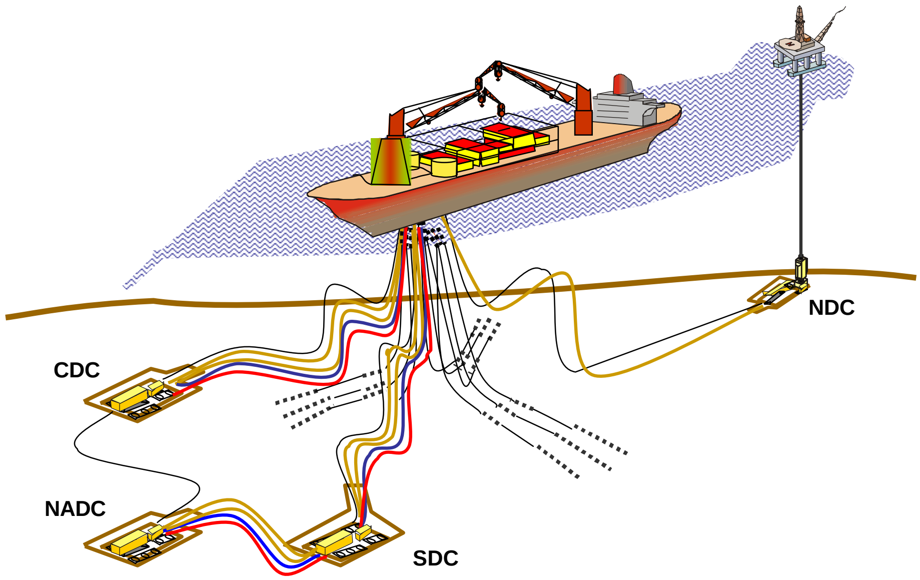



**Figure 8-3 Option B North Amethyst Tie-back Via Southern Drill Centre**

At this time, it is anticipated that the NADC will require seven to ten wells (four production wells and three to six water injection wells) with expansion capacity to sixteen wells. The glory hole for the North Amethyst Satellite Tie-back was constructed in 2007 following approval by the federal and provincial Ministers of Natural Resources.

## 8.1 Glory Hole Construction

Glory hole construction methods for the North Amethyst glory hole were mainly the same as those employed for development of the South Avalon Pool; that is, the glory hole was dredged using a trailing suction hopper dredging vessel. This type of dredger is a self-propelled ship which fills its hold or hopper during dredging while following a pre-set track. Dredged material was disposed of in the approved spoils disposal area used during construction of the glory holes for White Rose. However, the dimensions of the North Amethyst glory hole are different than those used for the White Rose project and from the dimensions proposed for the SWRX glory hole. The glory hole needed to accommodate the NADC was excavated to a measured depth of -9 to -11 metres below existing seabed level with a maximum "floor" dimension of 45 m by 80 m with 1 vertical by 3 horizontal graded sloped sides as required for stability and flowline ramps. The dimensions of the glory hole were modified to accommodate design evolution of the subsea equipment. Husky established through the course of preliminary FEED that critical clearances are required in some areas, particularly with respect to remotely operated vehicle (ROV) access during the life of field, installation tolerances for major equipment, and drilling and completions interface requirements.

Specifically:

- Glory hole design accommodates required fixed moored rig heading of 290º;
- Equipment layout in glory hole minimizes Dropped Object risk for MODU crane;
- Improved ROV access to all components; and
- Increased depth allows for sump to accommodate excess cement.

The glory hole configuration for North Amethyst is indicated in Figure 8-4.

**Figure 8-4 North Amethyst Glory Hole Layout**

## 8.2 Subsea Equipment Installation

The subsea facilities at North Amethyst will include all equipment necessary for the safe and efficient operation and control of the subsea wells and transportation of production and injection fluids between the wells and the *SeaRose*. It is expected that two 10" oil production flowlines, one 9" water injection flowline, and one 4.25" gas lift flowline will be routed from the NADC either directly back to the *SeaRose* FPSO via new flow lines and new dedicated riser systems (Option A) or via new flow lines to the existing subsea infrastructure (Option B).

Similar to the White Rose Development, flowlines for North Amethyst will be laid on the seafloor and will be insulated for temperature and flow assurance purposes. Although it is currently anticipated that the umbilical and flowlines utilized for North Amethyst are anticipated to be of similar design to those installed during initial development of White Rose, a rigid pipeline option is under evaluation by the FEED team. Verification of the exact flowline design and routing, and internal diameters and length will be determined during the FEED process.

For both Options A and B, an electro-hydraulic multiplex (EHMUX) umbilical is expected to be routed through the Central Drill Centre (CDC). This umbilical will extend from a new extension subsea distribution unit (SDU) in the CDC and terminate at the SDU in the NADC. The nominal umbilical length has been determined to be 7.0 km. To extend the CDC umbilical to the NADC, the CDC will require modifications including a new extension SDU and mounting base, a control jumper between the extension and existing SDUs, and a control jumper between the extension SDU and the umbilical termination assembly (UTA).

Subsea facilities will utilize the same design as previously used in the White Rose field. The following is the anticipated subsea equipment requirements for the NADC:

- 8 - two-slot TGB's;
- 7-10 - Permanent Guide Bases (PGB);
- 7-10 – XTrees (3 Production and 3-6 Water Injection) and assorted connections;
- 2 – Manifold support foundation (MSF) , each with 4 piles;
- 2-3 – Production Manifold modules;
- 2 – Water Injection Manifold modules;
- 3 – Insulated rigid spools;
- 3-6 – Un-insulated rigid spools;
- 2 – SDU bases (Anchored – Pile Driven, one per SDU);
- 2 – SDU's;

- 3 or 4 Gas Lift Jumpers;
- 1 – Subsea Umbilical Termination Assembly (UTA) – comes with umbilical;
- 7-10 - SDU to XTree control jumpers;
- 3 or 4 XTree to manifold control jumpers;
- 1 – UTA to SDU1 control jumper;
- 1 – SDU1 to SDU2 control jumper.

Procedures for installation of subsea facilities and subsequent operations for North Amethyst are anticipated to be similar to those currently employed for the initial phase of the White Rose Development. Subsea installation and connections work in the North Amethyst glory hole will require use of divers and ROV technology. Once installation is completed, the system will be fully tested prior to being brought into service through the *SeaRose* FPSO infrastructure.

Husky intends to conduct a design review of the use of subsea multi-phase flow meters in the design of the NADC. This technology will be considered for use in conjunction with the existing test separation facilities as a means of conducting well testing and allocation on a well/ drill centre basis. Whenever well testing is not ongoing, it is anticipated that the test line will continue to be used for production to optimize production flow and mitigate wax formation in the line. Round trip pigging of the production and test lines will be extended from the *SeaRose* FPSO to the NADC drill centre.

Iceberg protection measures applied to the current White Rose Development will also be applied to North Amethyst including placement of wellheads, Xmas trees and manifolds in glory holes, with the top of the equipment having a minimum clearance of 2 to 3 m below the seabed level and use of flowline and umbilical weak link technology. In addition to use of glory holes and weak link technology for subsea installations, active iceberg management will be employed. The *White Rose Ice Management Plan* (WR-DAC-PR-0003 D1) will be updated to include the new NADC drill centre.

Iceberg risk studies completed for White Rose include a *Glory Hole Iceberg Scour Risk Evaluation* (C-Core R-03-018-011) which identified glory hole design parameters that would minimize the risk of iceberg scour. The design of the new glory hole is consistent with the design parameters described in the evaluation. The study, *Iceberg Risk to Pipelines at White Rose* (C-Core 00-C45 V2), is currently being reviewed to confirm that the risk of damage to flowlines does not exceed Husky's Target Levels of Safety as a result of adding North Amethyst.

## 8.3 Drilling and Completions

It is anticipated that Drilling and Completions activities will be carried out using existing White Rose processes and systems. The North Amethyst Satellite Tie-back will utilize well templates and wellhead systems similar to those used on the White Rose Development. At this time it is anticipated that the NADC will require seven to 10 wells comprised of four production wells and three to six water injection wells with expansion capacity within the glory hole to 16 wells.

In general the North Amethyst well design and drilling operations programs will be based on experience from the White Rose Development. Synthetic-based muds will be used to drill the intermediate and production hole sections. Best available proven technology will continue to be utilized to minimize synthetic drill mud on cuttings. Advanced directional drilling tools and systems will continue to be used to drill the deviated and horizontal wells required to develop this region of the field.

Existing White Rose cementing practices will also be applied to North Amethyst. White Rose drilling practices employed to drill the conductor and surface hole sections will be applied to North Amethyst to mitigate the impact of drill cuttings and cement spillage into the glory hole. Specifically, Guar gum sweeps, cuttings transport systems and reduced excess cement will be used in conjunction with a modified template system.

The North Amethyst well completions will be designed to maximize well productivity while maintaining necessary standards of risk and well integrity. Intelligent water injection and production wells may be utilized for North Amethyst. Intelligent completion technology is required for the water injection wells to control injection profiles into two reservoir intervals. The control of flow would be from a variable interval control valve operated hydraulically from the subsea pod via the subsea umbilical. Final design of the drilling program and the North Amethyst wells will be addressed in the individual Approval to Drill a Well (ADW) applications. Details of the completion design and installation plan will be outlined in the individual completion programs.

Early samples collected from the North Amethyst reservoir indicated that risk of significant sand production might be higher than that defined in the original White Rose design specification. Subsequent detailed analysis indicated that sand production from North Amethyst is not expected to exceed the current White Rose design specification. However, further sensitivity analysis is continuing. At this time, no additional protection or monitoring equipment is planned for installation on the FPSO. However, sand detection capability may be incorporated into the subsea production system to further monitor sand production.

### 8.4 FPSO (Topsides/Turret) Modifications

Should Option A tie-back be selected, modifications to the *SeaRose* turret, buoy and topsides to accommodate the new flowlines and umbilical from the NADC will be required. The details of the *SeaRose* modifications for Option A are provided in the White Rose Development Plan Amendment (Husky Document No. SR-SRT-RP-0003) submitted concurrently with this document.

Should North Amethyst be tied back to *SeaRose* through existing infrastructure (Option B), there will still be a requirement for some minor modifications on the *SeaRose*, mainly in the area of chemical injection and storage, and controls software. These modifications would not require *SeaRose* to come to a shore-based facility.

### 8.5 Northern Drill Centre Expansion

Simulation modeling predicts a higher Gas Oil Ratio (GOR) over time. To accommodate the increased gas injection requirements for North Amethyst and any other future tie-backs, the two spare well slots (NG3 and NG4) in the NDC are available. Development of these wells was approved as part of the core White Rose Development. If the NDC is expanded to accommodate North Amethyst gas, details of the final design of the NDC wells would be addressed in the individual Approval to Drill a Well (ADW) applications. Details of the completion design and installation plan would be outlined in the individual completion programs.

## 9.0 Operations and Maintenance

Should North Amethyst be tied back directly to *SeaRose* (Option A), there will be a requirement to shut down production during installation and commissioning of the new NADC drill centre and for implementation of the FPSO modifications. Alternatively, if North Amethyst is tied back through existing infrastructure (Option B), onshore modifications to *SeaRose* will not be required. However, *SeaRose* may still be brought to shore to implement the modifications to increase produced water and gas handling capacity. A description of these potential modifications is included in *White Rose Development Plan Amendment SeaRose FPSO Modifications* (Husky Document No. SR-SRT-RP-0003), submitted concurrently with this document.

Should onshore modifications be required, the *SeaRose* will be taken off station and brought to a facility in Newfoundland. It is anticipated that the *SeaRose* would be at shore for a maximum of four months during which time there would be no production from the White Rose field. However, offshore subsea installation activities in the NADC would proceed during the period that the *SeaRose* is at shore. Following return of the *SeaRose* to the White Rose field, the NADC drill centre would be commissioned and brought on line.

The existing organizational structure (offshore and onshore) will not be impacted as a result of development of the North Amethyst Satellite Tie-back. The existing Operating and Maintenance Procedures will be reviewed and revised as required to include the operation and maintenance requirements of North Amethyst.

The Ice Management Plan will also be reviewed and updated or modified as required to reflect the additional “target” for icebergs as a result of the development of the satellite drill center. Logistics, Communications and Contingency Plans should not be impacted as a result of development of the North Amethyst Satellite Tie-back.

# 10.0 Safety Analysis

The *SeaRose FPSO* Safety Plan approved by the C-NLOPB details the approach to, and results of, the risk assessment process for the *SeaRose* FPSO. Activities associated with development of the North Amethyst Satellite Tie-back will utilize Husky’s formal safety assessment process. Existing Husky systems and processes for assessing risks of planned operations, modifications or changes will be used in assessing any identified risks related to the Tie-back. These processes include the Husky Management of Change Process and the Husky East Coast Risk Management Process. These processes will ensure that the risk profile of the projects tie-back to the *SeaRose* is not compromised and the Target Levels of Safety continue to be met.

A review of the impact of the North Amethyst Satellite Tie-back on safety studies and plans and the mitigation measures that will be implemented, has been submitted to the C-NLOPB as a separate report (Husky Document No. SR-HSE-RP-0003).

# 11.0 Development Costs

## 11.1 Capital Cost Estimates

This section discusses the capital cost estimates for glory hole development, subsea production systems, and the drilling/completions cost estimates for the North Amethyst Satellite Tie-back. All costs presented are in 2007 Canadian dollars.

### 11.1.1 Assumptions for Capital Cost Estimates

The capital cost estimates have been prepared under the following set of assumptions:

- The reservoir parameters for the North Amethyst reserves, technical basis, and scope of work are as described in this document.

- The tie-back will be executed in accordance with the management philosophies and schedule described in this document.

- All facilities, goods, and services will be acquired on a competitive basis in accordance with the approved Canada-Newfoundland and Labrador Benefits Plan.
- Regulatory approval and Project Sanction will be achieved in accordance with the timelines set out herein.

### 11.1.2 Capital Cost Estimates

The capital cost estimate for components of the North Amethyst Satellite Tie-back is in the range of approximately $1.3 billion (no OPEX included) for either option discussed in this Plan. Cost estimates for the components are as follows:

- Project Management and Engineering $74 M
- *SeaRose* Modifications $72 M
- Drilling and Completions (9 wells) $744 M
- Glory Hole Construction $36 M
- Subsea Production System $362 M

### 11.1.3 Operating Cost Implications

The North Amethyst Satellite Tie-back will not significantly increase White Rose operating costs. However, in addition to fixed OPEX, the addition of a new drill centre, additional wells, and new flowlines and umbilical will result in additional costs for inspection, maintenance and repairs.

Subsea inspections will increase proportionately in accordance with the count of drill centres and flowlines. Also, allowances must be made for well interventions and increased chemical usage due to the flow assurance challenges associated with the longer tie-back.

## 12.0 West White Rose Extension (WWRX)

Following drilling of the O-28Y well in the West Avalon Pool, it was estimated that this part of the White Rose field has recoverable oil resources of 120 million barrels on a P50 basis. At the present time Husky plans to develop this pool as a subsea tie-back to the *SeaRose*. Further delineation results, flow assurance studies and FEED, will determine the optimum flow line routings for the WWRX tie-back. Installation of WWRX subsea equipment will likely occur during the summer of 2010, concurrent with subsea installation at the NADC. A White Rose Development Plan Amendment for WWRX will be submitted in due course.

# 13.0 References Cited

N.R. Ainsworth, L.A. Riley and I.K. Sinclair. 2001. .A Mid-Cretaceous (Upper Barremian - Turonian) Lithostratigraphic and Biostratigraphic Framework for the Hibernia Oilfield Reservoir Sequence, Jeanne d'Arc Basin, Grand Banks of Newfoundland. In *Petroleum Resources and Reservoirs of the Grand Banks, Eastern Canadian Margin,* Edited by R.N. Hiscott and A.J. Pulham.

Armentrout, John M. 1999. Treatise of Petroleum Geology/Handbook of Petroleum Geology: Exploring for Oil and Gas Traps, Edited by Edward A. Beaumont and Norman H. Foster. Pages 4-1 — 4-123.

Boyd Exploration Consultants Limited. 1997. Final report of the R/V Airgun Reflection 3-D Seismic Program, White Rose, Cape Race and North Ben Nevis, and PGS Exploration Final Survey Report White Rose 3-D Survey.

# 14.0 Documents Used in Preparation of the Development Plan

- North Amethyst Subsea Handover Package (SR-S-93-U-RP-00018-001)
- White Rose Functional Specification (WR-ENG-SP-001).

# 15.0 Acronyms

| Term | Description |
|---|---|
| ADW | Approval to Drill a Well |
| API | American Petroleum Institute |
| ASME | American Society of Mechanical Engineers |
| bcf | billion cubic feet |
| Bbl/d | barrels per day |
| BN | Ben Nevis |
| BNA | Ben Nevis-Avalon |
| BRV | bulk rock volume |
| BS&W | base sediment and water |
| CA | Certifying Authority |
| CDC | Central Drill Centre |
| CMR | combinable magnetic resonance tool |
| C-NLOPB | Canada-Newfoundland and Labrador Offshore Petroleum Board |

| | |
|---|---|
| CSA | Canadian Standards Association |
| DA | Development Application |
| DGPS | Differential Global Positioning System |
| DNV | Det Norske Veritas |
| DST | drill stem test |
| EEM | environmental effects monitoring |
| EHMUX | electro-hydraulic multiplex umbilical |
| FA | facies associations |
| FEED | Front End Engineering Design |
| Fm | formation |
| FPSO | Floating Production, Storage and Offloading Facility |
| FVF | formation volume factor |
| GOR | gas oil ratio |
| GR | gamma ray |
| ISO | International Standards Organization |
| kPa | kilopascals |
| LWD | logging while drilling |
| Ma | million years |
| md | millidarcies |
| MDT | modular dynamic formation tester |
| MMbbls | million barrels |
| mmscf/d | million standard cubic feet per day |
| MODU | Mobile Offshore Drilling Unit |
| m/s | metres per second |
| mTVDss | metres true vertical depth subsea |
| NACE | National Association of Corrosion Engineers |
| NADC | North Amethyst Drill Centre |
| NDC | Northern Drill Centre |
| N:G | net to gross ratio |
| NPV | net present value |
| OGIP | original gas in place |
| OOIP | original oil in place |
| OWC | oil/water contact |
| PGB | permanent guide base |
| PVT | pressure, volume, temperature |
| Psi | pounds per square inch |

| | |
|---|---|
| ROV | remotely operated vehicle |
| Rs | solution gas-oil ratio |
| Rw | resistivity of water |
| RVP | Reid vapour pressure |
| s | seconds |
| SCAL | special core analysis |
| SDU | subsea distribution unit |
| SWRX | South White Rose Extension Tie-back |
| Sw | water saturation |
| TVD | true vertical depth |
| TGB | temporary guide base |
| UTA | umbilical termination assembly |
| VFP | vertical flow performance |
| WWRX | West White Rose Extension |
| XTree | Christmas (xmas) tree |

# Appendix A

# Vertical Interference Test and Mini-DST Interpretation

Husky Energy

Schlumberger

# MDT-VIT & MDT-Dual Packer

## Vertical Interference Test and mini-DST Interpretation

| | |
|---|---|
| Company | Husky Oil Operations Limited |
| Field | Whiterose |
| Well | North Amethyst K-15 |

| | | |
|---|---|---|
| Date Logged | Nov. 3, 2006 | By S. Thornhill, Smith, Khan |
| Date Processed | Feb. 20, 2006 | By Vinay K. Mishra |

| | |
|---|---|
| Remarks | MDT-VIT<br>Processed Interpretation<br>by Schlumberger DCS |

## 1. Objectives

MDT-VIT and mini-DST tests were conducted at three stations in the well K-12 with the following objectives.

1. Determine the horizontal and vertical permeability (Kh & Kv) of the tested layers.
2. Determine the vertical communication between the sink and observation probes.

## 2. Results and Conclusion

- Based on the three tests, reservoir permeability varies in the range of 155-450md.
- Ratio of vertical permeability to horizontal permeability is higher than 0.12
- All the tests indicated almost zero skin factor
- Mini DST was carried out using MDT Dual packer module.
- Interference Test (VIT) was carried out with MDT dual probes, set 2.44m apart and Packer-probes combination.
- Pump Out module of the tool was used to create pressure pulses in the formation.
- Interpretation results for the three tests are summarized in the tables below.

Table 1: Results for VIT at 2390.0 m

| Kh (md) | Kv (md) | Kh/Kv | Skin | Reservoir pressure at 2390m (kPa) |
|---|---|---|---|---|
| 450 | 70 | 0.16 | 0.0 | 23883.57 |

Table 2: Results for VIT at 2415.0 m

| Kh (md) | Kv (md) | Kh/Kv | Skin | Reservoir pressure at 2415m (kPa) |
|---|---|---|---|---|
| 302 | 42 | 0.14 | 0.0 | 24036.06 |

Table 3: Results for Dual Packer Mini-DST at 2400 m

| Kh (md) | Kv (md) | Kh/Kv | Skin | Reservoir pressure at 2400m (kPa) |
|---|---|---|---|---|
| 155 | 18 | 0.12 | 0.1 | 23953.35 |

## 3. Discussion

### VIT1 & VIT2

Vertical interference test was carried out by creating pressure pulses in the reservoir with the sink probe and pumpout followed by pressure measurements at both, the sink probe and the observation probes. Pressure pulses were created by pumping out fluid from the reservoir to the wellbore. For VIT1 and VIT2 the observation probe (also called vertical probe) was set 2.44 m above the sink probe for each of the tests.

The data quality looks quite good giving confidence in the results. For observation probes, strain gauge data were used due to their better stabilization. Both the tests indicate medium to high permeability reservoir. The model out matched well with the recorded data. Basic tool configuration with probe depths for VIT1 is shown in the **Figure 5 to Figure 8**. Tool configuration and interpretation plots for VIT2 are shown in the **Figure 9 to Figure 12**.

### Dual Packer Test (mini-DST)

In a separate MDT run Mini-DST was carried out using dual packer and pumpout modules of MDT. The distance between two packer elements is about one meter. Two single probes were also part of the tool string to record vertical interference test. In order to allow probe's contact with formation wall in presence of dual packer, the distance between packer and the probes were kept maximum.

Drawdown and build-up data was recorded with the dual packer module. In general the data quality looks good. During some part of the pumpout period, the pump was only pumping with pressure on one side causing build-up type of spikes. This might be due to filters plugging in the mud check valves of pumpout. Looking at the drawdown behavior when the pumpout data was normal, the pressure data was smoothed for the period pumpout was working in half cycle mode. This was achieved by removing the pressure spikes and averaging the rate over this period.

Model output plots from dual packer analysis are presented in the **Figure 13** to **Figure 18**. The build-up data indicate nice derivative curve. Probes data during this run indicate communication with the packer depth. The probes pressure data indicate high fluctuations, making it difficult to model. Qualitatively, it indicates average value of Kv/Kh more than 0.15 for the formation between 2400.0m and 2415.9m.

Interpretation of the VIT data was performed using Schlumberger software IPTT1.5. Based on openhole logs, single layer model was used in the analysis for all the tests. The input parameters used in the interpretation are presented in the **Table 4.**

**Table 4:** Input Parameters (Fluid/layer properties)

| DST/VIT Interpretation Input parameters Planning Data Sheet | | | |
|---|---|---|---|
| | | | |
| | | | |
| Company name | Husky Oil operations Ltd. | | |
| Well Name: | K-15 | | |
| Job date: | 27 Oct. 06 | | |
| Test type. | VIT 1 | VIT2 | DST-VIT3 |
| | | | |
| Depth (m) | **2415** | **2390** | **2400** |
| | | | |
| **Reservoir/Wellbore parameters** | | | |
| | | | |
| Rock Type | clean laminated sand | C.L.Sand | C.L.Sand |
| Formation boundaries | 22m (from 2398 to 2420) | 12m (from 2379 to 2391) | 22m (from 2398 to 2420) |
| | | | |
| Layer thickness | | | |
| Formation compressibility | 2.57 E-6 1/kPa | 2.57 E-6 1/kPa | 2.57 E-6 1/kPa |
| Porosity | 23% | 23 | 23 |
| Reservoir fluid type | oil | oil | oil |
| GOR | 100 m3/m3 | 100 m3/m3 | 100 m3/m3 |
| Oil FVF | 1.24 res m3/m3 | 1.24 res m3/m3 | 1.24 res m3/m3 |
| Viscosity | | | |
| Oil API density | 35.8 | 35.8 | 35.8 |
| Fluid compressibility | | | |
| Gas sp. Gr. | .7258 | .7258 | .7258 |
| Any additional information | | | |
| | | | |

**Figure 1:** Tool Diagram for VIT1 and VIT2

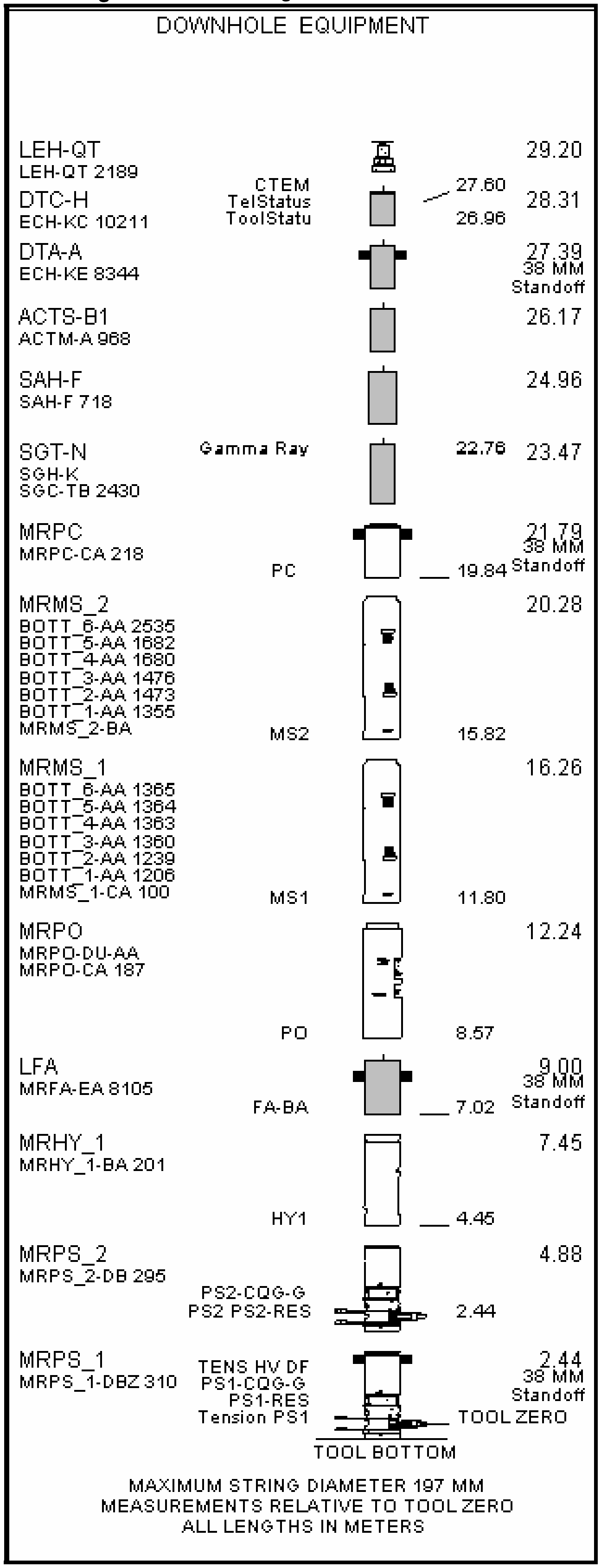


**Figure 2:** Tool Diagram for Dual Packer mini-DST

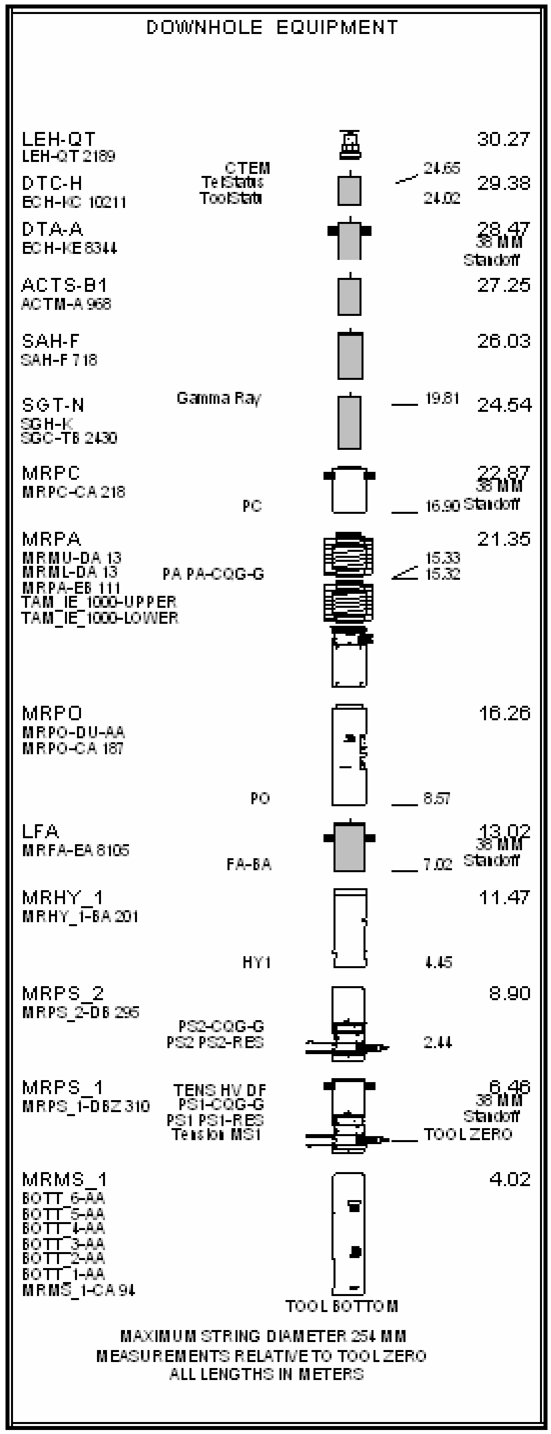


**Figure 3:** Well Schematic

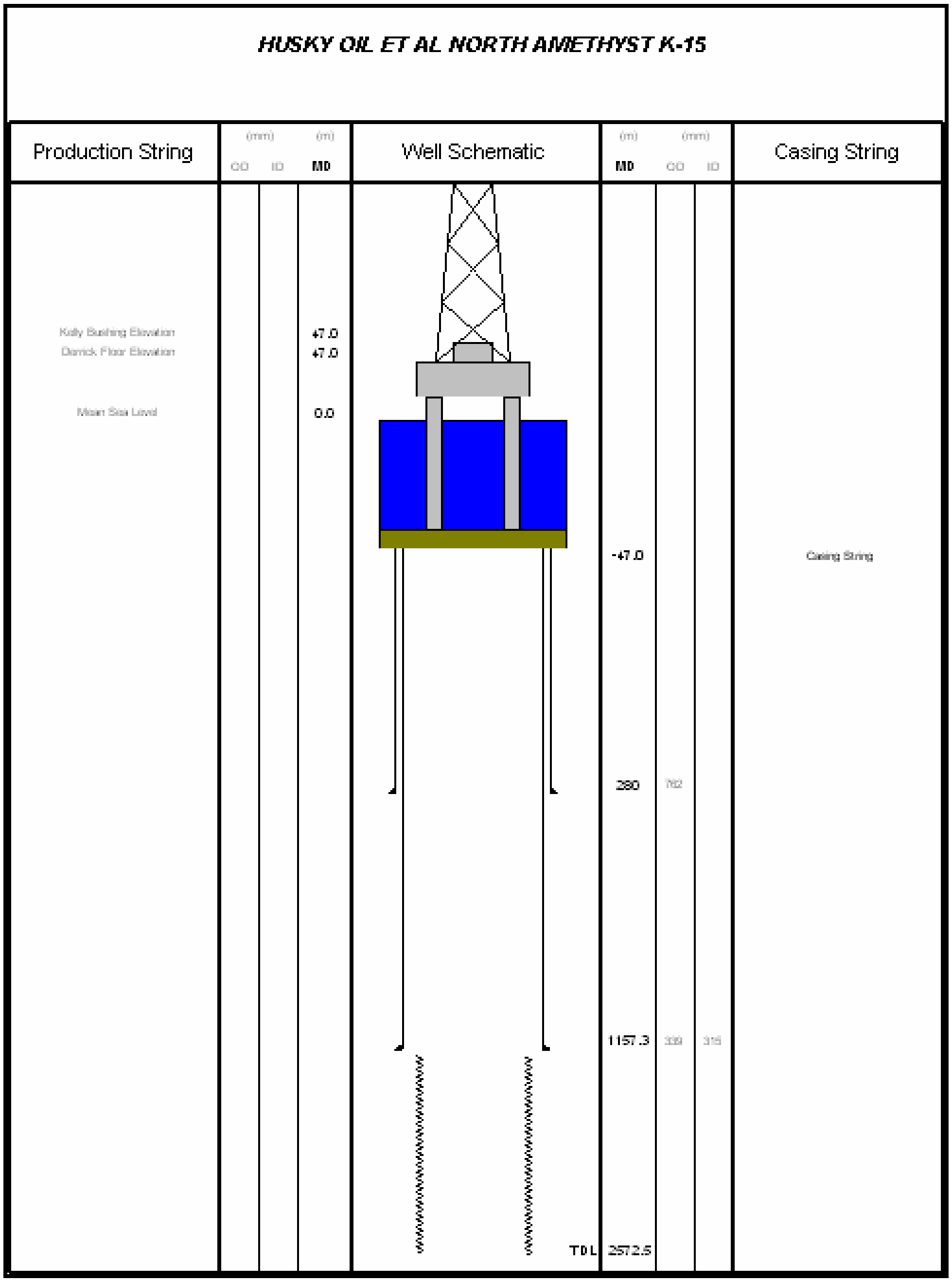
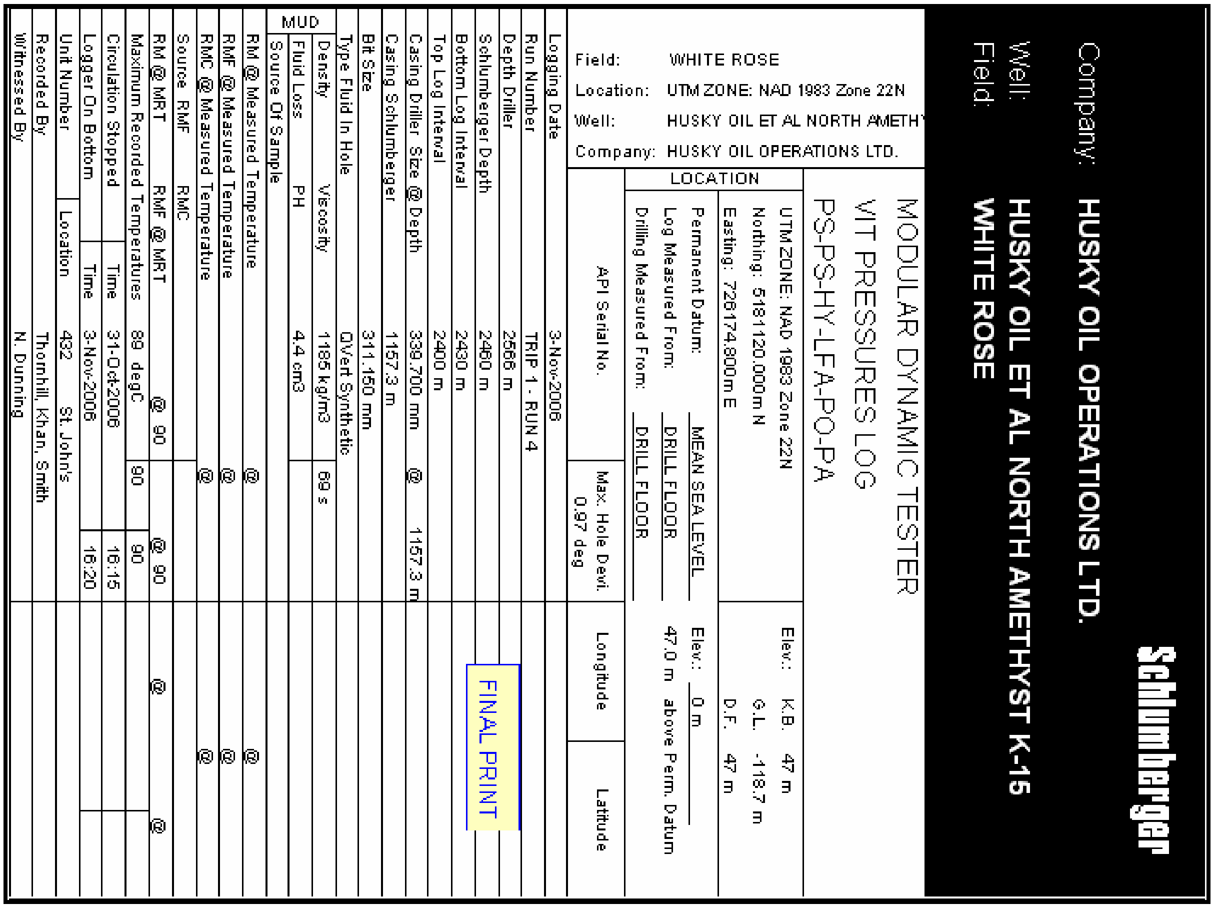


**Figure 4:** Field Log Header




REMARKS: RUN NUMBER 1
Correlated to Platform Express log dated 1-Nov-2006
38mm standoffs run on MDT to help prevent differential sticking
22.5mm wear rings run for wear and standoff purposes
Probe 2 (upper probe) run with large diameter probe and packer
Probe 1 (lower probe) run with standard diameter probe and packer
Large hole extension kit run on upper probe
Packer module run with probes for vertical interference tests
Refer to general pretest summary for details
Pretests: 4 of 4 good tests with probes. 1 good test with MRPA
MRPA elements leaked after first test, damaged downhole
Well near vertical but deviation survey entered and used for MDT data

HTCS run for tool compression/tension purposes and LWF contingency.
Max tension pull at bottom: 4500lb
Head thermometers(3): 89, 90, 90 degC (Max depth reached 2430m)
Mud filtrate density: 828 kg/m3

**Figure 5: Vertical Interpretation Test at 2390.0m**
MDT basic tool configuration

| | |
|---|---|
| Vertical Probe : | 2387.6 m |
| Horizontal probe: | 2390.0 m |

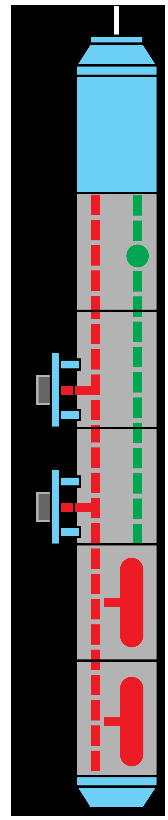


**Figure 6:** Horizontal probe pressure match
(Test at 2390.0m)

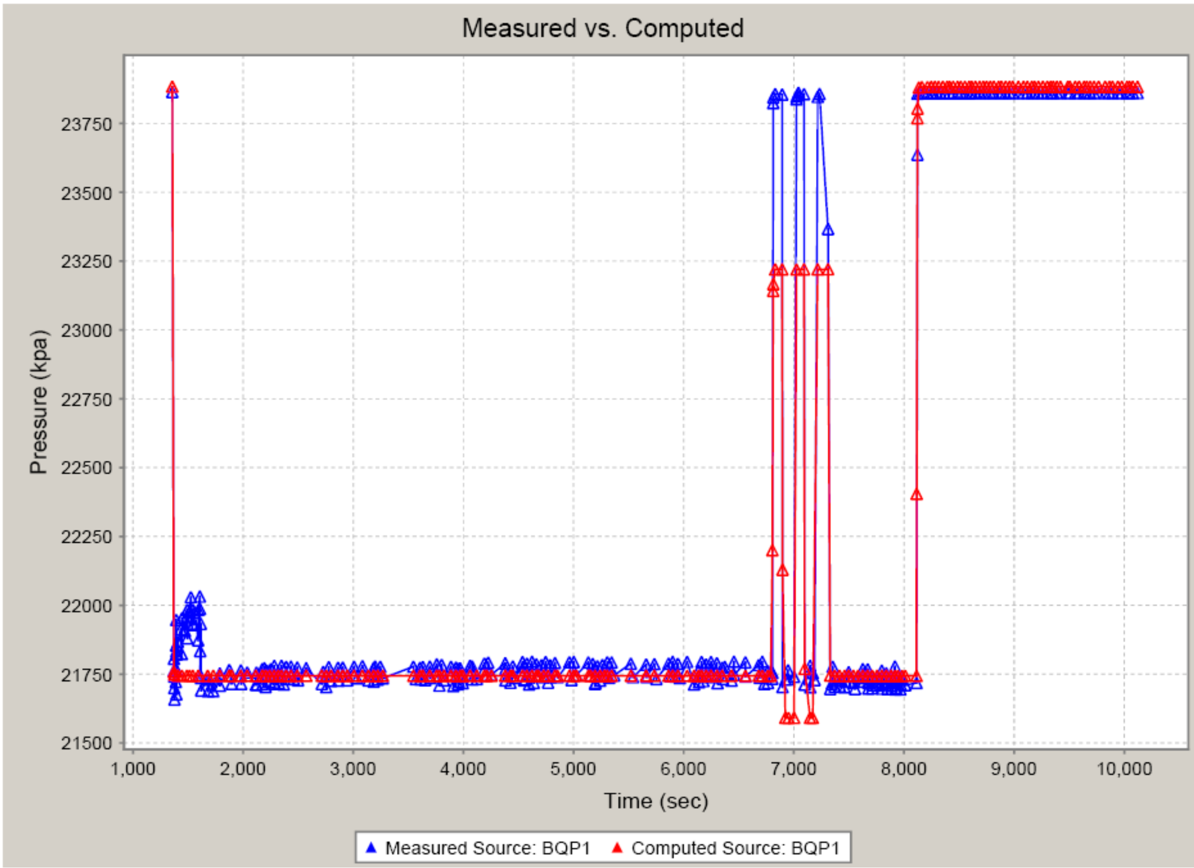


**Figure 7:** Vertical probe pressure match
(Test at 2390.0m)

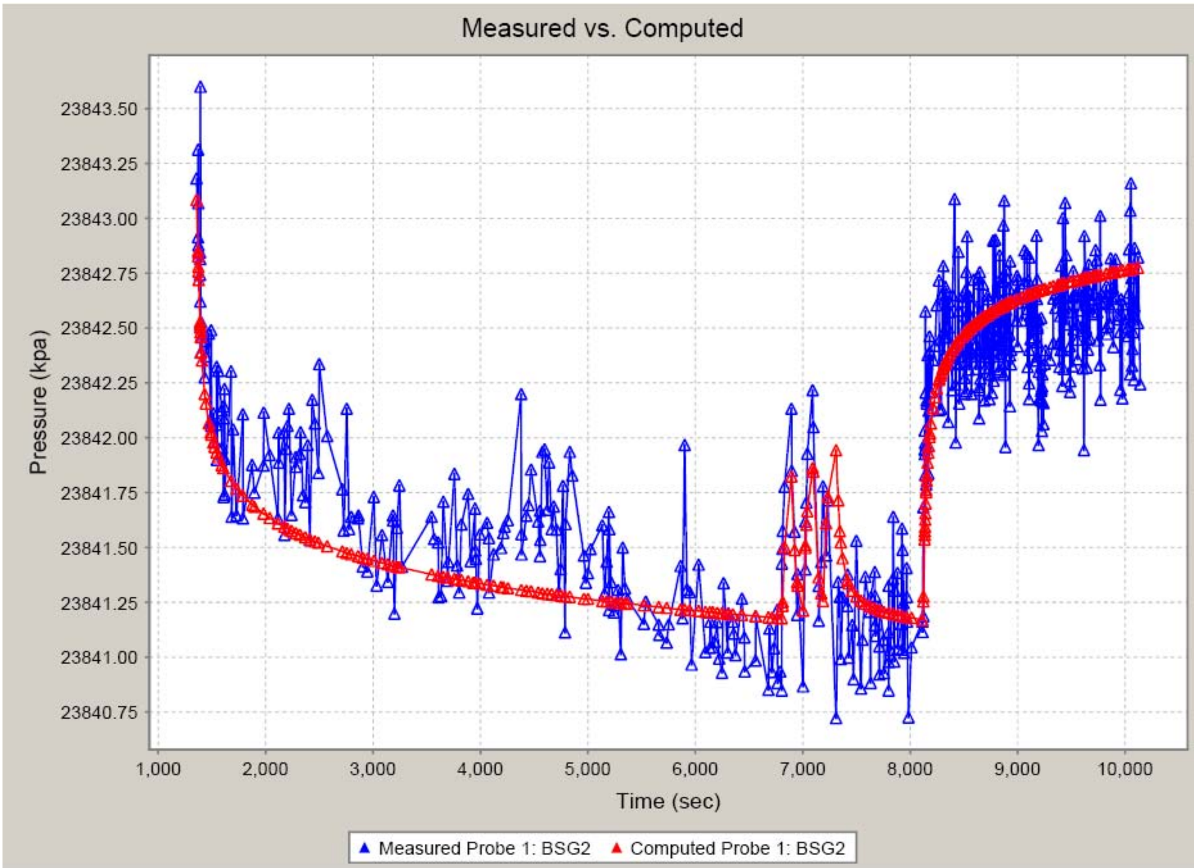


**Figure 8:** Pressure Derivative Plot (Build-up data)
(Test at 2390.0m)

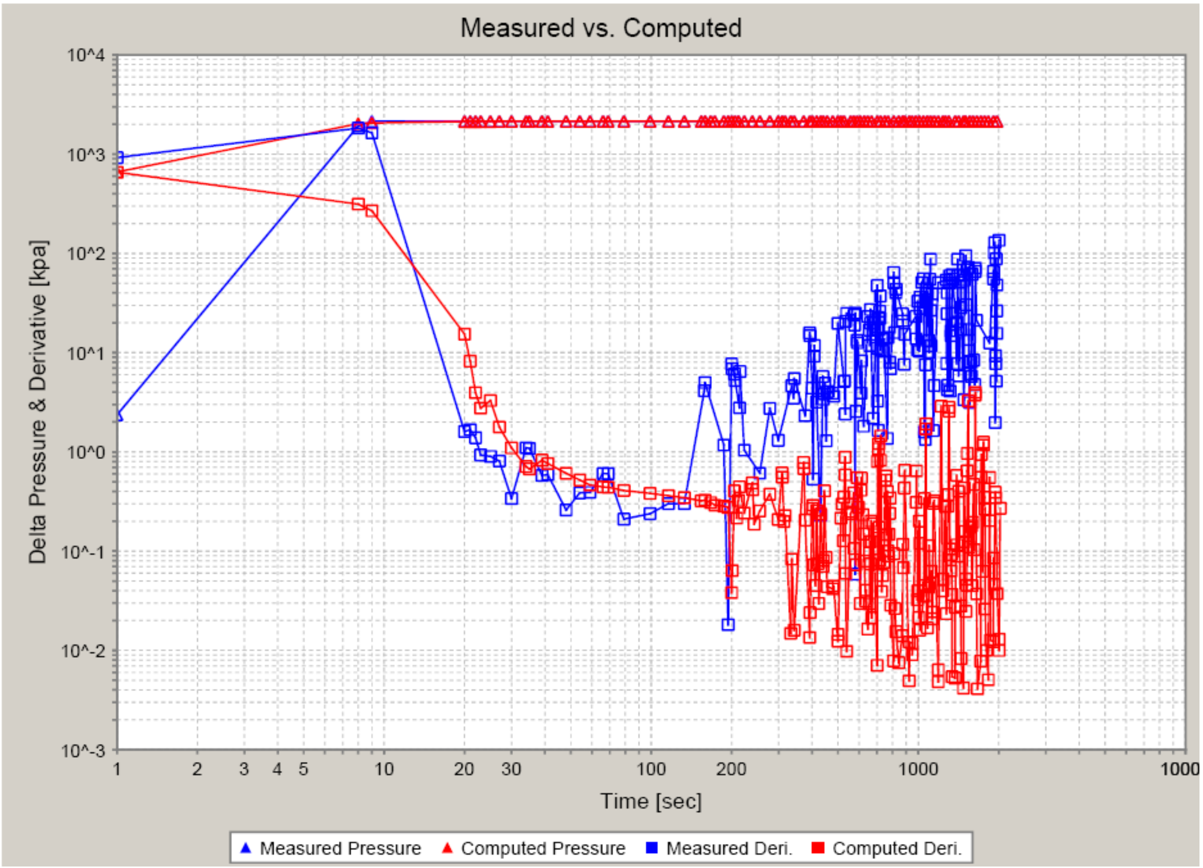


Figure 9: Vertical Interpretation Test at 2415.0m
MDT basic tool configuration

Vertical Probe : 2412.6 m

Horizontal probe: 2415.0 m

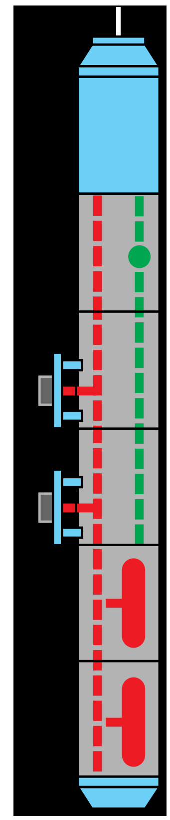


**Figure 10:** Horizontal probe pressure match
(Test at 2415.0m)

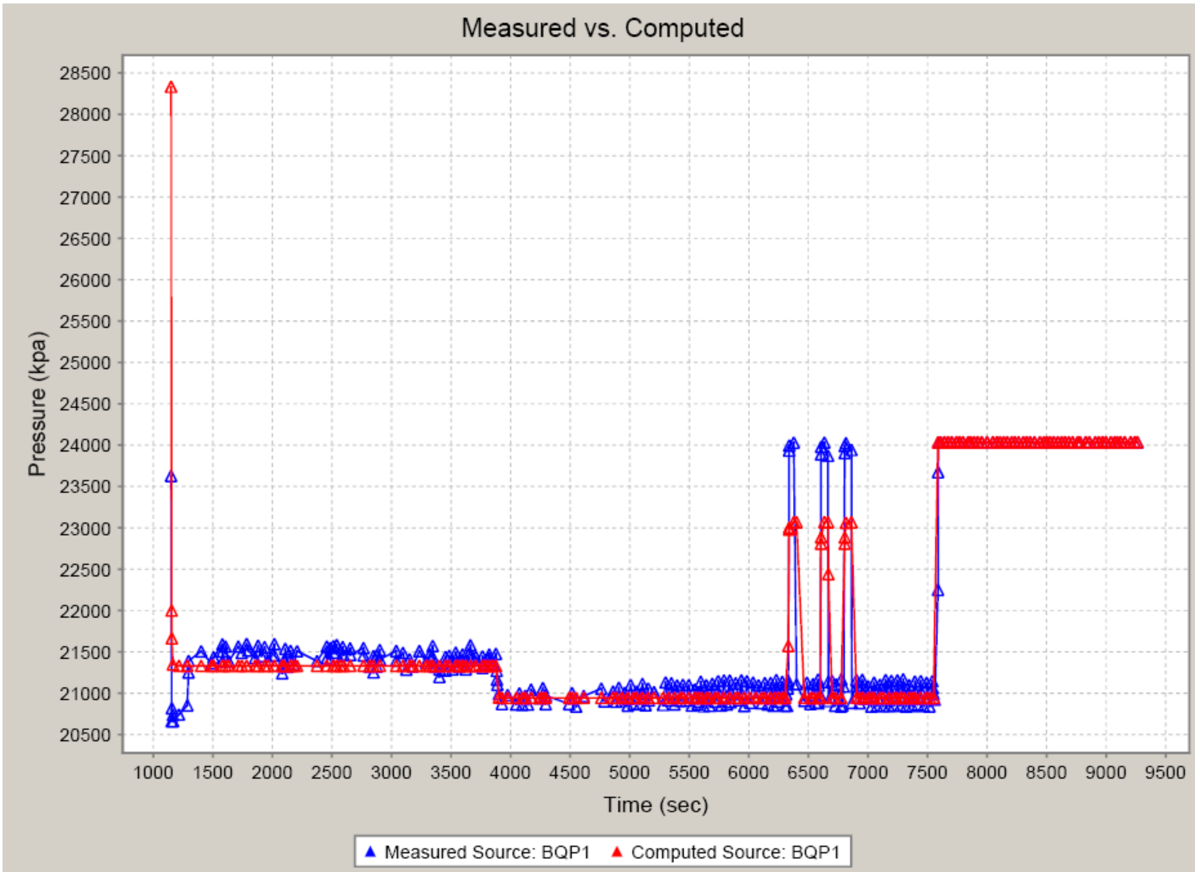


**Figure 11:** Vertical probe pressure match
(Test at 2415.0m)

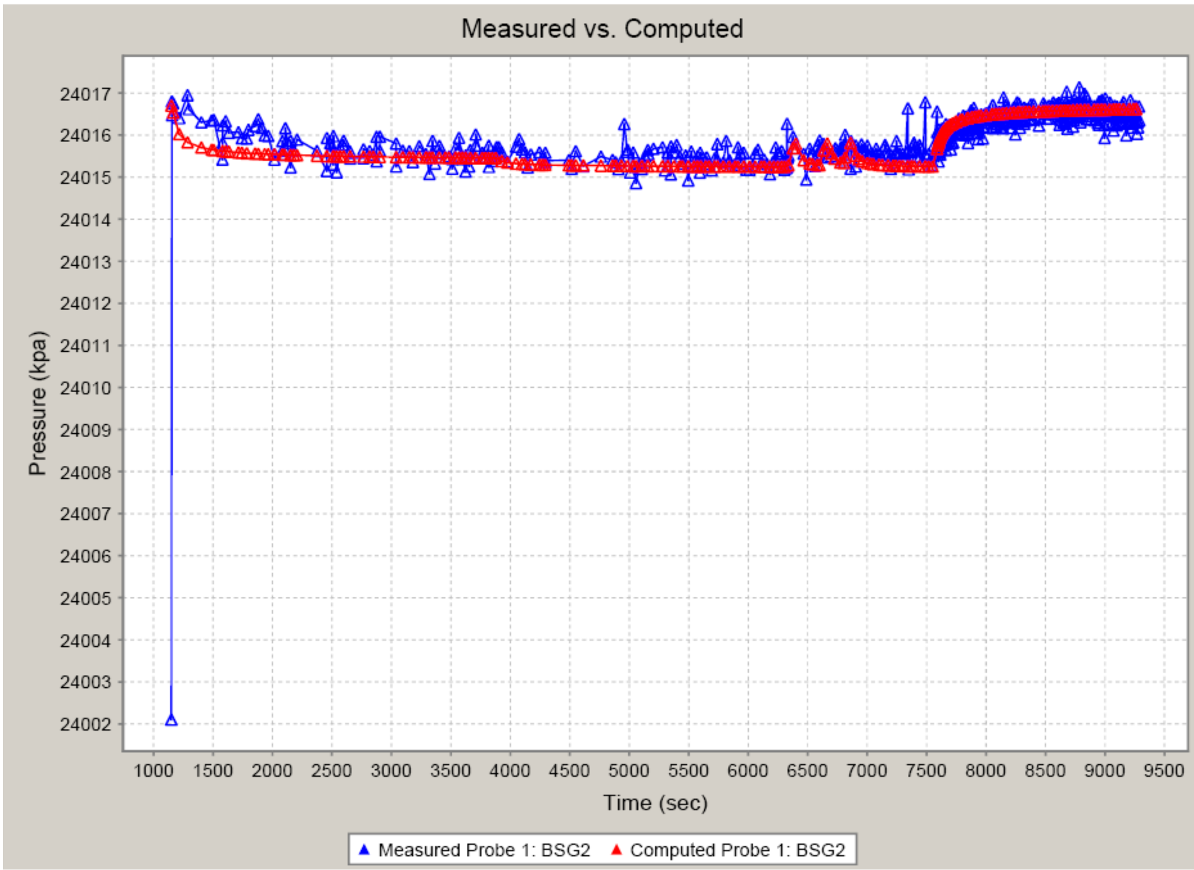


**Figure 12:** Pressure Derivative Plot (Build-up data)
(Test at 2415.0m)

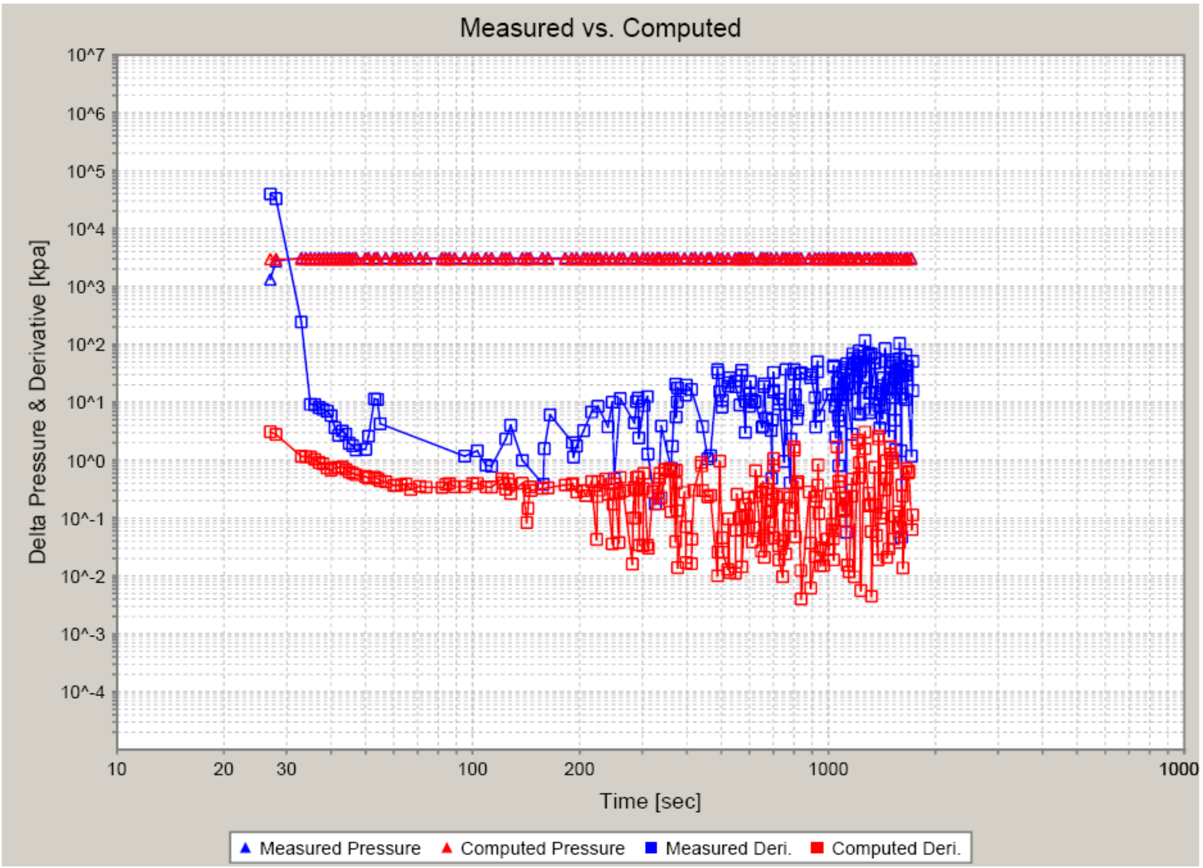


Figure 13: Mini-DST and VIT Test at 2400.0m

MDT tool configuration

Packer: 2400.00m

Probe 2: 2412.9m

Probe 1: 2415.3m

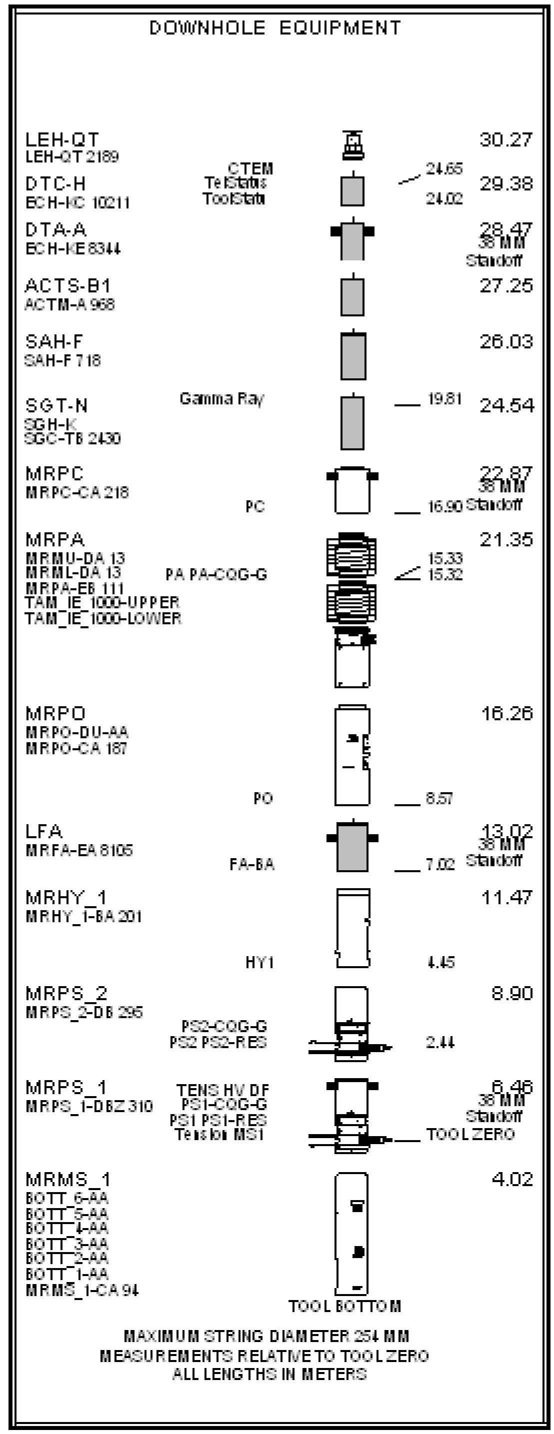
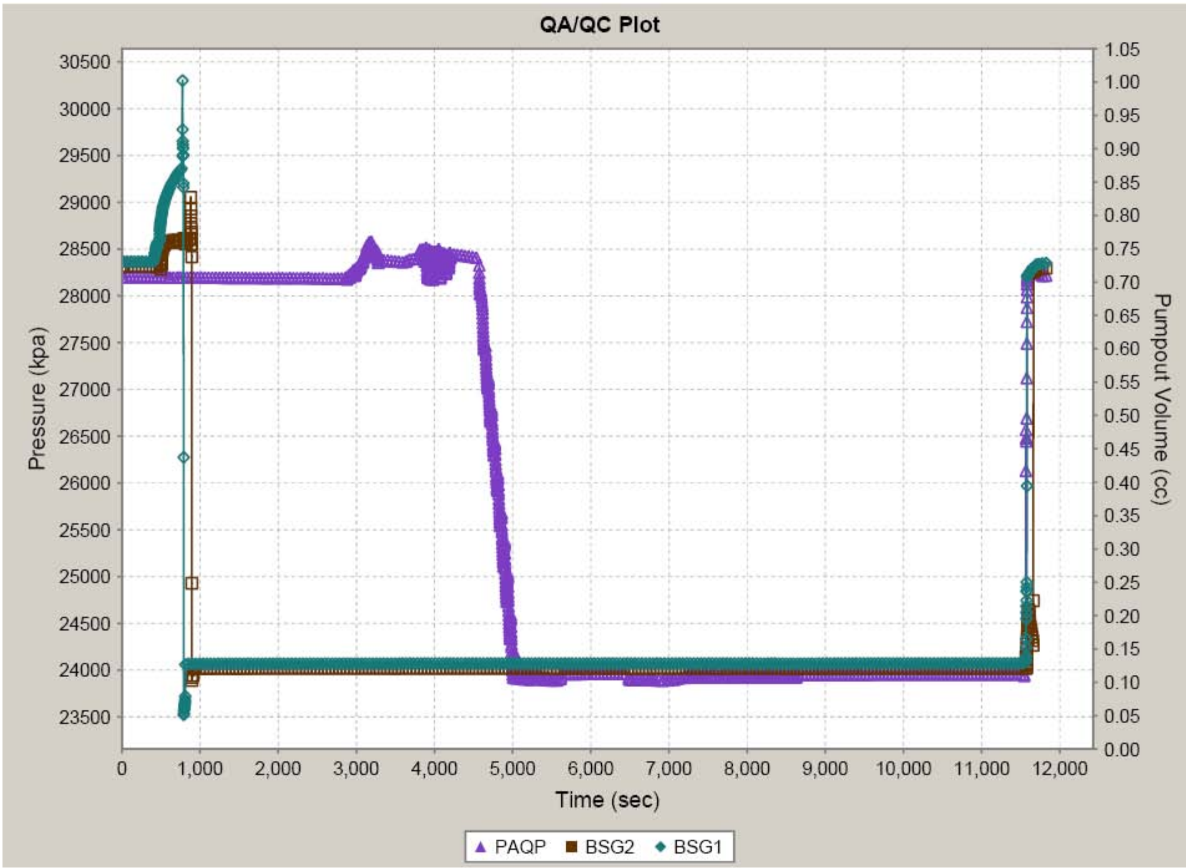


**Figure 14: Dual packer and probes pressure data**
(Test at 2400.0m)



## Figure 15: Dual packer Pressure data
(Test at 2400.0m)

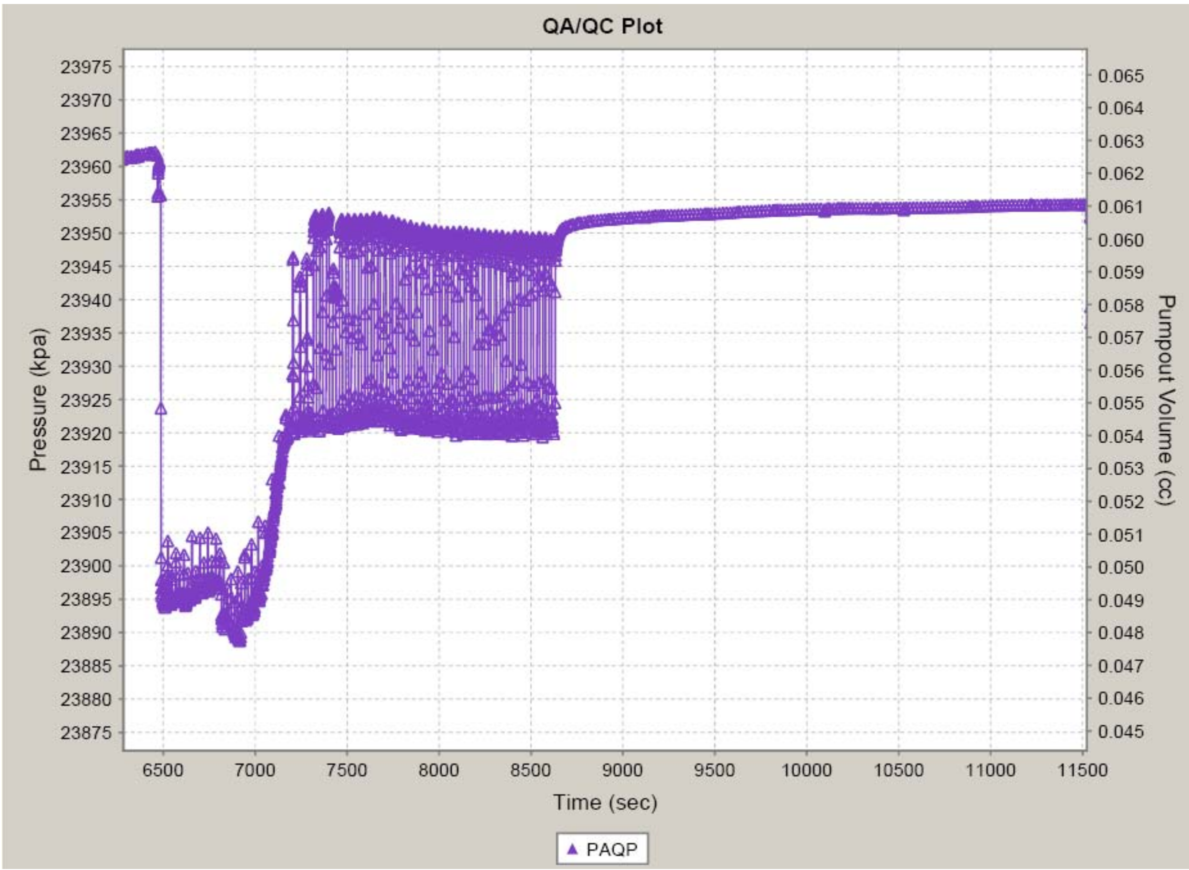


**Figure 16: Dual Packer** pressure match
(Test at 2400.0m)

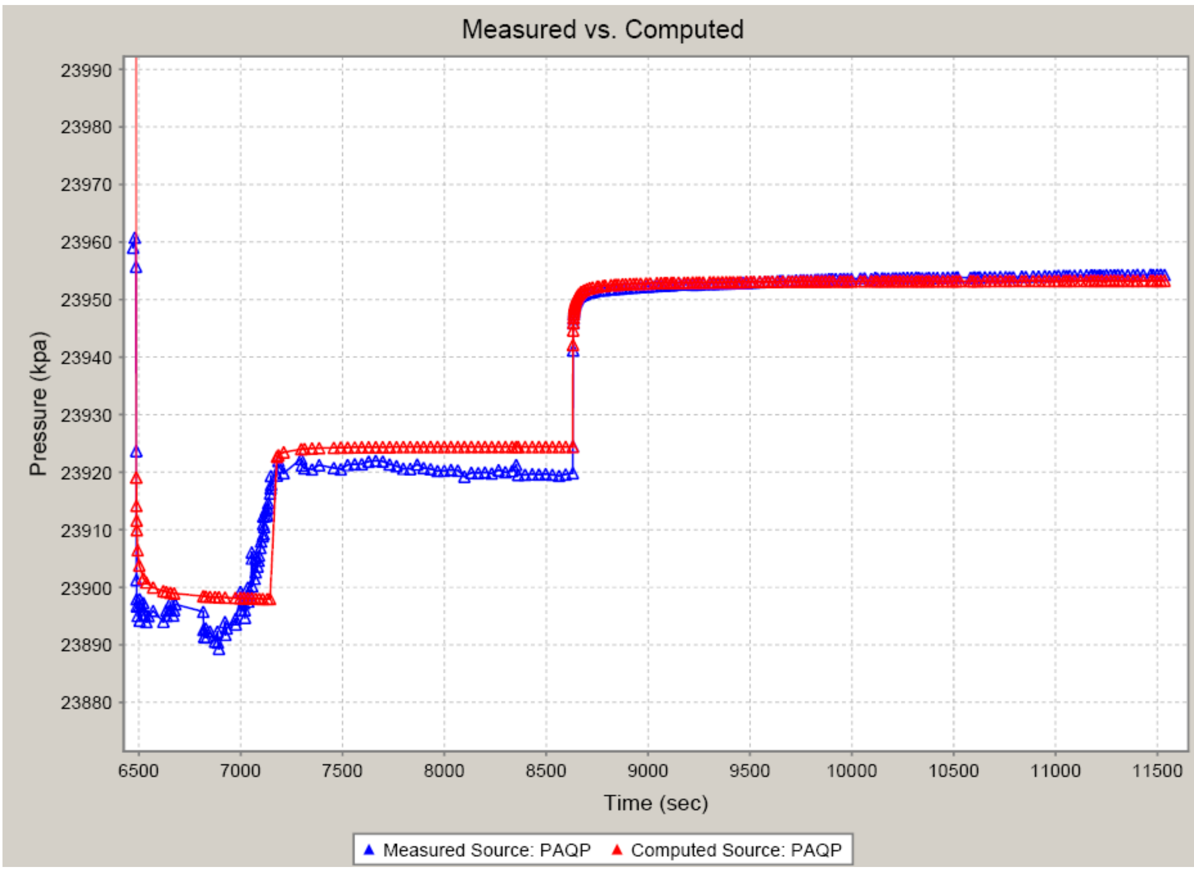


Figure 17: Pressure Derivative Plot (Build-up data)
(Test at 2400.0m)

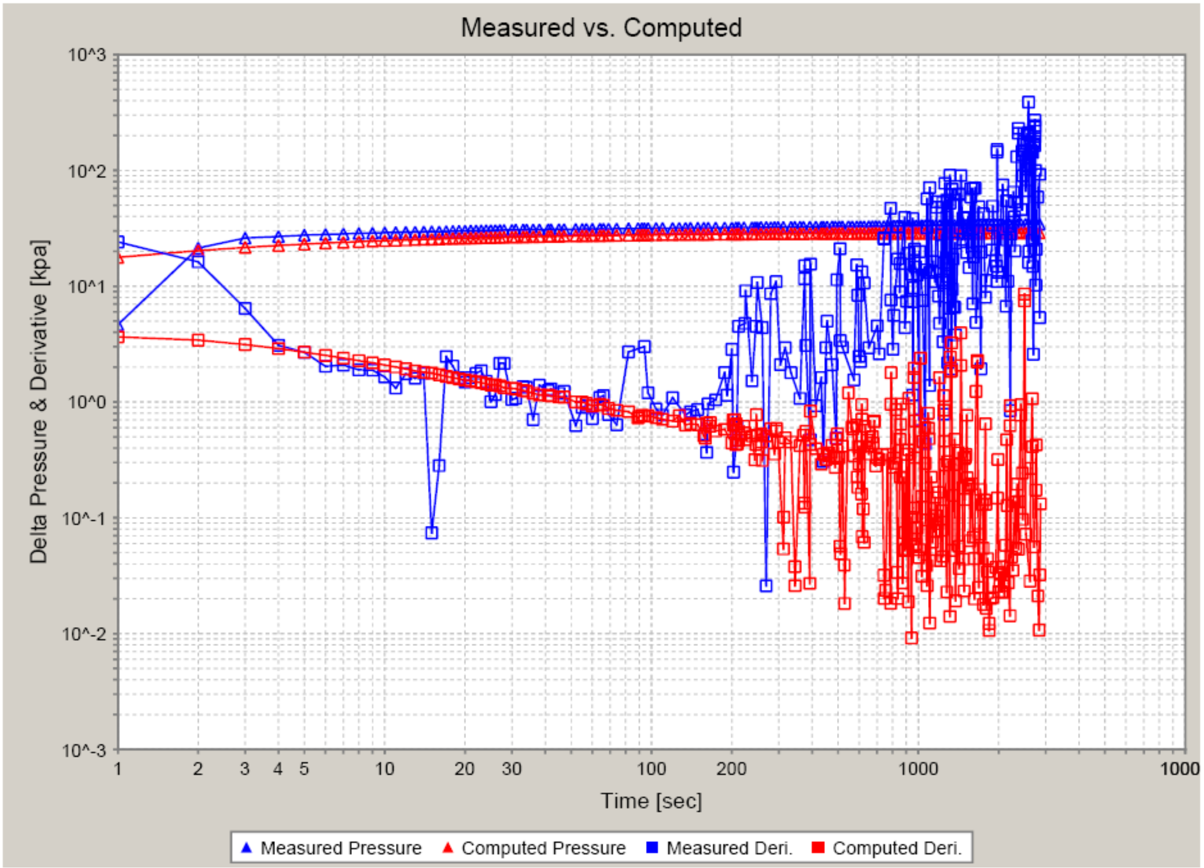
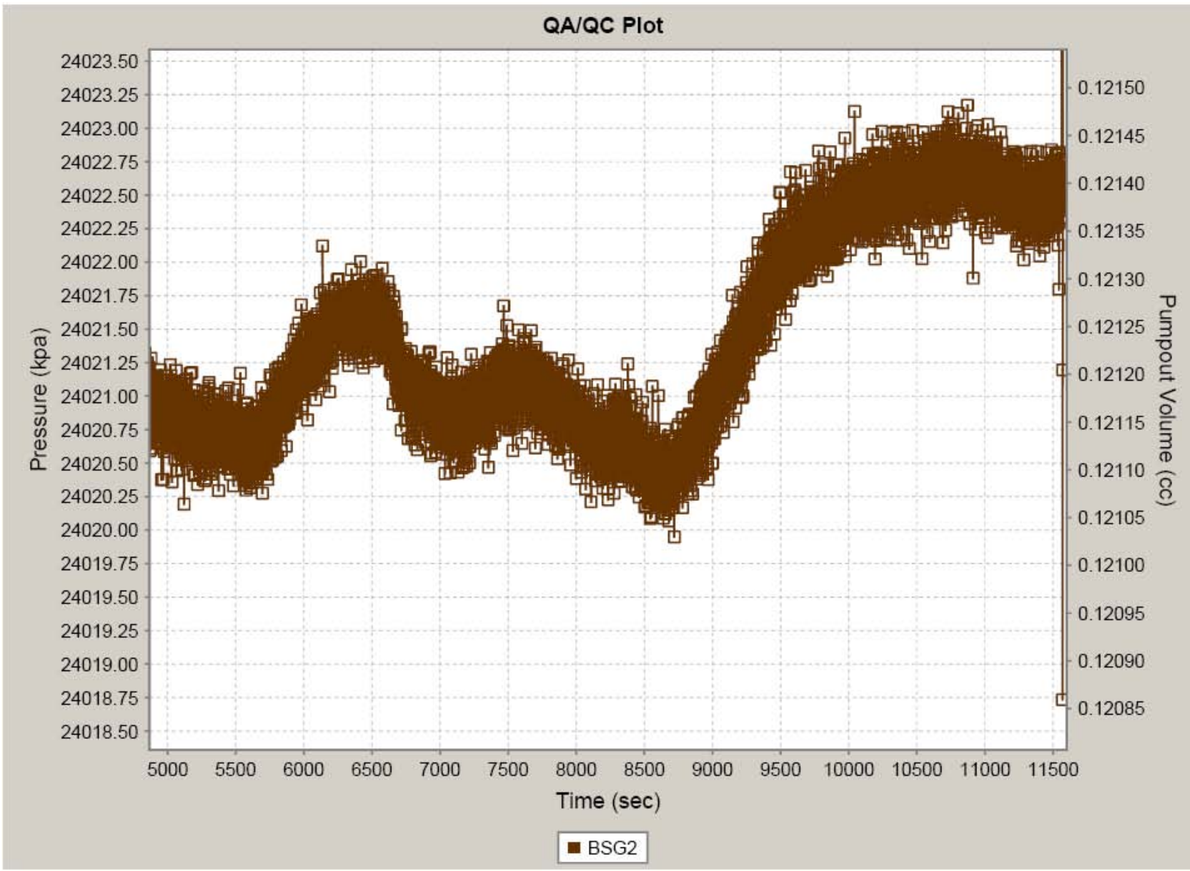


**Figure 18:** LQC of vertical probe pressure
(Test at 2400.0m)



# Appendix B

# North Amethyst Reservoir Fluid Study

# HUSKY ENERGY - NORTH AMETHYST
# RESERVOIR FLUID STUDY

## F I N A L   R E P O R T

Prepared for

HUSKY ENERGY

By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April 20, 2007

# I - RESERVOIR FLUID STUDY

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## RESULTS AND DISCUSSION

The reservoir fluid study was conducted on a BOTTOMHOLE sample prepared from separator oil and separator gas collected from Well K-15 of NORTH AMETHYST reservoir.

The sample collection data is provided in Table 1 and the sample validation data is given in Appendix A.

The PVT cell was charged with a portion of the live oil sample and a constant composition expansion experiment (CCE) was performed on the oil. Table 3 provides the CCE results of the average compressibility of the reservoir fluid at pressures above the bubblepoint. Table 4 contains the complete CCE results with the exception of the data already presented in Table 3. Figure 1 is the relative total volume (V/Vsat) data and Y-function.

Table 5 contains various property measurements made on the differentially liberated oil below the bubblepoint including live oil density, oil formation volume factor and gas-oil ratios, which are shown in Figures 2 through 4, respectively.

Table 6 contains a summary of the properties of the differentially liberated gas including gas gravities, deviation factors, gas formation volume factors and gas expansion factors. The gas deviation factor (Z), gas formation volume factor and gas expansion factor, and gas gravity are shown in Figures 5 through 7, respectively.

Table 7 provides the results of the reservoir fluid viscosity measurements. This data is represented by Figures 8 and 9. Gas phase viscosity was calculated using the compositional data and the Lee, Gonzalez, Eakin correlation.

Table 8 summarizes the effluent gas compositions from each pressure stage during the differential liberation experiment. Figures 10 shows this data plotted on semi-log co-ordinates. Table 9 presents the compositional analysis of the residual oil at completion of the experiment.

Table 10 provides the correlations of the measured PVT Data.

Appendix B contains the material balance check performed for this experiment. It is displayed as formation volume factors so that the balance can be checked on a point by point basis. Appendix C contains the compositional analyses of the liberated gases from the differential liberation test.

## SUMMARY

**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**MAIN PVT RESULTS**

### INITIAL RESERVOIR CONDITIONS

| | | | | |
|---|---|---|---|---|
| Reservoir Pressure | 3460 | psia | 23.86 | MPa |
| Reservoir Temperature: | 190.58 | F | 88.1 | C |

### CONSTANT COMPOSITION EXPANSION @ 190.6 F (88.1 C)

| | | | | |
|---|---|---|---|---|
| Saturation Pressure | 3032 | psia | 20.90 | MPa |
| Compressibility @ Reservoir Pressure | 1.1577E-05 | $psia^{-1}$ | 1.6791E-03 | $MPa^{-1}$ |
| Compressibility @ Saturation Pressure | 1.4065E-05 | $psia^{-1}$ | 2.0399E-03 | $MPa^{-1}$ |

### DIFFERENTIAL LIBERATION @ 190.6 F (88.1 C)

| | | | | |
|---|---|---|---|---|
| At Saturation Pressure | | | | |
| Oil Formation Volume Factor | 1.3208 | res.bbl/STB | 1.3208 | $res.m^3/m^3$ |
| Solution Gas-Oil Ratio | 594.01 | scf/STB | 105.79 | $m^3/m^3$ |
| Oil Density | 0.7226 | $g/cm^3$ | 722.6 | $kg/m^3$ |
| Oil Viscosity | 0.640 | cp | 0.640 | mPa.s |
| At Ambient Pressure | | | | |
| Residual Oil Density | 0.8061 | $g/cm^3$ | 806.1 | $kg/m^3$ |
| Residual Oil Viscosity | 2.506 | cp | 2.506 | mPa.s |
| At Tank Conditions | | | | |
| Residual Oil Density | 0.8560 | $g/cm^3$ | 856.0 | $kg/m^3$ |
| API Gravity | 33.80 | | 33.80 | |

### SINGLE-STAGE SEPARATOR TEST

| | | | | |
|---|---|---|---|---|
| At Saturation Pressure | | | | |
| Oil Formation Volume Factor | 1.3085 | res.bbl/STB | 1.3085 | $res.m^3/m^3$ |
| Solution Gas-Oil Ratio | 585.64 | scf/STB | 104.30 | m3/m3 |
| At Tank Conditions | | | | |
| Residual Oil Density | 0.8430 | $g/cm^3$ | 843.0 | $kg/m^3$ |
| API Gravity | 36.35 | | 36.35 | |

**TABLE 1**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**SAMPLE COLLECTION DATA**

| | | | | |
|---|---|---|---|---|
| Project File: | 2006-147 | | | |
| Operator Name: | HUSKY ENERGY | | | |
| Pool or Zone: | BEN NEVIS - AVALON | | | |
| Field or Area: | NORTH AMETHYST | | | |
| Well Location: | K-15 | | | |
| Fluid Sample: | BOTTOMHOLE | | | |
| | | | | |
| Sampling Company: | Schlumberger | | | |
| Name of Sampler: | N/A | | | |
| Sampling Date: | 6-Feb-06 | | | |
| Sampling Point: | SUBSURFACE | | | |
| Sampling (Separator) Temperature: | 190.6 | F | 88.1 | C |
| Sampling (Separator) Pressure: | 3460.0 | psia | 23.86 | MPa |
| | | | | |
| Reservoir Temperature: | 190.6 | F | 88.1 | C |
| Reservoir Pressure: | 3460.0 | psia | 23.86 | MPa |
| | | | | |
| Initial Reservoir Pressure (Pi) | 3460.0 | psia | 23.86 | MPa |
| Depth of Reported Pi | 2390.0 | mMD | N/A | mss |

**TABLE 2**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**COMPOSITIONAL ANALYSIS OF RESERVOIR FLUID**

| Boiling Point (K) | | | Mole Fraction | Mass Fraction | Calculated Properties | |
|---|---|---|---|---|---|---|
| 77.4 | Nitrogen | N2 | 0.0017 | 0.0004 | **Total Sample** | |
| 194.6 | Carbon Dioxide | CO2 | 0.0122 | 0.0047 | | |
| 212.8 | Hydrogen Sulphide | H2S | 0.0000 | 0.0000 | Molecular Weight | 113.92 |
| 111.5 | Methane | C1 | 0.4349 | 0.0613 | | |
| 184.3 | Ethane | C2 | 0.0408 | 0.0108 | | |
| 231.0 | Propane | C3 | 0.0281 | 0.0109 | **C6+ Fraction** | |
| 261.5 | i-Butane | i-C4 | 0.0058 | 0.0030 | | |
| 272.6 | n-Butane | n-C4 | 0.0168 | 0.0086 | Molecular Weight | 229.81 |
| 301.0 | i-Pentane | i-C5 | 0.0076 | 0.0048 | Mole Fraction | 0.4403 |
| 309.3 | n-Pentane | n-C5 | 0.0117 | 0.0074 | Density (g/cc) | 0.8668 |
| 309.3 - 342 | Hexanes | C6 | 0.0174 | 0.0132 | | |
| 342 - 371.4 | Heptanes | C7 | 0.0181 | 0.0160 | | |
| 371.4 - 398.8 | Octanes | C8 | 0.0235 | 0.0235 | **C7+ Fraction** | |
| 398.8 - 423.8 | Nonanes | C9 | 0.0238 | 0.0268 | | |
| 423.8 - 447 | Decanes | C10 | 0.0218 | 0.0273 | Molecular Weight | 236.12 |
| 447 - 469.3 | Undecanes | C11 | 0.0244 | 0.0314 | Mole Fraction | 0.4209 |
| 469.3 - 488.2 | Dodecanes | C12 | 0.0264 | 0.0374 | Density (g/cc) | 0.8704 |
| 488.2 - 508.2 | Tridecanes | C13 | 0.0263 | 0.0403 | | |
| 508.2 - 525.4 | Tetradecanes | C14 | 0.0213 | 0.0355 | | |
| 525.4 - 543.8 | Pentadecanes | C15 | 0.0175 | 0.0317 | **C12+ Fraction** | |
| 543.8 - 560.9 | Hexadecanes | C16 | 0.0161 | 0.0314 | | |
| 560.9 - 564.8 | Heptadecanes | C17 | 0.0137 | 0.0285 | Molecular Weight | 310.14 |
| 564.8 - 590.4 | Octadecanes | C18 | 0.0137 | 0.0301 | Mole Fraction | 0.2605 |
| 590.4 - 603.2 | Nonadecanes | C19 | 0.0112 | 0.0258 | Density (g/cc) | 0.8958 |
| 603.2 - 617.5 | Eicosanes | C20 | 0.0089 | 0.0215 | | |
| 617.5 - 630.4 | Heneicosanes | C21 | 0.0079 | 0.0202 | | |
| 630.4 - 642.5 | Docosanes | C22 | 0.0073 | 0.0196 | | |
| 642.5 - 653.2 | Tricosanes | C23 | 0.0068 | 0.0190 | | |
| 653.2 - 664.3 | Tetracosanes | C24 | 0.0061 | 0.0178 | | |
| 664.3 - 674.9 | Pentacosanes | C25 | 0.0060 | 0.0182 | | |
| 674.9 - 685.4 | Hexacosanes | C26 | 0.0054 | 0.0172 | | |
| 685.4 - 695.4 | Heptacosanes | C27 | 0.0051 | 0.0168 | | |
| 695.4 - 704.9 | Octacosanes | C28 | 0.0051 | 0.0174 | | |
| 704.9 - 714.3 | Nonacosanes | C29 | 0.0049 | 0.0173 | | |
| Above 714.3 | Tricontanes Plus | C30+ | 0.0507 | 0.2636 | | |
| | | | | | | |
| 322.0 | Cyclopentane | C5H10 | 0.0019 | 0.0012 | | |
| 345.4 | Methylcyclopentane | C6H12 | 0.0086 | 0.0063 | | |
| 354.3 | Cyclohexane | C6H12 | 0.0073 | 0.0054 | | |
| 374.3 | Methylcyclohexane | C7H14 | 0.0103 | 0.0089 | | |
| | | | | | | |
| 353.2 | Benzene | C6H6 | 0.0063 | 0.0043 | | |
| 383.8 | Toluene | C7H8 | 0.0082 | 0.0066 | | |
| 409.3 - 412 | Ethylbenzene & p,m-Xylene | C8H10 | 0.0029 | 0.0027 | | |
| 417.5 | o-Xylene | C8H10 | 0.0019 | 0.0017 | | |
| 442.0 | 1, 2, 4-Trimethylbenzene | C9H12 | 0.0034 | 0.0035 | | |
| **Total** | | | **1.0000** | **1.0000** | | |

**TABLE 3**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**OIL COMPRESSIBILITY @ 190.6 F (88.1 C)**

| Pressure Range From (psia) | Pressure Range To (psia) | Average Compressibility ($psi^{-1}$) |
|---|---|---|
| 5013 | 4713 | 9.2284E-06 |
| 4713 | 4413 | 9.3850E-06 |
| 4413 | 4113 | 9.6431E-06 |
| 4113 | 3813 | 1.0046E-05 |
| 3813 | 3513 | 1.0638E-05 |
| 3513 | 3213 | 1.1577E-05 |
| **3213** | **3032 Psat** | **1.4065E-05** |

| Pressure Range From (MPa) | Pressure Range To (MPa) | Average Compressibility ($MPa^{-1}$) |
|---|---|---|
| 34.56 | 32.49 | 1.3385E-03 |
| 32.49 | 30.42 | 1.3612E-03 |
| 30.42 | 28.36 | 1.3986E-03 |
| 28.36 | 26.29 | 1.4571E-03 |
| 26.29 | 24.22 | 1.5429E-03 |
| 24.22 | 22.15 | 1.6791E-03 |
| **22.15** | **20.90 Psat** | **2.0399E-03** |

Psat - Saturation Pressure

**TABLE 4**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT COMPOSITION EXPANSION @ 190.6 F (88.1 C)**

| Pressure (psia) | Pressure (MPa) | RelativeVolume [1] | Y-Function [2] | Fluid Density (g/cc) |
|---|---|---|---|---|
| 5013 | 34.56 | 0.979481 | | 0.7378 |
| 4713 | 32.49 | 0.982201 | | 0.7357 |
| 4413 | 30.42 | 0.984974 | | 0.7337 |
| 4113 | 28.36 | 0.987832 | | 0.7315 |
| 3813 | 26.29 | 0.990818 | | 0.7293 |
| 3513 | 24.22 | 0.993990 | | 0.7270 |
| 3213 | 22.15 | 0.997454 | | 0.7245 |
| **3032 Psat** | **20.90** | **1.000000** | | **0.7226** |
| 2918 | 20.12 | 1.011469 | 3.4067 | |
| 2819 | 19.43 | 1.022474 | 3.3623 | |
| 2665 | 18.37 | 1.041819 | 3.2933 | |
| 2492 | 17.18 | 1.067389 | 3.2158 | |
| 2268 | 15.64 | 1.108135 | 3.1155 | |
| 1999 | 13.78 | 1.172559 | 2.9950 | |
| 1633 | 11.26 | 1.302651 | 2.8311 | |
| 1391 | 9.59 | 1.433369 | 2.7227 | |
| 1133 | 7.81 | 1.643021 | 2.6071 | |
| 983 | 6.78 | 1.820864 | 2.5399 | |
| 826 | 5.69 | 2.081737 | 2.4696 | |
| 713 | 4.91 | 2.344994 | 2.4190 | |
| 595 | 4.10 | 2.731691 | 2.3661 | |
| 534 | 3.68 | 3.000998 | 2.3388 | |
| 510 | 3.51 | 3.125104 | 2.3280 | |

[1] Volume at indicated pressure per volume at saturation pressure
[2] Y Function = ((Psat-P)/P)/(Relative Volume - 1)
Psat - Saturation Pressure

**TABLE 5**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**DIFFERENTIAL LIBERATION OIL PROPERTIES @ 190.6 F (88.1 C)**

| Pressure (psia) | Pressure (MPa) | Oil Density ($g/cm^3$) | Oil Formation Volume Factor [1] | Total Formation Volume Factor [2] | Gas-Oil Ratio Solution (scf/STB) | Gas-Oil Ratio Liberated (scf/STB) | Gas-Oil Ratio Solution ($m^3/m^3$) | Gas-Oil Ratio Liberated ($m^3/m^3$) |
|---|---|---|---|---|---|---|---|---|
| 5013 | 34.56 | 0.7378 | 1.2937 | 1.2937 | 594.01 | 0.00 | 105.79 | 0.00 |
| 4713 | 32.49 | 0.7357 | 1.2973 | 1.2973 | 594.01 | 0.00 | 105.79 | 0.00 |
| 4413 | 30.42 | 0.7337 | 1.3009 | 1.3009 | 594.01 | 0.00 | 105.79 | 0.00 |
| 4113 | 28.36 | 0.7315 | 1.3047 | 1.3047 | 594.01 | 0.00 | 105.79 | 0.00 |
| 3813 | 26.29 | 0.7293 | 1.3087 | 1.3087 | 594.01 | 0.00 | 105.79 | 0.00 |
| 3513 | 24.22 | 0.7270 | 1.3129 | 1.3129 | 594.01 | 0.00 | 105.79 | 0.00 |
| 3213 | 22.15 | 0.7245 | 1.3174 | 1.3174 | 594.01 | 0.00 | 105.79 | 0.00 |
| **3032 Psat** | **20.90** | **0.7226** | **1.3208** | **1.3208** | **594.01** | **0.00** | **105.79** | **0.00** |
| 2663 | 18.36 | 0.7306 | 1.2951 | 1.3529 | 539.90 | 54.11 | 96.16 | 9.64 |
| 2313 | 15.95 | 0.7363 | 1.2702 | 1.4182 | 474.32 | 119.69 | 84.48 | 21.32 |
| 1963 | 13.53 | 0.7432 | 1.2447 | 1.5166 | 408.18 | 185.83 | 72.70 | 33.10 |
| 1613 | 11.12 | 0.7496 | 1.2207 | 1.6736 | 341.45 | 252.56 | 60.81 | 44.98 |
| 1263 | 8.71 | 0.7572 | 1.1951 | 1.9461 | 270.31 | 323.70 | 48.14 | 57.65 |
| 963 | 6.64 | 0.7640 | 1.1739 | 2.3597 | 209.50 | 384.51 | 37.31 | 68.48 |
| 663 | 4.57 | 0.7704 | 1.1532 | 3.1545 | 153.15 | 440.86 | 27.28 | 78.52 |
| 413 | 2.85 | 0.7764 | 1.1341 | 4.7133 | 106.42 | 487.59 | 18.95 | 86.84 |
| 163 | 1.12 | 0.7850 | 1.1089 | 10.8811 | 56.21 | 537.80 | 10.01 | 95.78 |
| 78 | 0.54 | 0.7889 | 1.0962 | 20.9787 | 33.73 | 560.28 | 6.01 | 99.79 |
| 13 | 0.09 | 0.8061 | 1.0640 | 76.5775 | 0.00 | 594.01 | 0.00 | 105.79 |

Density of Residual Oil = 0.8560 g/cm3 (856.0 kg/m3) @ 60 F (288.7K)
API Gravity of Residual Oil = 33.8

[1] Barrels (Cubic meters) of oil at indicated pressure and temperature per barrel (cubic meter) of residual oil @ 60 F (288.7 K).
[2] Total barrels (cubic meters) of oil and liberated gas at the indicated pressure and temperature per barrel (cubic meter) of residual oil @ 60 F (288.7 K).
Psat - Saturation Pressure
- Tank conditions: 60 F (288.7 K) @ 13 psia (0.0896 MPa); Standard conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa).

**TABLE 6**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**DIFFERENTIAL LIBERATION GAS PROPERTIES @ 190.6 F (88.1 C)**

| Pressure | | Gas Gravity | | Gas | Gas Deviation | Gas Formation | Gas Expansion |
|---|---|---|---|---|---|---|---|
| | | Incremental | Cumulative | Density | Factor | Volume Factor | Factor |
| (psia) | (MPa) | (Air = 1) | (Air = 1) | (g/cm$^3$) | (-) | [1] | [2] |
| 5013 | 34.56 | | | | | | |
| 4713 | 32.49 | | | | | | |
| 4413 | 30.42 | | | | | | |
| 4113 | 28.36 | | | | | | |
| 3813 | 26.29 | | | | | | |
| 3513 | 24.22 | | | | | | |
| 3213 | 22.15 | | | | | | |
| **3032 Psat** | **20.90** | | | | | | |
| 2663 | 18.36 | 0.6889 | 0.6889 | 0.1396 | 0.8735 | 0.0060 | 166.569 |
| 2313 | 15.95 | 0.6680 | 0.6774 | 0.1170 | 0.8780 | 0.0069 | 144.046 |
| 1963 | 13.53 | 0.6624 | 0.6721 | 0.0979 | 0.8827 | 0.0082 | 121.726 |
| 1613 | 11.12 | 0.6654 | 0.6703 | 0.0802 | 0.8901 | 0.0101 | 99.331 |
| 1263 | 8.71 | 0.6699 | 0.6702 | 0.0622 | 0.9037 | 0.0130 | 76.763 |
| 963 | 6.64 | 0.6824 | 0.6721 | 0.0476 | 0.9187 | 0.0173 | 57.754 |
| 663 | 4.57 | 0.7103 | 0.6770 | 0.0334 | 0.9363 | 0.0255 | 39.234 |
| 413 | 2.85 | 0.7572 | 0.6847 | 0.0218 | 0.9536 | 0.0412 | 24.263 |
| 163 | 1.12 | 0.8847 | 0.7034 | 0.0098 | 0.9744 | 0.1020 | 9.802 |
| 78 | 0.54 | 1.0547 | 0.7174 | 0.0056 | 0.9822 | 0.1993 | 5.019 |
| 13 | 0.09 | 1.4899 | 0.7611 | 0.0013 | 0.9931 | 0.7138 | 1.401 |

[1] Cubic feet (meters) of gas at indicated pressure and temperature per cubic feet (meter) @ standard conditions
[2] Cubic feet (meters) of gas @ standard conditions per cubic feet (meter) @ indicated pressure and temperature.
Psat - Saturation pressure
- Standard conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

**TABLE 7**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**DIFFERENTIAL LIBERATION FLUID VISCOSITY @ 190.6 F (88.1 C)**

| Pressure (psia) | Pressure (MPa) | Oil Viscosity (cp=mPa.s) | Gas Viscosity (cp=mPa.s) | Oil - Gas Viscosity Ratio |
|---|---|---|---|---|
| 4513 | 31.12 | 0.694 | | |
| 4013 | 27.67 | 0.676 | | |
| 3513 | 24.22 | 0.658 | | |
| 3032 **Psat** | 20.90 | 0.640 | | |
| 2663 | 18.36 | 0.703 | 0.01883 | 37.34 |
| 2313 | 15.95 | 0.775 | 0.01756 | 44.16 |
| 1963 | 13.53 | 0.864 | 0.01656 | 52.21 |
| 1613 | 11.12 | 0.961 | 0.01569 | 61.25 |
| 1263 | 8.71 | 1.098 | 0.01491 | 73.61 |
| 963 | 6.64 | 1.254 | 0.01431 | 87.68 |
| 663 | 4.57 | 1.440 | 0.01372 | 104.97 |
| 413 | 2.85 | 1.668 | 0.01318 | 126.58 |
| 163 | 1.12 | 1.985 | 0.01235 | 160.75 |
| 78 | 0.54 | 2.159 | 0.01160 | 186.18 |
| 13 | 0.09 | 2.506 | 0.01015 | 246.91 |

Psat - Saturation Pressure

# TABLE 8
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF LIBERATED GAS @ 190.6 F (88.1 C)

| Component | Differential Liberation Stage Pressure (psia/MPa) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2663 | 2313 | 1963 | 1613 | 1263 | 963 | 663 | 413 | 163 | 78 | 13 |
| | 18.36 | 15.95 | 13.53 | 11.12 | 8.71 | 6.64 | 4.57 | 2.85 | 1.12 | 0.54 | 0.09 |
| **N2** | 0.0042 | 0.0039 | 0.0033 | 0.0027 | 0.0020 | 0.0014 | 0.0009 | 0.0005 | 0.0002 | 0.0002 | 0.0001 |
| **CO2** | 0.0154 | 0.0162 | 0.0171 | 0.0181 | 0.0191 | 0.0212 | 0.0247 | 0.0274 | 0.0324 | 0.0371 | 0.0142 |
| **H2S** | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **C1** | 0.8804 | 0.8891 | 0.8909 | 0.8847 | 0.8786 | 0.8654 | 0.8370 | 0.7919 | 0.6659 | 0.4935 | 0.1225 |
| **C2** | 0.0413 | 0.0434 | 0.0442 | 0.0488 | 0.0527 | 0.0591 | 0.0721 | 0.0911 | 0.1398 | 0.2021 | 0.1467 |
| **C3** | 0.0202 | 0.0194 | 0.0198 | 0.0215 | 0.0231 | 0.0259 | 0.0319 | 0.0434 | 0.0816 | 0.1398 | 0.5133 |
| **i-C4** | 0.0038 | 0.0031 | 0.0030 | 0.0032 | 0.0033 | 0.0036 | 0.0044 | 0.0061 | 0.0119 | 0.0221 | 0.0374 |
| **n-C4** | 0.0104 | 0.0081 | 0.0074 | 0.0073 | 0.0075 | 0.0085 | 0.0105 | 0.0147 | 0.0288 | 0.0529 | 0.0973 |
| **i-C5** | 0.0039 | 0.0026 | 0.0021 | 0.0021 | 0.0022 | 0.0025 | 0.0032 | 0.0043 | 0.0073 | 0.0107 | 0.0150 |
| **n-C5** | 0.0050 | 0.0033 | 0.0027 | 0.0028 | 0.0028 | 0.0031 | 0.0039 | 0.0053 | 0.0083 | 0.0121 | 0.0173 |
| **C6** | 0.0053 | 0.0031 | 0.0025 | 0.0024 | 0.0024 | 0.0025 | 0.0028 | 0.0037 | 0.0068 | 0.0099 | 0.0127 |
| **C7+** | 0.0101 | 0.0078 | 0.0070 | 0.0064 | 0.0063 | 0.0070 | 0.0086 | 0.0117 | 0.0168 | 0.0197 | 0.0235 |
| **Total** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** |
| **Calculated Properties of Total Sample @ Standard Conditions** | | | | | | | | | | | |
| **MW (g/mol)** | 19.95 | 19.35 | 19.18 | 19.27 | 19.40 | 19.76 | 20.57 | 21.93 | 25.63 | 30.55 | 43.15 |
| **Gravity (Air=1.0)** | 0.6889 | 0.6680 | 0.6624 | 0.6654 | 0.6699 | 0.6824 | 0.7103 | 0.7572 | 0.8847 | 1.0547 | 1.4899 |
| **Calculated Properties of C7+ @ Standard Conditions** | | | | | | | | | | | |
| **MW (g/mol)** | 96.61 | 96.69 | 96.98 | 97.25 | 96.85 | 96.77 | 97.05 | 97.04 | 96.57 | 96.36 | 96.08 |
| **Density (g/cc)** | 0.7232 | 0.7234 | 0.7240 | 0.7245 | 0.7237 | 0.7235 | 0.7241 | 0.7241 | 0.7231 | 0.7227 | 0.7221 |

**TABLE 9**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**COMPOSITIONAL ANALYSIS OF RESIDUAL OIL**

| Boiling Point (K) | | | Mole Fraction | Mass Fraction | Calculated Properties | |
|---|---|---|---|---|---|---|
| 77.4 | Nitrogen | N2 | 0.0000 | 0.0000 | **Total Sample** | |
| 194.6 | Carbon Dioxide | CO2 | 0.0000 | 0.0000 | | |
| 212.8 | Hydrogen Sulphide | H2S | 0.0000 | 0.0000 | Molecular Weight | 229.29 |
| 111.5 | Methane | C1 | 0.0000 | 0.0000 | | |
| 184.3 | Ethane | C2 | 0.0000 | 0.0000 | | |
| 231.0 | Propane | C3 | 0.0028 | 0.0005 | **C6+ Fraction** | |
| 261.5 | i-Butane | i-C4 | 0.0023 | 0.0006 | | |
| 272.6 | n-Butane | n-C4 | 0.0097 | 0.0025 | Molecular Weight | 235.44 |
| 301.0 | i-Pentane | i-C5 | 0.0077 | 0.0024 | Mole Fraction | 0.9638 |
| 309.3 | n-Pentane | n-C5 | 0.0136 | 0.0043 | Density (g/cc) | 0.8328 |
| 309.3 - 342 | Hexanes | C6 | 0.0274 | 0.0103 | | |
| 342 - 371.4 | Heptanes | C7 | 0.0347 | 0.0152 | | |
| 371.4 - 398.8 | Octanes | C8 | 0.0457 | 0.0228 | **C7+ Fraction** | |
| 398.8 - 423.8 | Nonanes | C9 | 0.0533 | 0.0298 | | |
| 423.8 - 447 | Decanes | C10 | 0.0576 | 0.0358 | Molecular Weight | 240.34 |
| 447 - 469.3 | Undecanes | C11 | 0.0544 | 0.0349 | Mole Fraction | 0.9332 |
| 469.3 - 488.2 | Dodecanes | C12 | 0.0584 | 0.0410 | Density (g/cc) | 0.8368 |
| 488.2 - 508.2 | Tridecanes | C13 | 0.0594 | 0.0454 | | |
| 508.2 - 525.4 | Tetradecanes | C14 | 0.0497 | 0.0412 | | |
| 525.4 - 543.8 | Pentadecanes | C15 | 0.0420 | 0.0378 | **C12+ Fraction** | |
| 543.8 - 560.9 | Hexadecanes | C16 | 0.0389 | 0.0377 | | |
| 560.9 - 564.8 | Heptadecanes | C17 | 0.0317 | 0.0327 | Molecular Weight | 308.05 |
| 564.8 - 590.4 | Octadecanes | C18 | 0.0324 | 0.0355 | Mole Fraction | 0.5986 |
| 590.4 - 603.2 | Nonadecanes | C19 | 0.0275 | 0.0316 | Density (g/cc) | 0.8699 |
| 603.2 - 617.5 | Eicosanes | C20 | 0.0212 | 0.0254 | | |
| 617.5 - 630.4 | Heneicosanes | C21 | 0.0187 | 0.0238 | | |
| 630.4 - 642.5 | Docosanes | C22 | 0.0172 | 0.0228 | | |
| 642.5 - 653.2 | Tricosanes | C23 | 0.0158 | 0.0219 | | |
| 653.2 - 664.3 | Tetracosanes | C24 | 0.0141 | 0.0204 | | |
| 664.3 - 674.9 | Pentacosanes | C25 | 0.0136 | 0.0204 | | |
| 674.9 - 685.4 | Hexacosanes | C26 | 0.0122 | 0.0190 | | |
| 685.4 - 695.4 | Heptacosanes | C27 | 0.0112 | 0.0183 | | |
| 695.4 - 704.9 | Octacosanes | C28 | 0.0110 | 0.0186 | | |
| 704.9 - 714.3 | Nonacosanes | C29 | 0.0102 | 0.0180 | | |
| Above 714.3 | Tricontanes Plus | C30+ | 0.1134 | 0.2929 | | |
| | | | | | | |
| 322.0 | Cyclopentane | C5H10 | 0.0033 | 0.0010 | | |
| 345.4 | Methylcyclopentane | C6H12 | 0.0096 | 0.0035 | | |
| 354.3 | Cyclohexane | C6H12 | 0.0132 | 0.0048 | | |
| 374.3 | Methylcyclohexane | C7H14 | 0.0204 | 0.0087 | | |
| | | | | | | |
| 353.2 | Benzene | C6H6 | 0.0118 | 0.0040 | | |
| 383.8 | Toluene | C7H8 | 0.0205 | 0.0082 | | |
| 409.3 - 412 | Ethylbenzene & p,m-Xylene | C8H10 | 0.0057 | 0.0026 | | |
| 417.5 | o-Xylene | C8H10 | 0.0040 | 0.0019 | | |
| 442.0 | 1, 2, 4-Trimethylbenzene | C9H12 | 0.0038 | 0.0020 | | |
| **Total** | | | **1.0000** | **1.0000** | | |

**TABLE 10**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CORRELATIONS OF MEASURED PVT LABORATORY DATA**

**CONSTANT COMPOSITION EXPANSION @ 190.6 F (88.1 C)**

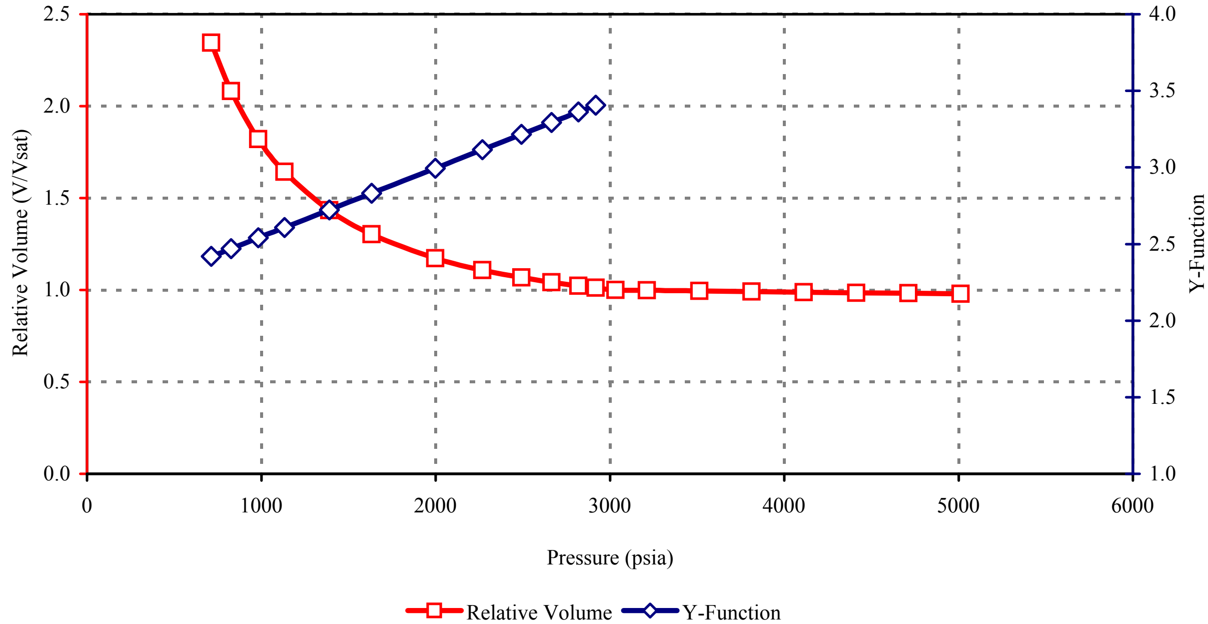
| | | |
|---|---|---|
| Relative Volume (V/Vsat) | (P >= Psat) | y=(-0.020779*x^2 + 1.732761*x + 1.305946)/(1.808251*x + 1.210123)<br>R Squared = 0.996525 |
| Relative Volume (V/Vsat) | (P <= Psat) | y=(1.198371*x^2 + 2.591509*x + 2.963957)/(6.787911*x + -0.042878)<br>R Squared = 0.999996 |

**DIFFERENTIAL LIBERATION @ 190.6 F (88.1 C)**

| | | |
|---|---|---|
| Live Oil Density (g/cc) | (P >= Psat) | y=(0.016189*x^2 + 1.526916*x + 0.994195)/(2.018840*x + 1.492144)<br>R Squared = 0.999761 |
| Live Oil Density (g/cc) | (P <= Psat) | y=(-1.945116*x^2 + 25.383147*x + 0.243755)/(32.486345*x + 0.298158)<br>R Squared = 0.999336 |
| Oil FVF [1] | (P >= Psat) | y=(-0.032861*x^2 + 2.582764*x + 1.927707)/(2.036328*x + 1.354329)<br>R Squared = 0.999798 |
| Oil FVF [1] | (P <= Psat) | y=(0.320476*x^2 + 1.676053*x + 0.016304)/(1.508507*x + 0.015609)<br>R Squared = 0.999951 |
| GOR (vol/vol) | (P <= Psat) | y=(57.085208*x^2 + 2.840529*x + -0.012996)/(0.546822*x + 0.001828)<br>R Squared = 0.999408 |
| Oil Viscosity (cp=mPa.s) | (P >= Psat) | y=(0.245314*x^2 + 3.757580*x + 0.000354)/(5.341867*x + 0.924598)<br>R Squared = 0.995839 |
| Oil Viscosity (cp=mPa.s) | (P <= Psat) | y=(-1.951017*x^2 + 4.484478*x + 1.276190)/(5.851316*x + 0.119205)<br>R Squared = 0.999787 |

y is the measured parameter and x = P/Psat, dimensionless
[1] Barrels (Cubic meters) of oil at indicated pressure and temperature per barrel (cubic meter) of residual oil @ 60 F (288.7 K).
[2] Cubic feet (meters) of gas at indicated pressure and temperature per cubic feet (meter) @ standard conditions

**FIGURE 1**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT COMPOSITION EXPANSION @ 190.6 F (88.1 C)**



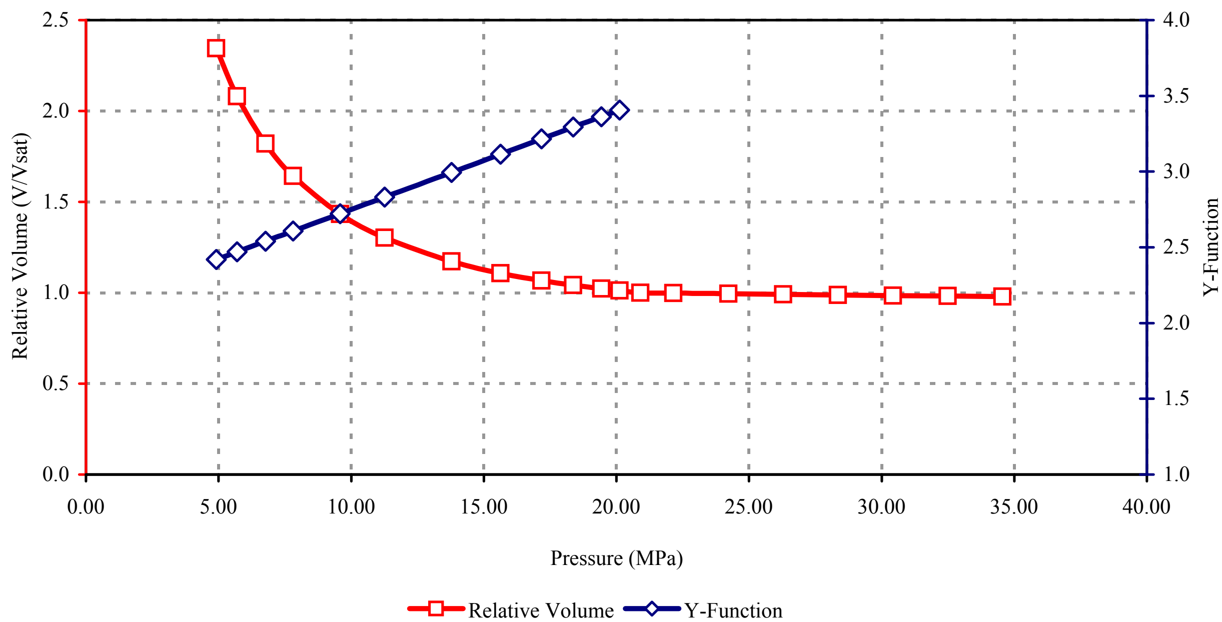
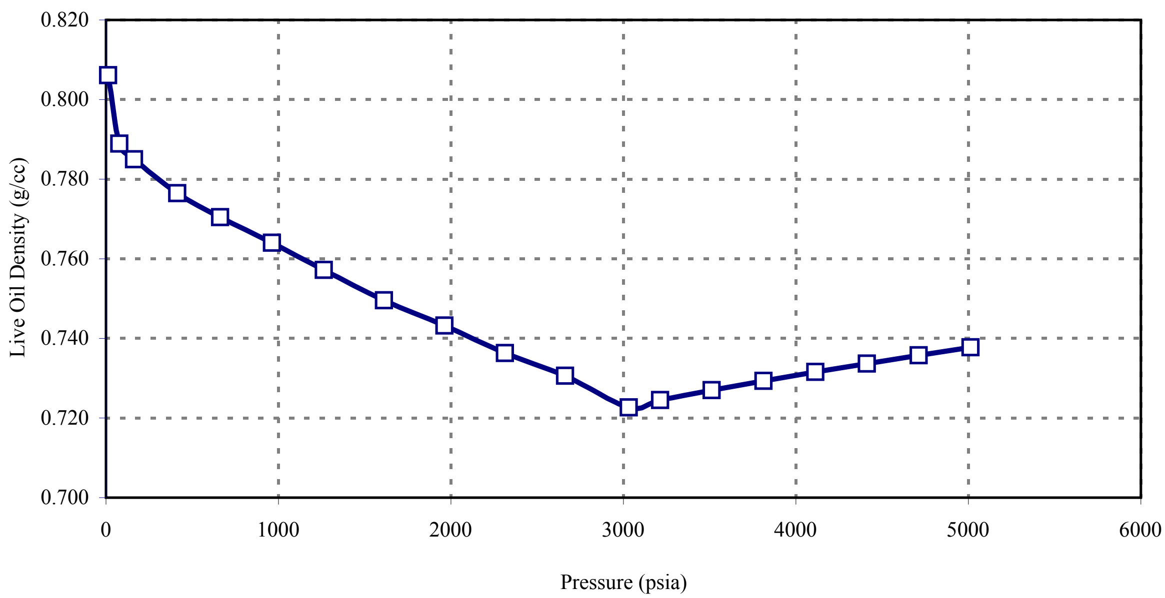



**FIGURE 2**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**DIFFERENTIAL LIBERATION OIL DENSITY @ 190.6 F (88.1 C)**



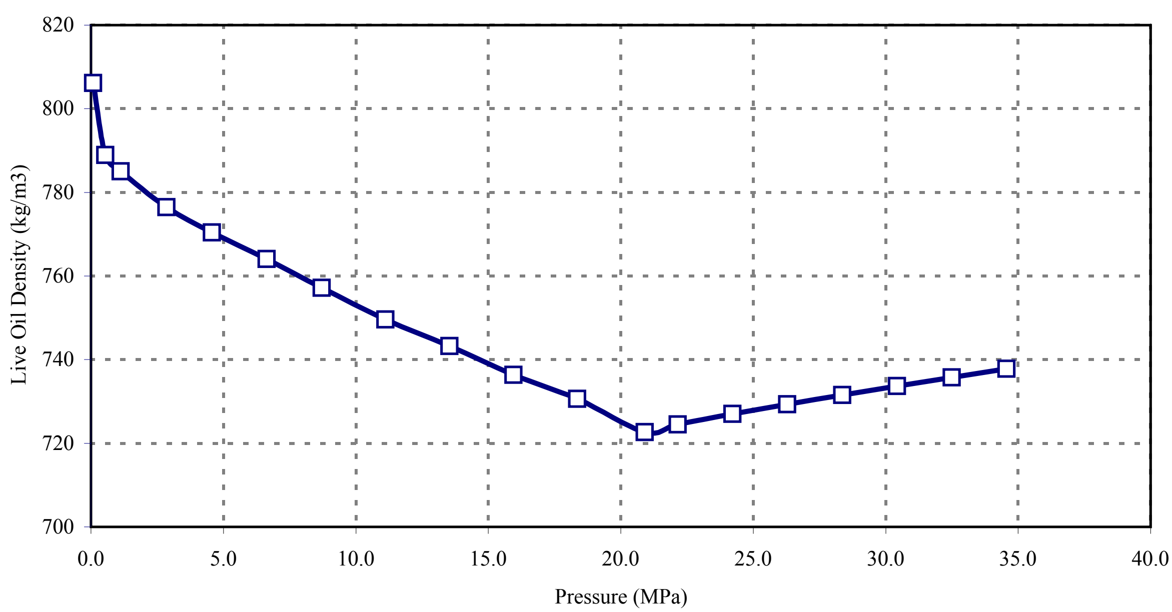
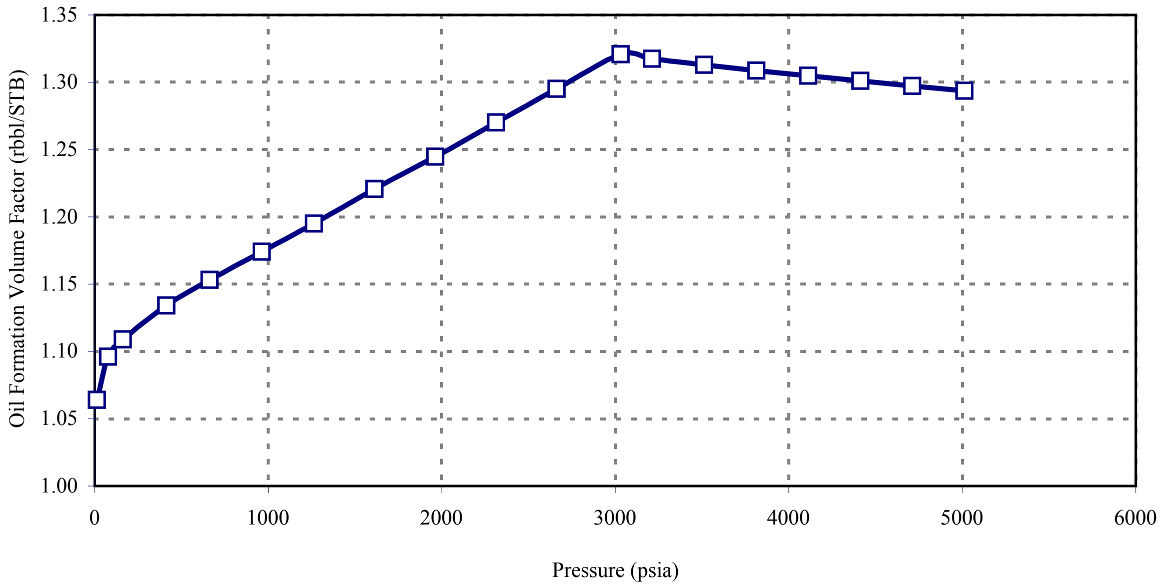



**FIGURE 2**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**DIFFERENTIAL LIBERATION OIL FORMATION VOLUME FACTOR @ 190.6 F (88.1 C)**



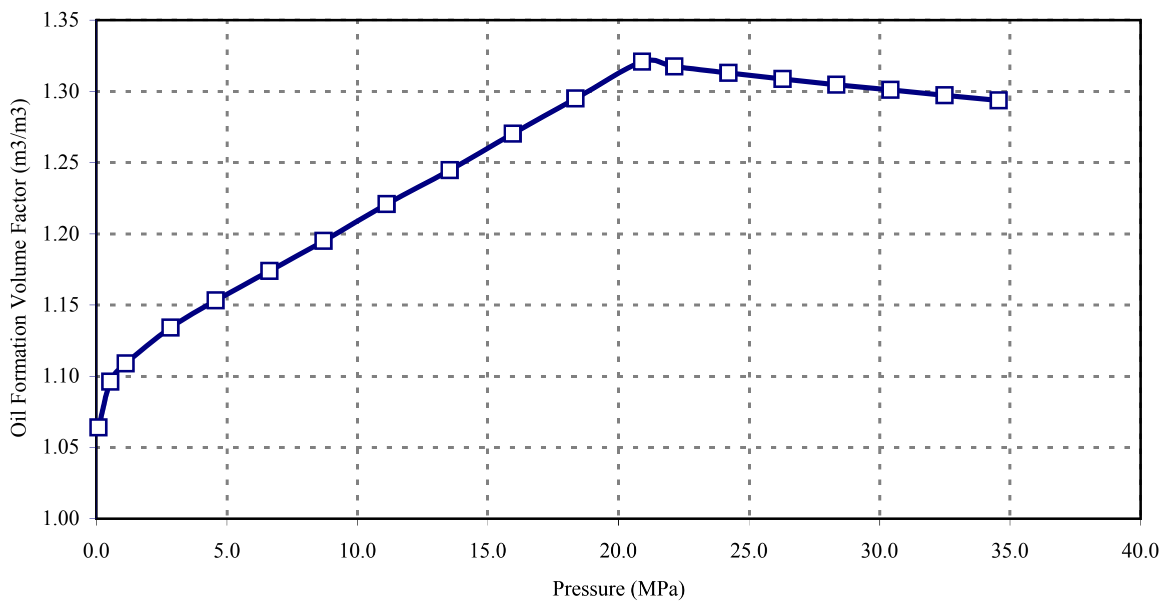
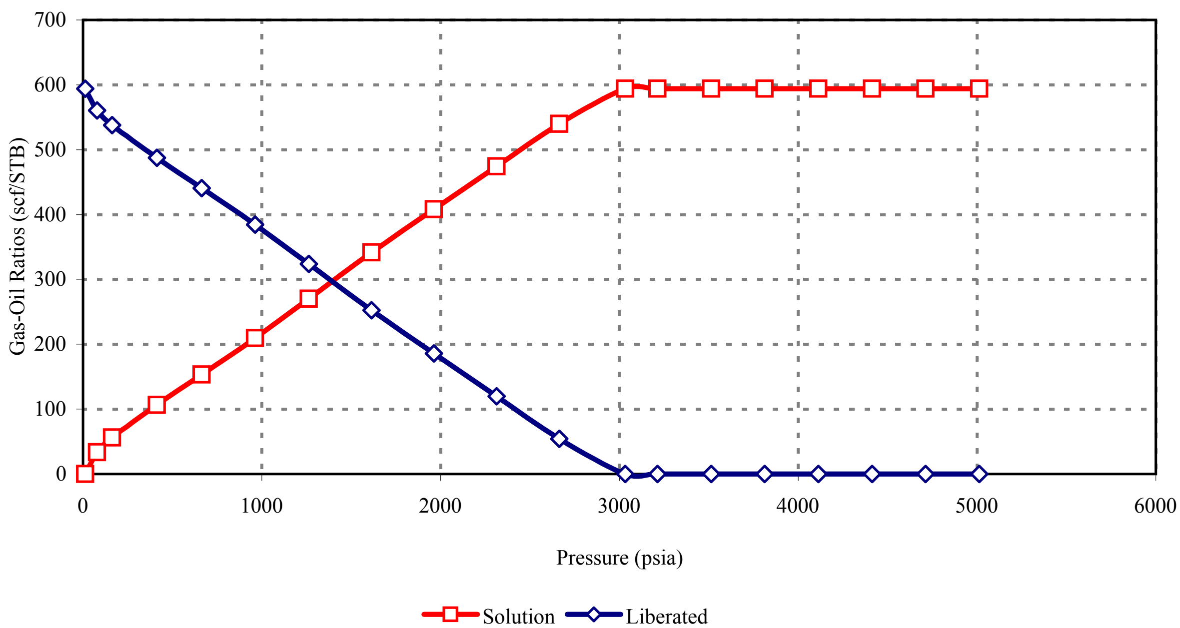



**FIGURE 4**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**DIFFERENTIAL LIBERATION GAS-OIL RATIOS @ 190.6 F (88.1 C)**



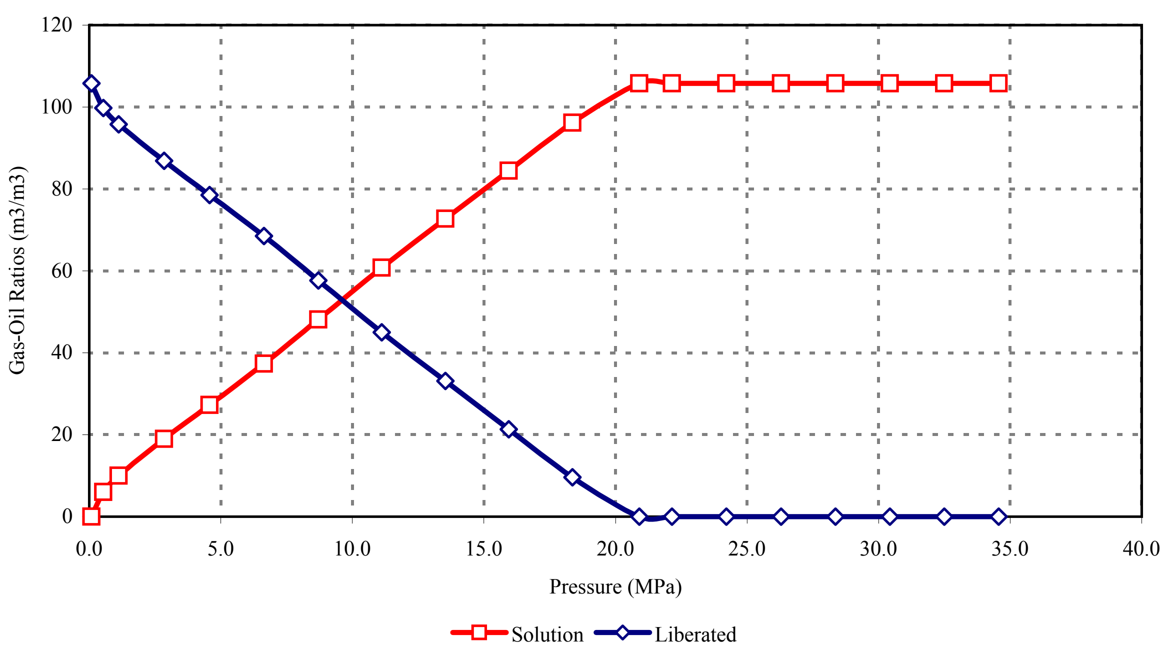
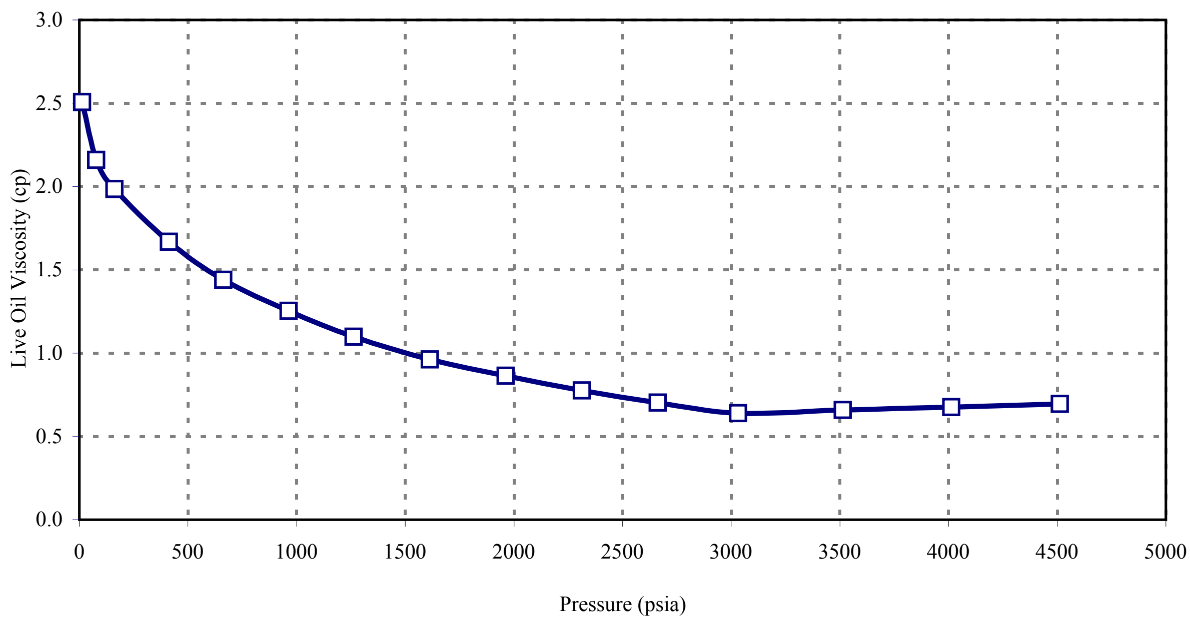



**FIGURE 5**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**DIFFERENTIAL LIBERATION OIL VISCOSITY @ 190.6 F (88.1 C)**



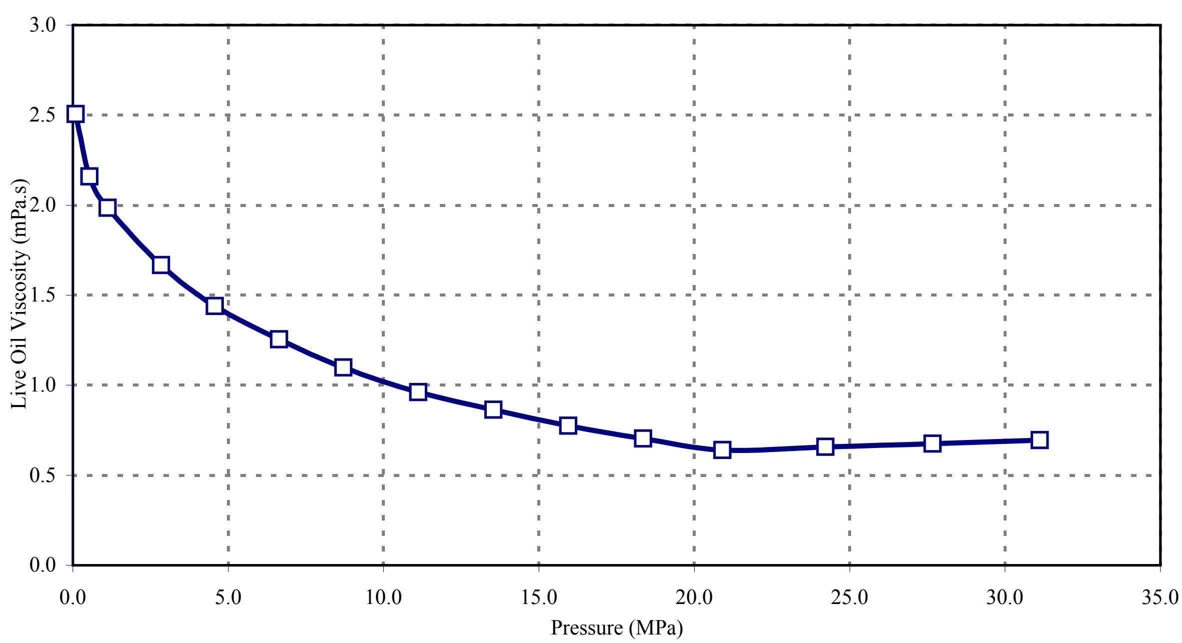
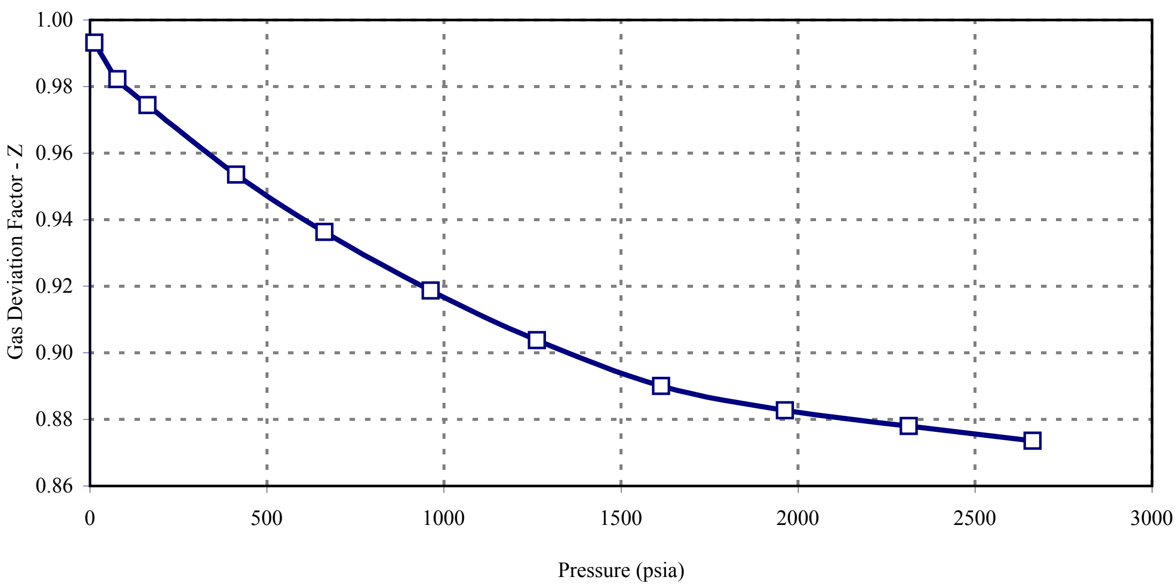



**FIGURE 6**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**DIFFERENTIAL LIBERATION GAS DEVIATION FACTOR @ 190.6 F (88.1 C)**



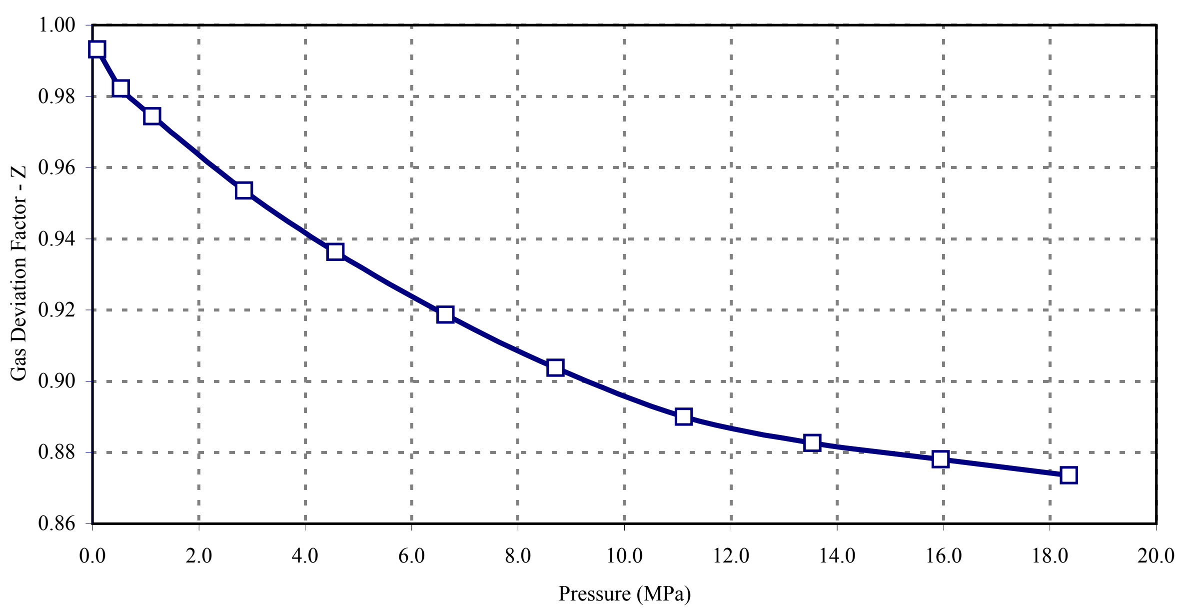
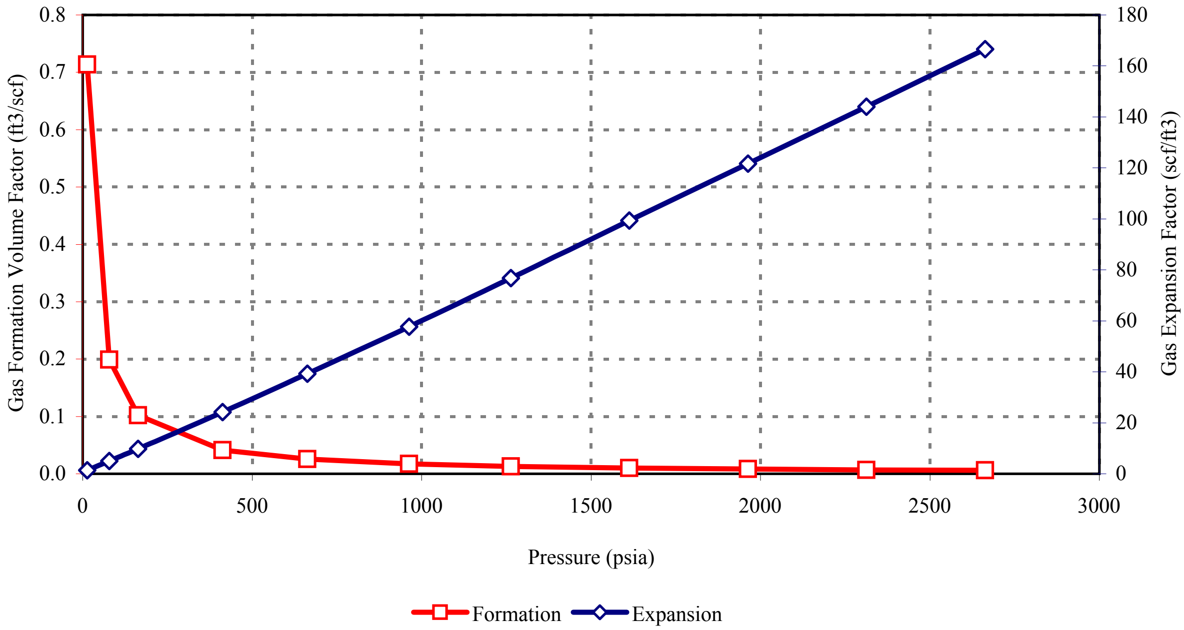



**FIGURE 7**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**DIFFERENTIAL LIBERATION GAS VOLUME FACTORS @ 190.6 F (88.1 C)**



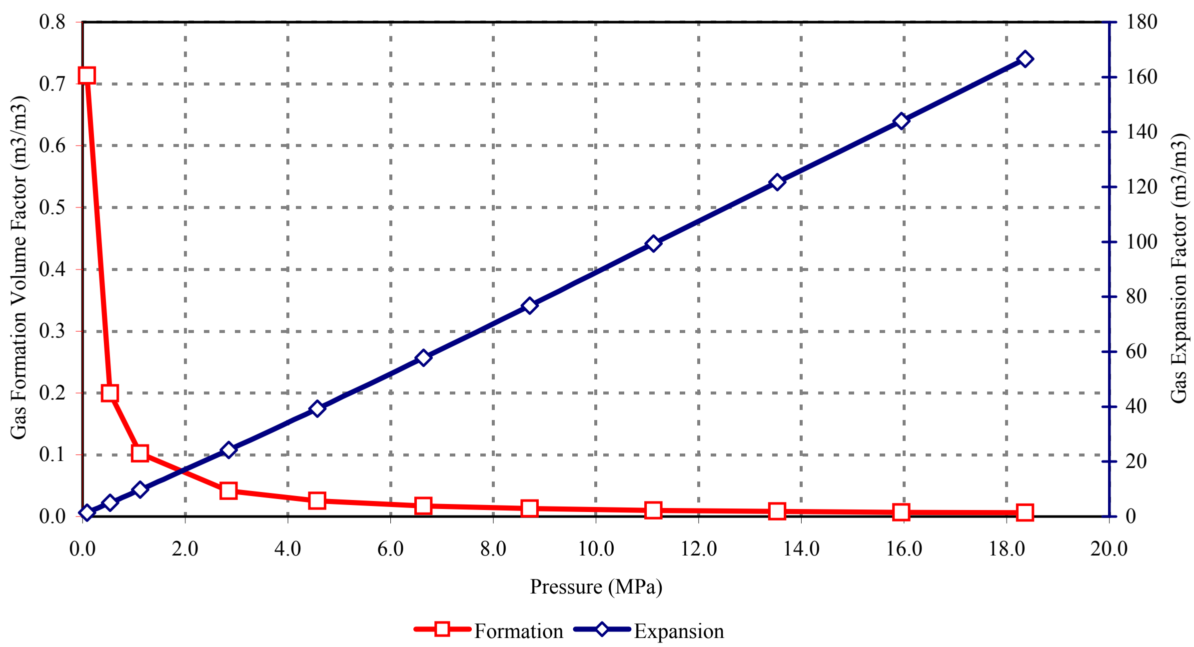
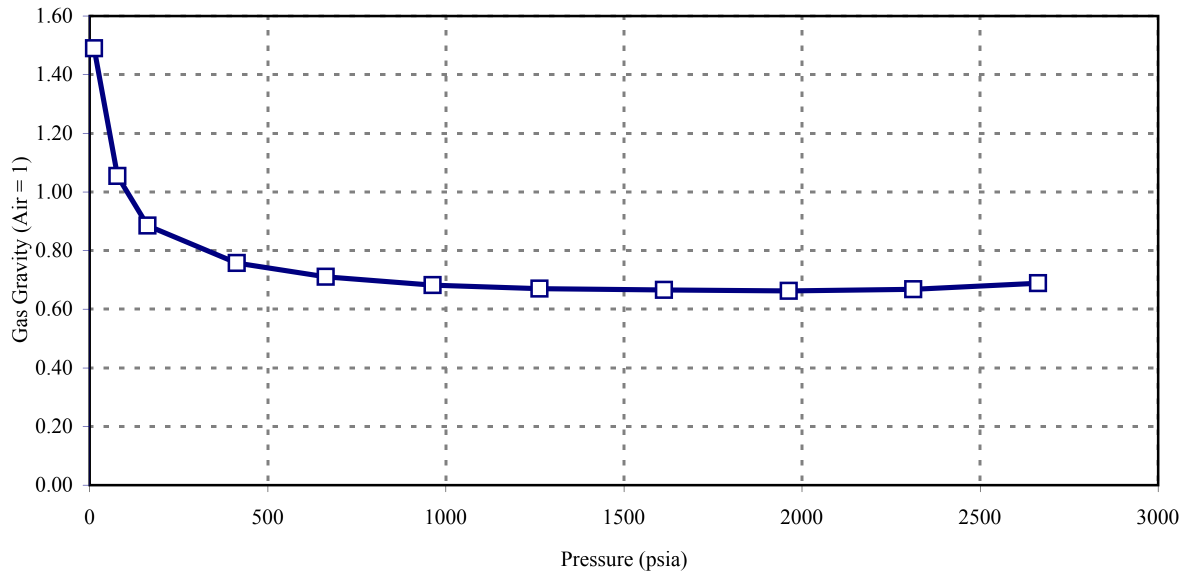



**FIGURE 8**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**DIFFERENTIAL LIBERATION GAS GRAVITY @ 190.6 F (88.1 C)**



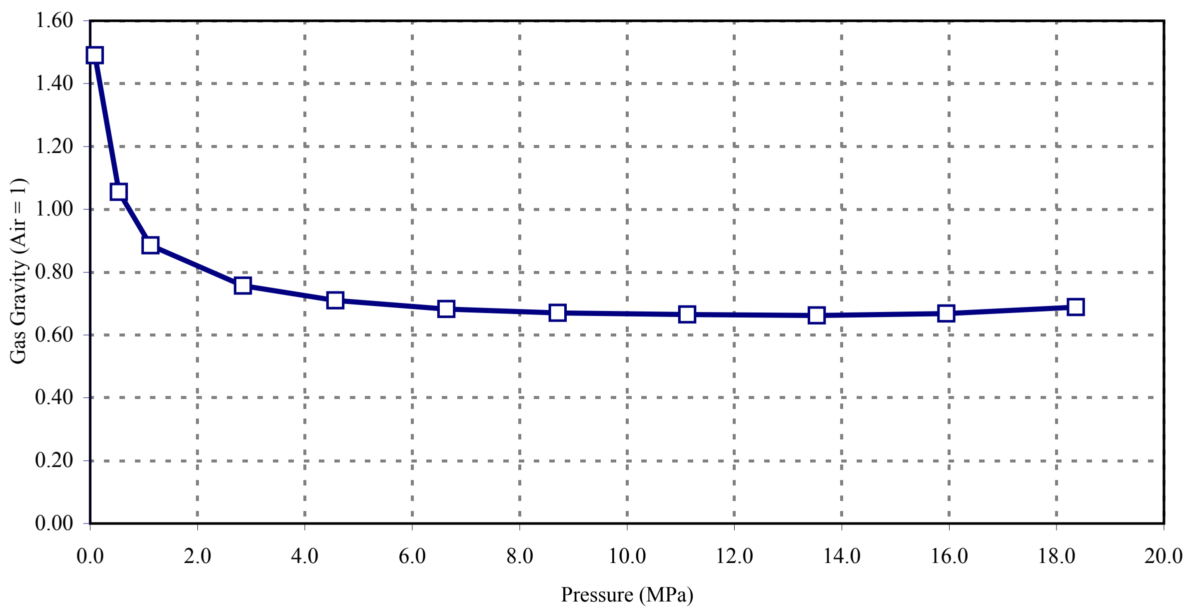
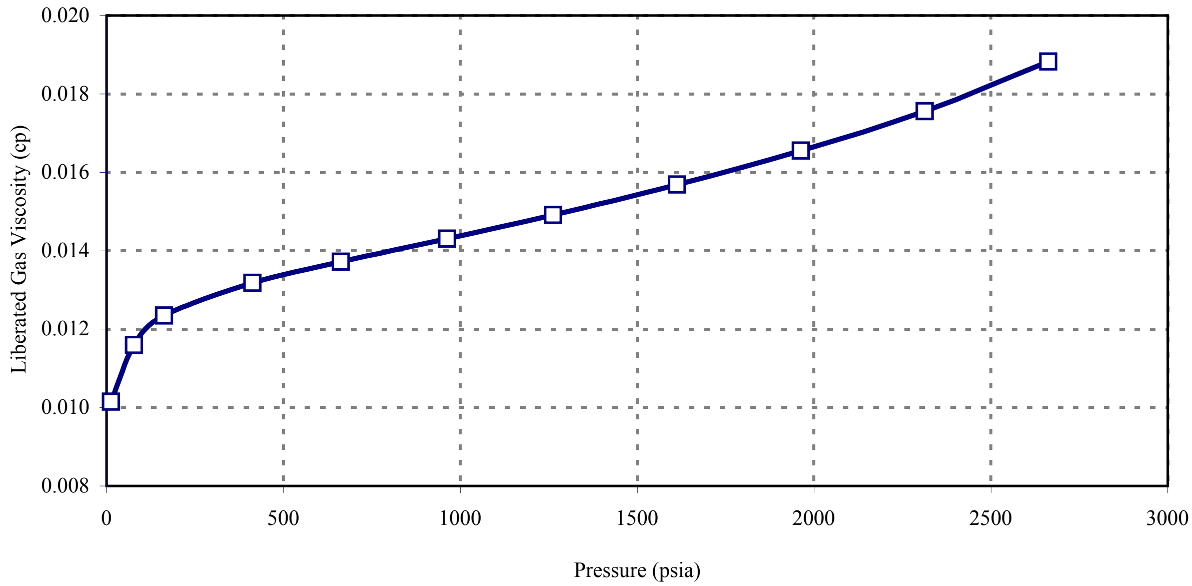



**FIGURE 9**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**DIFFERENTIAL LIBERATION GAS VISCOSITY @ 190.6 F (88.1 C)**



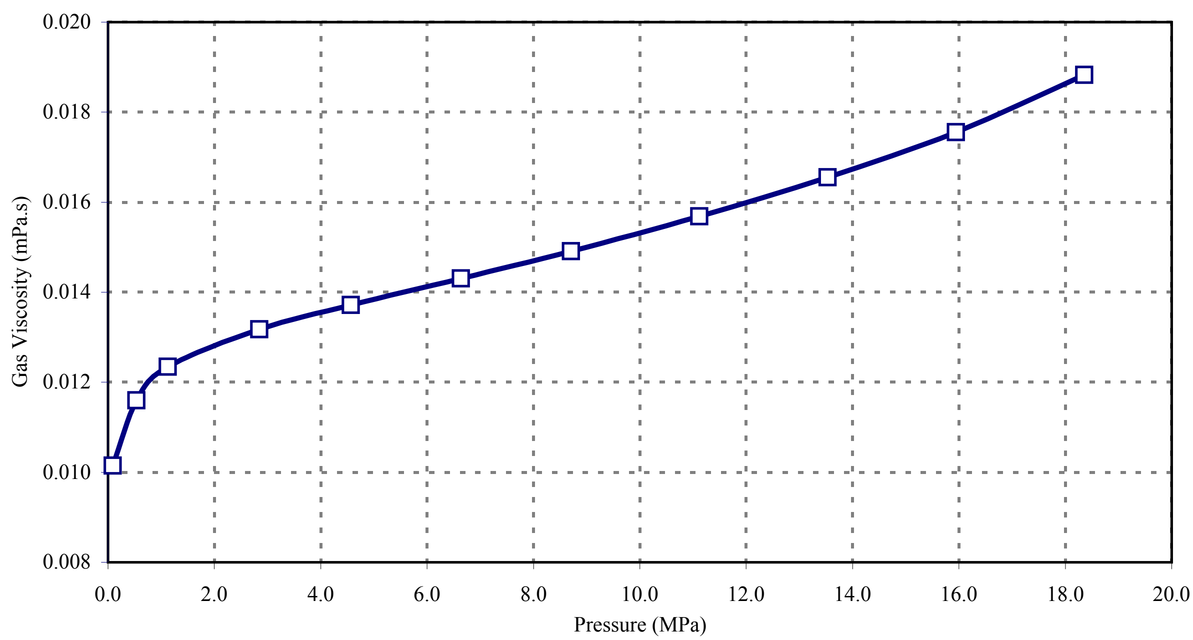
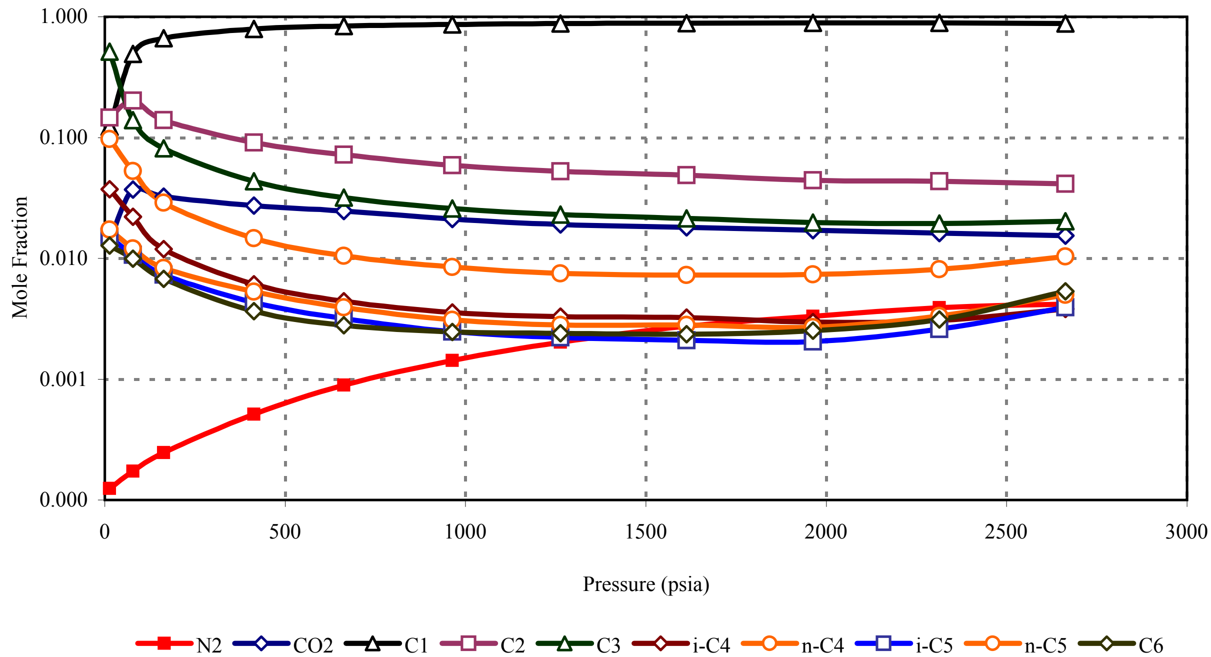
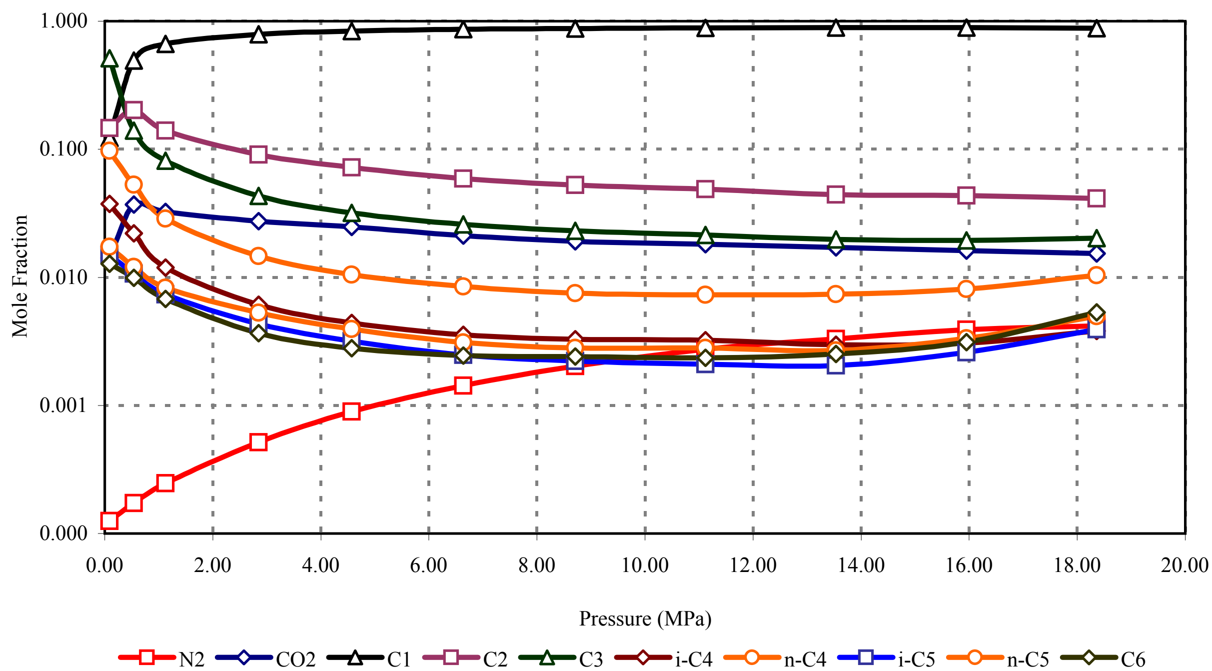



**FIGURE 10**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**LIBERATED GAS COMPOSITION PROFILE @ 190.6 F (88.1 C)**



# APPENDIX A

**SAMPLE VALIDATION**

## TABLE A1
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF RESERVOIR FLUID

| Boiling Point (F) | Component Name | Chemical Symbol | Mole Fraction | Mass Fraction | Calculated Properties | |
|---|---|---|---|---|---|---|
| -320.4 | Nitrogen | $N_2$ | 0.0017 | 0.0004 | **Total Sample** | |
| -109.3 | Carbon Dioxide | $CO_2$ | 0.0122 | 0.0047 | | |
| -76.6 | Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | Molecular Weight | 113.92 |
| -259.1 | Methane | $C_1$ | 0.4349 | 0.0613 | Density (g/cc) | 0.7536 |
| -128.0 | Ethane | $C_2$ | 0.0408 | 0.0108 | | |
| -44.0 | Propane | $C_3$ | 0.0281 | 0.0109 | **$C_{6+}$ Fraction** | |
| 10.9 | i-Butane | $i\text{-}C_4$ | 0.0058 | 0.0030 | | |
| 30.9 | n-Butane | $n\text{-}C_4$ | 0.0168 | 0.0086 | Molecular Weight | 229.81 |
| 82.0 | i-Pentane | $i\text{-}C_5$ | 0.0076 | 0.0048 | Mole Fraction | 0.4403 |
| 97.0 | n-Pentane | $n\text{-}C_5$ | 0.0117 | 0.0074 | Density (g/cc) | 0.8668 |
| 97 - 156 | Hexanes | $C_6$ | 0.0174 | 0.0132 | | |
| 156 - 208.9 | Heptanes | $C_7$ | 0.0181 | 0.0160 | **$C_{7+}$ Fraction** | |
| 208.9 - 258.1 | Octanes | $C_8$ | 0.0235 | 0.0235 | | |
| 258.1 - 303.1 | Nonanes | $C_9$ | 0.0238 | 0.0268 | Molecular Weight | 236.12 |
| 303.1 - 345 | Decanes | $C_{10}$ | 0.0218 | 0.0273 | Mole Fraction | 0.4209 |
| 345 - 385 | Undecanes | $C_{11}$ | 0.0244 | 0.0314 | Density (g/cc) | 0.8704 |
| 385 - 419 | Dodecanes | $C_{12}$ | 0.0264 | 0.0374 | | |
| 419 - 455 | Tridecanes | $C_{13}$ | 0.0263 | 0.0403 | **$C_{12+}$ Fraction** | |
| 455 - 486 | Tetradecanes | $C_{14}$ | 0.0213 | 0.0355 | | |
| 486 - 519.1 | Pentadecanes | $C_{15}$ | 0.0175 | 0.0317 | Molecular Weight | 310.14 |
| 519.1 - 550 | Hexadecanes | $C_{16}$ | 0.0161 | 0.0314 | Mole Fraction | 0.2605 |
| 550 - 557 | Heptadecanes | $C_{17}$ | 0.0137 | 0.0285 | Density (g/cc) | 0.8958 |
| 557 - 603 | Octadecanes | $C_{18}$ | 0.0137 | 0.0301 | | |
| 603 - 626 | Nonadecanes | $C_{19}$ | 0.0112 | 0.0258 | **$C_{30+}$ Fraction** | |
| 626 - 651.9 | Eicosanes | $C_{20}$ | 0.0089 | 0.0215 | | |
| 651.9 - 675 | Heneicosanes | $C_{21}$ | 0.0079 | 0.0202 | Molecular Weight | 592.13 |
| 675 - 696.9 | Docosanes | $C_{22}$ | 0.0073 | 0.0196 | Mole Fraction | 0.0507 |
| 696.9 - 716 | Tricosanes | $C_{23}$ | 0.0068 | 0.0190 | Density (g/cc) | 0.9851 |
| 716 - 736 | Tetracosanes | $C_{24}$ | 0.0061 | 0.0178 | | |
| 736 - 755.1 | Pentacosanes | $C_{25}$ | 0.0060 | 0.0182 | | |
| 755.1 - 774 | Hexacosanes | $C_{26}$ | 0.0054 | 0.0172 | **Recombination Parameters** | |
| 774.1 - 792 | Heptacosanes | $C_{27}$ | 0.0051 | 0.0168 | | |
| 792.1 - 809.1 | Octacosanes | $C_{28}$ | 0.0051 | 0.0174 | Gas-Oil Ratio (cc/cc) | 104.30 |
| 809.1 - 826 | Nonacosanes | $C_{29}$ | 0.0049 | 0.0173 | Dead Oil Density (g/cc) | 0.8430 |
| Above 826 | Tricontanes Plus | $C_{30+}$ | 0.0507 | 0.2636 | Dead Oil MW (g/mol) | 220.80 |
| | NAPHTHENES | | | | | |
| 120.0 | Cyclopentane | $C_5H_{10}$ | 0.0019 | 0.0012 | | |
| 162.0 | Methylcyclopentane | $C_6H_{12}$ | 0.0086 | 0.0063 | | |
| 178.0 | Cyclohexane | $C_6H_{12}$ | 0.0073 | 0.0054 | | |
| 214.0 | Methylcyclohexane | $C_7H_{14}$ | 0.0103 | 0.0089 | | |
| | AROMATICS | | | | | |
| 176.0 | Benzene | $C_6H_6$ | 0.0063 | 0.0043 | | |
| 231.1 | Toluene | $C_7H_8$ | 0.0082 | 0.0066 | | |
| 277 - 282 | Ethylbenzene & p,m-Xylene | $C_8H_{10}$ | 0.0029 | 0.0027 | | |
| 291.9 | o-Xylene | $C_8H_{10}$ | 0.0019 | 0.0017 | | |
| 336.0 | 1, 2, 4-Trimethylbenzene | $C_9H_{12}$ | 0.0034 | 0.0035 | | |
| **Total** | | | **1.0000** | **1.0000** | | |

Note: Physical Properties calculated based GPA 2145-00 physical constants

## TABLE A2
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF FLASHED OIL

| Boiling Point (F) | Component Name | Chemical Symbol | Mole Fraction | Mass Fraction |
|---|---|---|---|---|
| -320.4 | Nitrogen | $N_2$ | 0.0000 | 0.0000 |
| -109.3 | Carbon Dioxide | $CO_2$ | 0.0000 | 0.0000 |
| -76.6 | Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 |
| -259.1 | Methane | $C_1$ | 0.0000 | 0.0000 |
| -128.0 | Ethane | $C_2$ | 0.0000 | 0.0000 |
| -44.0 | Propane | $C_3$ | 0.0102 | 0.0029 |
| 10.9 | i-Butane | $i\text{-}C_4$ | 0.0052 | 0.0019 |
| 30.9 | n-Butane | $n\text{-}C_4$ | 0.0190 | 0.0071 |
| 82.0 | i-Pentane | $i\text{-}C_5$ | 0.0116 | 0.0053 |
| 97.0 | n-Pentane | $n\text{-}C_5$ | 0.0197 | 0.0091 |
| 97 - 156 | Hexanes | $C_6$ | 0.0338 | 0.0186 |
| 156 - 208.9 | Heptanes | $C_7$ | 0.0382 | 0.0245 |
| 208.9 - 258.1 | Octanes | $C_8$ | 0.0505 | 0.0370 |
| 258.1 - 303.1 | Nonanes | $C_9$ | 0.0512 | 0.0420 |
| 303.1 - 345 | Decanes | $C_{10}$ | 0.0470 | 0.0429 |
| 345 - 385 | Undecanes | $C_{11}$ | 0.0525 | 0.0494 |
| 385 - 419 | Dodecanes | $C_{12}$ | 0.0570 | 0.0587 |
| 419 - 455 | Tridecanes | $C_{13}$ | 0.0565 | 0.0634 |
| 455 - 486 | Tetradecanes | $C_{14}$ | 0.0458 | 0.0557 |
| 486 - 519.1 | Pentadecanes | $C_{15}$ | 0.0378 | 0.0498 |
| 519.1 - 550 | Hexadecanes | $C_{16}$ | 0.0347 | 0.0494 |
| 550 - 557 | Heptadecanes | $C_{17}$ | 0.0295 | 0.0448 |
| 557 - 603 | Octadecanes | $C_{18}$ | 0.0294 | 0.0473 |
| 603 - 626 | Nonadecanes | $C_{19}$ | 0.0241 | 0.0406 |
| 626 - 651.9 | Eicosanes | $C_{20}$ | 0.0192 | 0.0338 |
| 651.9 - 675 | Heneicosanes | $C_{21}$ | 0.0170 | 0.0318 |
| 675 - 696.9 | Docosanes | $C_{22}$ | 0.0157 | 0.0307 |
| 696.9 - 716 | Tricosanes | $C_{23}$ | 0.0147 | 0.0299 |
| 716 - 736 | Tetracosanes | $C_{24}$ | 0.0132 | 0.0280 |
| 736 - 755.1 | Pentacosanes | $C_{25}$ | 0.0129 | 0.0285 |
| 755.1 - 774 | Hexacosanes | $C_{26}$ | 0.0117 | 0.0270 |
| 774.1 - 792 | Heptacosanes | $C_{27}$ | 0.0110 | 0.0263 |
| 792.1 - 809.1 | Octacosanes | $C_{28}$ | 0.0110 | 0.0274 |
| 809.1 - 826 | Nonacosanes | $C_{29}$ | 0.0106 | 0.0272 |
| Above 826 | Tricontanes Plus | $C_{30+}$ | 0.1092 | 0.2929 |
| | NAPHTHENES | | | |
| 120.0 | Cyclopentane | $C_5H_{10}$ | 0.0042 | 0.0019 |
| 162.0 | Methylcyclopentane | $C_6H_{12}$ | 0.0111 | 0.0060 |
| 178.0 | Cyclohexane | $C_6H_{12}$ | 0.0150 | 0.0081 |
| 214.0 | Methylcyclohexane | $C_7H_{14}$ | 0.0220 | 0.0138 |
| | AROMATICS | | | |
| 176.0 | Benzene | $C_6H_6$ | 0.0130 | 0.0065 |
| 231.1 | Toluene | $C_7H_8$ | 0.0175 | 0.0103 |
| 277 - 282 | Ethylbenzene & p,m-Xylene | $C_8H_{10}$ | 0.0063 | 0.0043 |
| 291.9 | o-Xylene | $C_8H_{10}$ | 0.0040 | 0.0027 |
| 336.0 | 1, 2, 4-Trimethylbenzene | $C_9H_{12}$ | 0.0072 | 0.0056 |
| **Total** | | | **1.0000** | **1.2929** |

| Calculated Properties | |
|---|---|
| **Total Sample** | |
| Molecular Weight | 220.80 |
| Density (g/cc) | 0.8601 |
| **$C_{6+}$ Fraction** | |
| Molecular Weight | 231.91 |
| Mole Fraction | 0.9344 |
| Density (g/cc) | 0.8676 |
| **$C_{7+}$ Fraction** | |
| Molecular Weight | 238.16 |
| Mole Fraction | 0.8964 |
| Density (g/cc) | 0.8710 |
| **$C_{12+}$ Fraction** | |
| Molecular Weight | 310.14 |
| Mole Fraction | 0.5610 |
| Density (g/cc) | 0.8958 |
| **$C_{30+}$ Fraction** | |
| Molecular Weight | 592.13 |
| Mole Fraction | 0.0507 |
| Density (g/cc) | 0.9851 |

Note: Physical Properties calculated based GPA 2145-00 physical constants

## TABLE A3
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF FLASHED GAS

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0033 | 0.0033 | | |
| Carbon Dioxide | $CO_2$ | 0.0228 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.8120 | 0.8309 | | |
| Ethane | $C_2$ | 0.0761 | 0.0779 | | |
| Propane | $C_3$ | 0.0437 | 0.0448 | 28.562 | 160.364 |
| i-Butane | $i\text{-}C_4$ | 0.0064 | 0.0065 | 4.946 | 27.769 |
| n-Butane | $n\text{-}C_4$ | 0.0149 | 0.0153 | 11.182 | 62.781 |
| i-Pentane | $i\text{-}C_5$ | 0.0041 | 0.0042 | 3.548 | 19.918 |
| n-Pentane | $n\text{-}C_5$ | 0.0049 | 0.0050 | 4.170 | 23.414 |
| Hexanes | $C_6$ | 0.0033 | 0.0034 | 3.211 | 18.027 |
| Heptanes | $C_7$ | 0.0081 | 0.0083 | 8.897 | 49.952 |
| Octanes | $C_8$ | 0.0004 | 0.0004 | 0.523 | 2.935 |
| Nonanes | $C_9$ | 0.0000 | 0.0000 | 0.056 | 0.314 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **65.095** | **365.474** |
| Propanes Plus | $C_{3+}$ | 0.0859 | 0.0879 | 65.095 | 365.474 |
| Butanes Plus | $C_{4+}$ | 0.0421 | 0.0431 | 36.532 | 205.110 |
| Pentanes Plus | $C_{5+}$ | 0.0208 | 0.0213 | 20.404 | 114.559 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 21.34 kg/kmol | 21.34 lb/lb-mol | Ppc | 669.9 psia | 4.62 MPa |
| Specific Gravity | 0.7367 (Air = 1) | 0.7367 (Air = 1) | Tpc | 397.8 R | 221.0 K |
| MW of C7+ | 0.83 kg/kmol | 0.83 lb/lbmol | Ppc* | 663.6 psia | 4.58 MPa |
| Density of C7+ | 0.7234 g/cc | 723.4 kg/m3 | Tpc* | 394.0 R | 218.9 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,233.2 Btu/scf | 46.03 MJ/m3 | Dry | 1,118.4 Btu/scf | 41.75 MJ/m3 |
| Wet | 1,211.7 Btu/scf | 45.23 MJ/m3 | Wet | 1,099.0 Btu/scf | 41.02 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 7926

# APPENDIX B

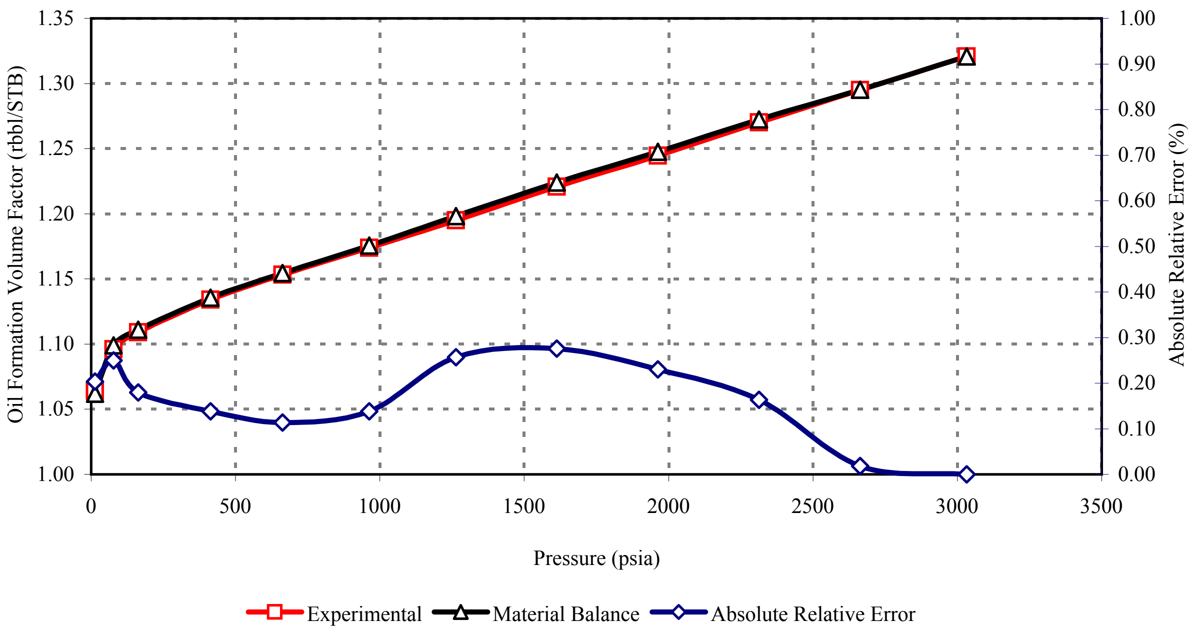
**DIFFERENTIAL LIBERATION - MATERIAL BALANCE**

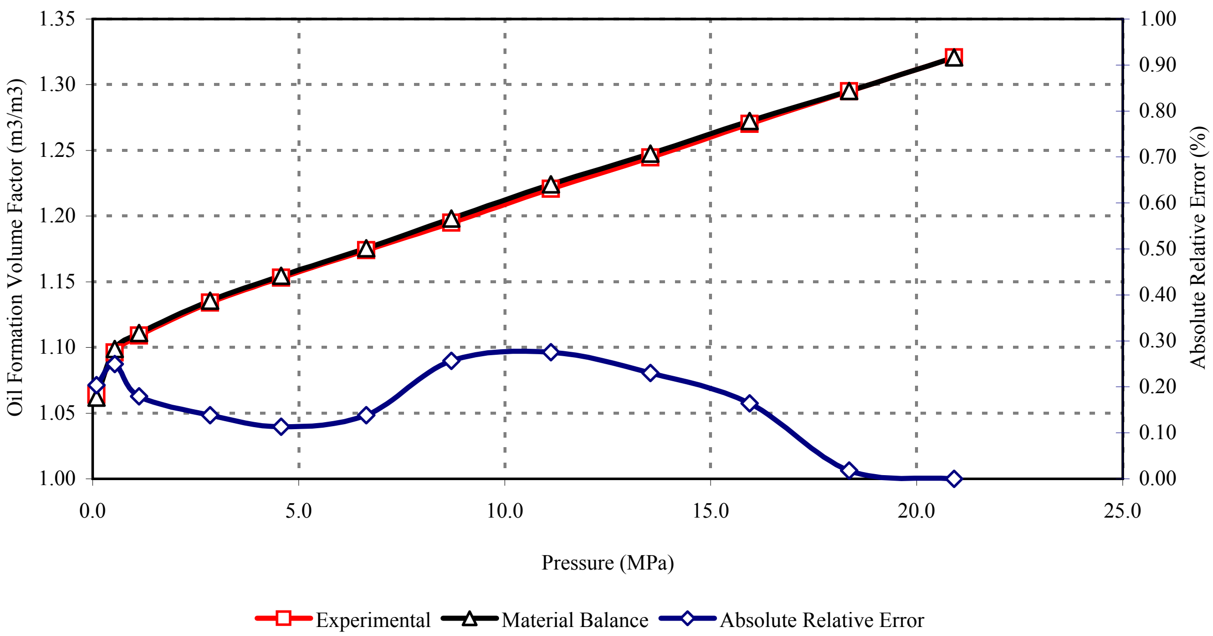
**TABLE B1**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**DIFFERENTIAL LIBERATION @ 190.6 F (88.1 C) - MATERIAL BALANCE**

| Pressure (psia) | Pressure (MPa) | Measured Oil FVF [1] | Calculated Oil FVF [1] | Absolute Relative Error (%) |
|---|---|---|---|---|
| **3032 Psat** | **20.90** | **1.3208** | **1.3208** | **0.0000** |
| 2663 | 18.36 | 1.2951 | 1.2953 | 0.0184 |
| 2313 | 15.95 | 1.2702 | 1.2723 | 0.1638 |
| 1963 | 13.53 | 1.2447 | 1.2476 | 0.2302 |
| 1613 | 11.12 | 1.2207 | 1.2241 | 0.2757 |
| 1263 | 8.71 | 1.1951 | 1.1981 | 0.2565 |
| 963 | 6.64 | 1.1739 | 1.1756 | 0.1384 |
| 663 | 4.57 | 1.1532 | 1.1545 | 0.1135 |
| 413 | 2.85 | 1.1341 | 1.1357 | 0.1381 |
| 163 | 1.12 | 1.1089 | 1.1109 | 0.1796 |
| 78 | 0.54 | 1.0962 | 1.0989 | 0.2496 |
| 13 | 0.09 | 1.0640 | 1.0618 | 0.2035 |

[1] (res bbl/STB) (res m3/m3)
Psat - Saturation Pressure
- Tank conditions: 60 F (288.7 K) @ 13 psia (0.09 MPa)

**FIGURE B1**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**DIFFERENTIAL LIBERATION @ 190.6 F (88.1 C) - MATERIAL BALANCE**



# APPENDIX C

**DIFFERENTIAL LIBERATION - LIBERATED GAS ANALYSES**

## TABLE C1
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## DIFFERENTIAL LIBERATION GAS COMPOSITION @ 2,663 psia (18.36 MPa )

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0042 | 0.0042 | | |
| Carbon Dioxide | $CO_2$ | 0.0154 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.8804 | 0.8941 | | |
| Ethane | $C_2$ | 0.0413 | 0.0419 | | |
| Propane | $C_3$ | 0.0202 | 0.0205 | 13.212 | 74.182 |
| i-Butane | $i\text{-}C_4$ | 0.0038 | 0.0039 | 2.956 | 16.599 |
| n-Butane | $n\text{-}C_4$ | 0.0104 | 0.0106 | 7.781 | 43.687 |
| i-Pentane | $i\text{-}C_5$ | 0.0039 | 0.0040 | 3.414 | 19.167 |
| n-Pentane | $n\text{-}C_5$ | 0.0050 | 0.0051 | 4.284 | 24.055 |
| Hexanes | $C_6$ | 0.0053 | 0.0054 | 5.210 | 29.249 |
| Heptanes | $C_7$ | 0.0096 | 0.0097 | 10.484 | 58.865 |
| Octanes | $C_8$ | 0.0005 | 0.0005 | 0.549 | 3.081 |
| Nonanes | $C_9$ | 0.0000 | 0.0000 | 0.064 | 0.361 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **47.955** | **269.246** |
| Propanes Plus | $C_{3+}$ | 0.0588 | 0.0597 | 47.955 | 269.246 |
| Butanes Plus | $C_{4+}$ | 0.0385 | 0.0391 | 34.743 | 195.064 |
| Pentanes Plus | $C_{5+}$ | 0.0243 | 0.0247 | 24.005 | 134.779 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 19.95 kg/kmol | 19.95 lb/lb-mol | Ppc | 666.6 psia | 4.60 MPa |
| Specific Gravity | 0.6889 (Air = 1) | 0.6889 (Air = 1) | Tpc | 380.5 R | 211.4 K |
| MW of C7+ | 96.61 kg/kmol | 96.61 lb/lbmol | Ppc* | 661.9 psia | 4.56 MPa |
| Density of C7+ | 0.7232 g/cc | 723.2 kg/m3 | Tpc* | 377.9 R | 209.9 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,176.2 Btu/scf | 43.90 MJ/m3 | Dry | 1,065.0 Btu/scf | 39.75 MJ/m3 |
| Wet | 1,155.7 Btu/scf | 43.14 MJ/m3 | Wet | 1,046.5 Btu/scf | 39.06 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa) GC No.: 7958

## TABLE C2
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## DIFFERENTIAL LIBERATION GAS COMPOSITION @ 2,313 psia (15.95 MPa )

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0039 | 0.0040 | | |
| Carbon Dioxide | $CO_2$ | 0.0162 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.8891 | 0.9037 | | |
| Ethane | $C_2$ | 0.0434 | 0.0441 | | |
| Propane | $C_3$ | 0.0194 | 0.0197 | 12.675 | 71.163 |
| i-Butane | $i\text{-}C_4$ | 0.0031 | 0.0031 | 2.373 | 13.321 |
| n-Butane | $n\text{-}C_4$ | 0.0081 | 0.0083 | 6.080 | 34.136 |
| i-Pentane | $i\text{-}C_5$ | 0.0026 | 0.0026 | 2.255 | 12.660 |
| n-Pentane | $n\text{-}C_5$ | 0.0033 | 0.0034 | 2.874 | 16.134 |
| Hexanes | $C_6$ | 0.0031 | 0.0032 | 3.052 | 17.133 |
| Heptanes | $C_7$ | 0.0074 | 0.0075 | 8.049 | 45.192 |
| Octanes | $C_8$ | 0.0004 | 0.0004 | 0.475 | 2.665 |
| Nonanes | $C_9$ | 0.0000 | 0.0000 | 0.058 | 0.326 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **37.889** | **212.730** |
| Propanes Plus | $C_{3+}$ | 0.0474 | 0.0482 | 37.889 | 212.730 |
| Butanes Plus | $C_{4+}$ | 0.0280 | 0.0285 | 25.215 | 141.567 |
| Pentanes Plus | $C_{5+}$ | 0.0168 | 0.0171 | 16.762 | 94.110 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 19.35 kg/kmol | 19.35 lb/lb-mol | Ppc | 669.1 psia | 4.61 MPa |
| Specific Gravity | 0.6680 (Air = 1) | 0.6680 (Air = 1) | Tpc | 375.4 R | 208.6 K |
| MW of C7+ | 96.69 kg/kmol | 96.69 lb/lbmol | Ppc* | 664.2 psia | 4.58 MPa |
| Density of C7+ | 0.7234 g/cc | 723.4 kg/m3 | Tpc* | 372.7 R | 207.0 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,141.6 Btu/scf | 42.61 MJ/m3 | Dry | 1,032.8 Btu/scf | 38.55 MJ/m3 |
| Wet | 1,121.8 Btu/scf | 41.87 MJ/m3 | Wet | 1,014.8 Btu/scf | 37.88 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 7965

## TABLE C3
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## DIFFERENTIAL LIBERATION GAS COMPOSITION @ 1,963 psia (13.53 MPa )

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0033 | 0.0034 | | |
| Carbon Dioxide | $CO_2$ | 0.0171 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.8909 | 0.9064 | | |
| Ethane | $C_2$ | 0.0442 | 0.0450 | | |
| Propane | $C_3$ | 0.0198 | 0.0202 | 12.934 | 72.619 |
| i-Butane | $i\text{-}C_4$ | 0.0030 | 0.0030 | 2.311 | 12.973 |
| n-Butane | $n\text{-}C_4$ | 0.0074 | 0.0075 | 5.521 | 30.995 |
| i-Pentane | $i\text{-}C_5$ | 0.0021 | 0.0021 | 1.783 | 10.012 |
| n-Pentane | $n\text{-}C_5$ | 0.0027 | 0.0027 | 2.311 | 12.975 |
| Hexanes | $C_6$ | 0.0025 | 0.0026 | 2.459 | 13.807 |
| Heptanes | $C_7$ | 0.0065 | 0.0066 | 7.074 | 39.716 |
| Octanes | $C_8$ | 0.0005 | 0.0005 | 0.631 | 3.542 |
| Nonanes | $C_9$ | 0.0000 | 0.0000 | 0.063 | 0.353 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **35.086** | **196.992** |
| Propanes Plus | $C_{3+}$ | 0.0444 | 0.0452 | 35.086 | 196.992 |
| Butanes Plus | $C_{4+}$ | 0.0246 | 0.0251 | 22.152 | 124.373 |
| Pentanes Plus | $C_{5+}$ | 0.0143 | 0.0145 | 14.321 | 80.405 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 19.18 kg/kmol | 19.18 lb/lb-mol | Ppc | 670.2 psia | 4.62 MPa |
| Specific Gravity | 0.6624 (Air = 1) | 0.6624 (Air = 1) | Tpc | 374.2 R | 207.9 K |
| MW of C7+ | 96.98 kg/kmol | 96.98 lb/lbmol | Ppc* | 665.0 psia | 4.59 MPa |
| Density of C7+ | 0.7240 g/cc | 724.0 kg/m3 | Tpc* | 371.3 R | 206.3 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,131.5 Btu/scf | 42.24 MJ/m3 | Dry | 1,023.4 Btu/scf | 38.20 MJ/m3 |
| Wet | 1,111.8 Btu/scf | 41.50 MJ/m3 | Wet | 1,005.6 Btu/scf | 37.54 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 7970

## TABLE C4
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## DIFFERENTIAL LIBERATION GAS COMPOSITION @ 1,613 psia (11.12 MPa )

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0027 | 0.0028 | | |
| Carbon Dioxide | $CO_2$ | 0.0181 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.8847 | 0.9010 | | |
| Ethane | $C_2$ | 0.0488 | 0.0497 | | |
| Propane | $C_3$ | 0.0215 | 0.0219 | 14.015 | 78.686 |
| i-Butane | $i\text{-}C_4$ | 0.0032 | 0.0033 | 2.510 | 14.091 |
| n-Butane | $n\text{-}C_4$ | 0.0073 | 0.0074 | 5.461 | 30.659 |
| i-Pentane | $i\text{-}C_5$ | 0.0021 | 0.0021 | 1.823 | 10.233 |
| n-Pentane | $n\text{-}C_5$ | 0.0028 | 0.0029 | 2.414 | 13.555 |
| Hexanes | $C_6$ | 0.0024 | 0.0024 | 2.298 | 12.899 |
| Heptanes | $C_7$ | 0.0057 | 0.0059 | 6.294 | 35.335 |
| Octanes | $C_8$ | 0.0006 | 0.0006 | 0.711 | 3.995 |
| Nonanes | $C_9$ | 0.0001 | 0.0001 | 0.085 | 0.475 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **35.609** | **199.928** |
| Propanes Plus | $C_{3+}$ | 0.0456 | 0.0465 | 35.609 | 199.928 |
| Butanes Plus | $C_{4+}$ | 0.0242 | 0.0246 | 21.594 | 121.242 |
| Pentanes Plus | $C_{5+}$ | 0.0137 | 0.0139 | 13.624 | 76.492 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 19.27 kg/kmol | 19.27 lb/lb-mol | Ppc | 671.0 psia | 4.63 MPa |
| Specific Gravity | 0.6654 (Air = 1) | 0.6654 (Air = 1) | Tpc | 375.7 R | 208.7 K |
| MW of C7+ | 97.25 kg/kmol | 97.25 lb/lbmol | Ppc* | 665.5 psia | 4.59 MPa |
| Density of C7+ | 0.7245 g/cc | 724.5 kg/m3 | Tpc* | 372.6 R | 207.0 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,134.6 Btu/scf | 42.35 MJ/m3 | Dry | 1,026.3 Btu/scf | 38.31 MJ/m3 |
| Wet | 1,114.8 Btu/scf | 41.61 MJ/m3 | Wet | 1,008.4 Btu/scf | 37.64 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 7978

**TABLE C5**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**DIFFERENTIAL LIBERATION GAS COMPOSITION @ 1,263 psia (8.71 MPa )**

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0020 | 0.0021 | | |
| Carbon Dioxide | $CO_2$ | 0.0191 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.8786 | 0.8956 | | |
| Ethane | $C_2$ | 0.0527 | 0.0537 | | |
| Propane | $C_3$ | 0.0231 | 0.0236 | 15.091 | 84.730 |
| i-Butane | $i\text{-}C_4$ | 0.0033 | 0.0034 | 2.556 | 14.353 |
| n-Butane | $n\text{-}C_4$ | 0.0075 | 0.0077 | 5.618 | 31.541 |
| i-Pentane | $i\text{-}C_5$ | 0.0022 | 0.0023 | 1.930 | 10.835 |
| n-Pentane | $n\text{-}C_5$ | 0.0028 | 0.0029 | 2.418 | 13.576 |
| Hexanes | $C_6$ | 0.0024 | 0.0025 | 2.347 | 13.175 |
| Heptanes | $C_7$ | 0.0059 | 0.0060 | 6.411 | 35.997 |
| Octanes | $C_8$ | 0.0004 | 0.0004 | 0.482 | 2.706 |
| Nonanes | $C_9$ | 0.0000 | 0.0000 | 0.053 | 0.296 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **36.906** | **207.209** |
| Propanes Plus | $C_{3+}$ | 0.0476 | 0.0486 | 36.906 | 207.209 |
| Butanes Plus | $C_{4+}$ | 0.0245 | 0.0250 | 21.815 | 122.479 |
| Pentanes Plus | $C_{5+}$ | 0.0137 | 0.0140 | 13.641 | 76.585 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 19.40 kg/kmol | 19.40 lb/lb-mol | Ppc | 671.5 psia | 4.63 MPa |
| Specific Gravity | 0.6699 (Air = 1) | 0.6699 (Air = 1) | Tpc | 377.4 R | 209.7 K |
| MW of C7+ | 96.85 kg/kmol | 96.85 lb/lbmol | Ppc* | 665.9 psia | 4.59 MPa |
| Density of C7+ | 0.7237 g/cc | 723.7 kg/m3 | Tpc* | 374.2 R | 207.9 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,140.3 Btu/scf | 42.56 MJ/m3 | Dry | 1,031.6 Btu/scf | 38.51 MJ/m3 |
| Wet | 1,120.5 Btu/scf | 41.82 MJ/m3 | Wet | 1,013.7 Btu/scf | 37.84 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 7983

## TABLE C6
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## DIFFERENTIAL LIBERATION GAS COMPOSITION @ 963 psia (6.64 MPa )

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0014 | 0.0015 | | |
| Carbon Dioxide | $CO_2$ | 0.0212 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.8654 | 0.8841 | | |
| Ethane | $C_2$ | 0.0591 | 0.0603 | | |
| Propane | $C_3$ | 0.0259 | 0.0264 | 16.906 | 94.920 |
| i-Butane | $i\text{-}C_4$ | 0.0036 | 0.0036 | 2.764 | 15.519 |
| n-Butane | $n\text{-}C_4$ | 0.0085 | 0.0087 | 6.341 | 35.600 |
| i-Pentane | $i\text{-}C_5$ | 0.0025 | 0.0025 | 2.153 | 12.087 |
| n-Pentane | $n\text{-}C_5$ | 0.0031 | 0.0032 | 2.663 | 14.950 |
| Hexanes | $C_6$ | 0.0025 | 0.0025 | 2.398 | 13.463 |
| Heptanes | $C_7$ | 0.0066 | 0.0067 | 7.192 | 40.381 |
| Octanes | $C_8$ | 0.0004 | 0.0004 | 0.489 | 2.744 |
| Nonanes | $C_9$ | 0.0000 | 0.0000 | 0.051 | 0.284 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **40.956** | **229.949** |
| Propanes Plus | $C_{3+}$ | 0.0530 | 0.0541 | 40.956 | 229.949 |
| Butanes Plus | $C_{4+}$ | 0.0271 | 0.0277 | 24.050 | 135.029 |
| Pentanes Plus | $C_{5+}$ | 0.0150 | 0.0154 | 14.945 | 83.910 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 19.76 kg/kmol | 19.76 lb/lb-mol | Ppc | 672.2 psia | 4.63 MPa |
| Specific Gravity | 0.6824 (Air = 1) | 0.6824 (Air = 1) | Tpc | 381.4 R | 211.9 K |
| MW of C7+ | 96.77 kg/kmol | 96.77 lb/lbmol | Ppc* | 666.0 psia | 4.59 MPa |
| Density of C7+ | 0.7235 g/cc | 723.5 kg/m3 | Tpc* | 377.9 R | 209.9 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,155.6 Btu/scf | 43.14 MJ/m3 | Dry | 1,046.0 Btu/scf | 39.04 MJ/m3 |
| Wet | 1,135.5 Btu/scf | 42.39 MJ/m3 | Wet | 1,027.8 Btu/scf | 38.36 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 7986

## TABLE C7
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## DIFFERENTIAL LIBERATION GAS COMPOSITION @ 663 psia (4.57 MPa )

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0009 | 0.0009 | | |
| Carbon Dioxide | $CO_2$ | 0.0247 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.8370 | 0.8582 | | |
| Ethane | $C_2$ | 0.0721 | 0.0739 | | |
| Propane | $C_3$ | 0.0319 | 0.0327 | 20.845 | 117.035 |
| i-Butane | $i\text{-}C_4$ | 0.0044 | 0.0045 | 3.419 | 19.199 |
| n-Butane | $n\text{-}C_4$ | 0.0105 | 0.0107 | 7.835 | 43.989 |
| i-Pentane | $i\text{-}C_5$ | 0.0032 | 0.0033 | 2.765 | 15.526 |
| n-Pentane | $n\text{-}C_5$ | 0.0039 | 0.0040 | 3.388 | 19.023 |
| Hexanes | $C_6$ | 0.0028 | 0.0029 | 2.729 | 15.322 |
| Heptanes | $C_7$ | 0.0079 | 0.0081 | 8.658 | 48.610 |
| Octanes | $C_8$ | 0.0007 | 0.0007 | 0.792 | 4.447 |
| Nonanes | $C_9$ | 0.0001 | 0.0001 | 0.102 | 0.570 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **50.534** | **283.721** |
| Propanes Plus | $C_{3+}$ | 0.0654 | 0.0670 | 50.534 | 283.721 |
| Butanes Plus | $C_{4+}$ | 0.0334 | 0.0343 | 29.689 | 166.686 |
| Pentanes Plus | $C_{5+}$ | 0.0186 | 0.0190 | 18.434 | 103.499 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 20.57 kg/kmol | 20.57 lb/lb-mol | Ppc | 672.7 psia | 4.64 MPa |
| Specific Gravity | 0.7103 (Air = 1) | 0.7103 (Air = 1) | Tpc | 390.0 R | 216.7 K |
| MW of C7+ | 97.05 kg/kmol | 97.05 lb/lbmol | Ppc* | 665.9 psia | 4.59 MPa |
| Density of C7+ | 0.7241 g/cc | 724.1 kg/m3 | Tpc* | 386.0 R | 214.4 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,191.4 Btu/scf | 44.47 MJ/m3 | Dry | 1,079.4 Btu/scf | 40.29 MJ/m3 |
| Wet | 1,170.6 Btu/scf | 43.70 MJ/m3 | Wet | 1,060.6 Btu/scf | 39.59 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 7988

## TABLE C8
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## DIFFERENTIAL LIBERATION GAS COMPOSITION @ 413 psia (2.85 MPa )

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0005 | 0.0005 | | |
| Carbon Dioxide | $CO_2$ | 0.0274 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.7919 | 0.8142 | | |
| Ethane | $C_2$ | 0.0911 | 0.0936 | | |
| Propane | $C_3$ | 0.0434 | 0.0446 | 28.316 | 158.982 |
| i-Butane | $i\text{-}C_4$ | 0.0061 | 0.0063 | 4.736 | 26.588 |
| n-Butane | $n\text{-}C_4$ | 0.0147 | 0.0151 | 10.999 | 61.756 |
| i-Pentane | $i\text{-}C_5$ | 0.0043 | 0.0044 | 3.755 | 21.082 |
| n-Pentane | $n\text{-}C_5$ | 0.0053 | 0.0054 | 4.546 | 25.525 |
| Hexanes | $C_6$ | 0.0037 | 0.0038 | 3.576 | 20.075 |
| Heptanes | $C_7$ | 0.0108 | 0.0111 | 11.786 | 66.172 |
| Octanes | $C_8$ | 0.0009 | 0.0009 | 1.034 | 5.807 |
| Nonanes | $C_9$ | 0.0001 | 0.0001 | 0.153 | 0.858 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **68.901** | **386.845** |
| Propanes Plus | $C_{3+}$ | 0.0892 | 0.0917 | 68.901 | 386.845 |
| Butanes Plus | $C_{4+}$ | 0.0458 | 0.0471 | 40.585 | 227.864 |
| Pentanes Plus | $C_{5+}$ | 0.0250 | 0.0257 | 24.850 | 139.520 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 21.93 kg/kmol | 21.93 lb/lb-mol | Ppc | 671.8 psia | 4.63 MPa |
| Specific Gravity | 0.7572 (Air = 1) | 0.7572 (Air = 1) | Tpc | 404.3 R | 224.6 K |
| MW of C7+ | 97.04 kg/kmol | 97.04 lb/lbmol | Ppc* | 664.6 psia | 4.58 MPa |
| Density of C7+ | 0.7241 g/cc | 724.1 kg/m3 | Tpc* | 400.0 R | 222.2 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,258.8 Btu/scf | 46.99 MJ/m3 | Dry | 1,142.4 Btu/scf | 42.64 MJ/m3 |
| Wet | 1,236.9 Btu/scf | 46.17 MJ/m3 | Wet | 1,122.5 Btu/scf | 41.90 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa) GC No.: 7995

# TABLE C9
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## DIFFERENTIAL LIBERATION GAS COMPOSITION @ 163 psia (1.12 MPa )

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0002 | 0.0003 | | |
| Carbon Dioxide | $CO_2$ | 0.0324 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.6659 | 0.6883 | | |
| Ethane | $C_2$ | 0.1398 | 0.1445 | | |
| Propane | $C_3$ | 0.0816 | 0.0844 | 53.306 | 299.285 |
| i-Butane | $i\text{-}C_4$ | 0.0119 | 0.0123 | 9.237 | 51.860 |
| n-Butane | $n\text{-}C_4$ | 0.0288 | 0.0298 | 21.562 | 121.060 |
| i-Pentane | $i\text{-}C_5$ | 0.0073 | 0.0076 | 6.381 | 35.825 |
| n-Pentane | $n\text{-}C_5$ | 0.0083 | 0.0086 | 7.146 | 40.123 |
| Hexanes | $C_6$ | 0.0068 | 0.0070 | 6.619 | 37.160 |
| Heptanes | $C_7$ | 0.0160 | 0.0166 | 17.556 | 98.569 |
| Octanes | $C_8$ | 0.0007 | 0.0007 | 0.860 | 4.831 |
| Nonanes | $C_9$ | 0.0001 | 0.0001 | 0.094 | 0.531 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **122.761** | **689.244** |
| Propanes Plus | $C_{3+}$ | 0.1616 | 0.1670 | 122.761 | 689.244 |
| Butanes Plus | $C_{4+}$ | 0.0800 | 0.0827 | 69.455 | 389.958 |
| Pentanes Plus | $C_{5+}$ | 0.0392 | 0.0406 | 38.657 | 217.038 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 25.63 kg/kmol | 25.63 lb/lb-mol | Ppc | 668.2 psia | 4.61 MPa |
| Specific Gravity | 0.8847 (Air = 1) | 0.8847 (Air = 1) | Tpc | 444.0 R | 246.7 K |
| MW of C7+ | 96.57 kg/kmol | 96.57 lb/lbmol | Ppc* | 660.7 psia | 4.56 MPa |
| Density of C7+ | 0.7231 g/cc | 723.1 kg/m3 | Tpc* | 439.0 R | 243.9 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,446.0 Btu/scf | 53.98 MJ/m3 | Dry | 1,317.2 Btu/scf | 49.17 MJ/m3 |
| Wet | 1,420.8 Btu/scf | 53.04 MJ/m3 | Wet | 1,294.3 Btu/scf | 48.31 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 7997

**TABLE C10**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**DIFFERENTIAL LIBERATION GAS COMPOSITION @ 78 psia (0.54 MPa )**

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0002 | 0.0002 | | |
| Carbon Dioxide | $CO_2$ | 0.0371 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.4935 | 0.5125 | | |
| Ethane | $C_2$ | 0.2021 | 0.2098 | | |
| Propane | $C_3$ | 0.1398 | 0.1452 | 91.317 | 512.701 |
| i-Butane | $i\text{-}C_4$ | 0.0221 | 0.0230 | 17.152 | 96.300 |
| n-Butane | $n\text{-}C_4$ | 0.0529 | 0.0550 | 39.612 | 222.400 |
| i-Pentane | $i\text{-}C_5$ | 0.0107 | 0.0111 | 9.273 | 52.062 |
| n-Pentane | $n\text{-}C_5$ | 0.0121 | 0.0125 | 10.360 | 58.164 |
| Hexanes | $C_6$ | 0.0099 | 0.0103 | 9.672 | 54.305 |
| Heptanes | $C_7$ | 0.0191 | 0.0198 | 20.911 | 117.406 |
| Octanes | $C_8$ | 0.0005 | 0.0006 | 0.653 | 3.668 |
| Nonanes | $C_9$ | 0.0000 | 0.0000 | 0.060 | 0.337 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **199.010** | **1117.343** |
| Propanes Plus | $C_{3+}$ | 0.2672 | 0.2775 | 199.010 | 1117.343 |
| Butanes Plus | $C_{4+}$ | 0.1274 | 0.1323 | 107.693 | 604.642 |
| Pentanes Plus | $C_{5+}$ | 0.0523 | 0.0543 | 50.929 | 285.941 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 30.55 kg/kmol | 30.55 lb/lb-mol | Ppc | 662.6 psia | 4.57 MPa |
| Specific Gravity | 1.0547 (Air = 1) | 1.0547 (Air = 1) | Tpc | 497.9 R | 276.6 K |
| MW of C7+ | 96.36 kg/kmol | 96.36 lb/lbmol | Ppc* | 655.2 psia | 4.52 MPa |
| Density of C7+ | 0.7227 g/cc | 722.7 kg/m3 | Tpc* | 492.3 R | 273.5 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,699.3 Btu/scf | 63.43 MJ/m3 | Dry | 1,553.7 Btu/scf | 58.00 MJ/m3 |
| Wet | 1,669.7 Btu/scf | 62.33 MJ/m3 | Wet | 1,526.7 Btu/scf | 56.99 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa) GC No.: 8002

# TABLE C11
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## DIFFERENTIAL LIBERATION GAS COMPOSITION @ 13 psia (0.09 MPa )

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0001 | 0.0001 | | |
| Carbon Dioxide | $CO_2$ | 0.0142 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.1225 | 0.1242 | | |
| Ethane | $C_2$ | 0.1467 | 0.1488 | | |
| Propane | $C_3$ | 0.5133 | 0.5207 | 335.183 | 1881.886 |
| i-Butane | i-$C_4$ | 0.0374 | 0.0380 | 29.061 | 163.166 |
| n-Butane | n-$C_4$ | 0.0973 | 0.0987 | 72.781 | 408.632 |
| i-Pentane | i-$C_5$ | 0.0150 | 0.0152 | 13.046 | 73.249 |
| n-Pentane | n-$C_5$ | 0.0173 | 0.0176 | 14.903 | 83.675 |
| Hexanes | $C_6$ | 0.0127 | 0.0129 | 12.438 | 69.834 |
| Heptanes | $C_7$ | 0.0233 | 0.0237 | 25.563 | 143.521 |
| Octanes | $C_8$ | 0.0001 | 0.0001 | 0.067 | 0.375 |
| Nonanes | $C_9$ | 0.0001 | 0.0001 | 0.067 | 0.375 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **503.110** | **2824.713** |
| Propanes Plus | $C_{3+}$ | 0.7165 | 0.7269 | 503.110 | 2824.713 |
| Butanes Plus | $C_{4+}$ | 0.2033 | 0.2062 | 167.927 | 942.827 |
| Pentanes Plus | $C_{5+}$ | 0.0685 | 0.0695 | 66.084 | 371.030 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 43.15 kg/kmol | 43.15 lb/lb-mol | Ppc | 621.3 psia | 4.28 MPa |
| Specific Gravity | 1.4899 (Air = 1) | 1.4899 (Air = 1) | Tpc | 635.8 R | 353.2 K |
| MW of C7+ | 96.08 kg/kmol | 96.08 lb/lbmol | Ppc* | 618.8 psia | 4.27 MPa |
| Density of C7+ | 0.7221 g/cc | 722.1 kg/m3 | Tpc* | 633.3 R | 351.8 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 2,433.8 Btu/scf | 90.85 MJ/m3 | Dry | 2,238.3 Btu/scf | 83.55 MJ/m3 |
| Wet | 2,391.4 Btu/scf | 89.26 MJ/m3 | Wet | 2,199.4 Btu/scf | 82.10 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 8007

# HUSKY ENERGY - NORTH AMETHYST
# RESERVOIR FLUID STUDY

## F I N A L  R E P O R T

Prepared for

HUSKY ENERGY

By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# RESERVOIR FLUID STUDY

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## RESULTS AND DISCUSSION

The reservoir fluid study was conducted on the bottomhole sample BOTTOMHOLE collected from K-15 of NORTH AMETHYST reservoir.

The sample collection data is provided in Table 1 and the sample validation data is given in Appendix A.

The PVT cell was charged with a portion of the fluid sample and a constant composition expansion experiment (CCE) was performed on the fluid. The compositional analysis of reservoir fluid is given in Table 2.

Table 3 provides the CCE results of the average compressibility of the reservoir fluid at pressures above the saturation pressure. Table 4 contains the complete CCE results with the exception of the data already presented in Table 3. Figure 1 is the relative total volume (V/Vsat) data and Y-function. Figure 2 shows the liquid drop out during constant composition expansion experiment.

Table 5 contains fluid recovery data from the constant volume depletion including liquid drop out, cumulative produced fluid, cumulative liquid recovery and separator condensate-gas ratios, which are shown in Figures 3 through 6, respectively.

Table 6 contains a summary of the properties of the constant volume depletion wellstream produced including densities, viscosities, deviation factors, two-phase deviation factors, P/Z parameters. The gas deviation factor (Z) and two-phase deviation factor, density, viscosity and the P/Z parameters are shown in Figures 7 through 10, respectively.

Table 7 summarizes the wellstream produced compositions from each pressure stage during the constant volume depletion experiment. Figure 11 shows this data plotted on semi-log co-ordinates. Table 8 and 9 present the compositional analysis of the yields and cumulative compositional recovery, respectively.

## SUMMARY

**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**MAIN PVT RESULTS**

### INITIAL RESERVOIR CONDITIONS

| | | | | |
|---|---|---|---|---|
| Reservoir Pressure | 3450 | psia | 23.79 | MPa |
| Reservoir Temperature: | 190.4 | F | 88 | C |

### CONSTANT COMPOSITION EXPANSION @ 190.4 F (88.0 C)

| | | | | |
|---|---|---|---|---|
| Saturation Pressure | 3186 | psia | 21.97 | MPa |
| Compressibility @ Reservoir Pressure | 0.00022154 | $psia^{-1}$ | 3.21318E-02 | $MPa^{-1}$ |
| Compressibility @ Saturation Pressure | 2.54187E-04 | $psia^{-1}$ | 3.68668E-02 | $MPa^{-1}$ |
| Maximum Liquid Drop (% of Vtot) | 0.32 | @ 1,442 psia (9.94 MPa) | | |

### CONSTANT VOLUME DEPLETION @ 190.4 F (88.0 C)

| | | | | |
|---|---|---|---|---|
| At Saturation Pressure | | | | |
| Fluid Density | 0.1641 | $g/cm^3$ | 164.1 | $kg/m^3$ |
| Fluid Viscosity | 0.0201 | cp | 0.0201 | mPa.s |
| Maximum Liquid Drop (% of Vsat) | 0.42 | @ 1,013 psia (6.98 MPa) | | |

### SINGLE-STAGE SEPARATOR TEST

| | | | | |
|---|---|---|---|---|
| At Saturation Pressure | | | | |
| Fluid Formation Volume Factor | 53.0663 | res.bbl/STB | 53.0663 | $res.m^3/m^3$ |
| Solution Gas-Oil Ratio | 54745.34 | scf/STB | 9750.19 | $m^3/m^3$ |
| At Tank Conditions | | | | |
| Flashed Oil Density | 0.7700 | $g/cm^3$ | 770.0 | $kg/m^3$ |
| API Gravity | 52.27 | | 52.27 | |

**TABLE 1**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**SAMPLE COLLECTION DATA**

| | | | | |
|---|---|---|---|---|
| Project File: | 2006-147 | | | |
| Operator Name: | HUSKY ENERGY | | | |
| Pool or Zone: | BEN NEVIS - AVALON | | | |
| Field or Area: | NORTH AMETHYST | | | |
| Well Location: | K-15 | | | |
| Fluid Sample: | BOTTOMHOLE | | | |
| Sampling Company: | Schlumberger | | | |
| Name of Sampler: | N/A | | | |
| Sampling Date: | 2-Nov-06 | | | |
| Sampling Point: | SUBSURFACE | | | |
| Sampling Temperature: | 190.6 | F | 88.1 | C |
| Sampling Pressure: | 3450.0 | psia | 23.79 | MPa |
| Reservoir Temperature: | 190.4 | F | 88.0 | C |
| Reservoir Pressure: | 3450.0 | psia | 23.79 | MPa |
| Initial Reservoir Pressure (Pi) | 3450.0 | psia | 23.79 | MPa |
| Depth of Reported Pi | 2375.0 | mMD | N/A | mss |

## TABLE 2
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF RESERVOIR FLUID

| Boiling Point (K) | | | Mole Fraction | Mass Fraction | Calculated Properties | |
|---|---|---|---|---|---|---|
| 77.4 | Nitrogen | N2 | 0.0052 | 0.0070 | **Total Sample** | |
| 194.6 | Carbon Dioxide | CO2 | 0.0161 | 0.0344 | | |
| 212.8 | Hydrogen Sulphide | H2S | 0.0000 | 0.0000 | Molecular Weight | 20.64 |
| 111.5 | Methane | C1 | 0.8813 | 0.6853 | | |
| 184.3 | Ethane | C2 | 0.0398 | 0.0580 | | |
| 231.0 | Propane | C3 | 0.0198 | 0.0424 | **C6+ Fraction** | |
| 261.5 | i-Butane | i-C4 | 0.0031 | 0.0089 | | |
| 272.6 | n-Butane | n-C4 | 0.0077 | 0.0216 | Molecular Weight | 117.88 |
| 301.0 | i-Pentane | i-C5 | 0.0022 | 0.0076 | Mole Fraction | 0.0218 |
| 309.3 | n-Pentane | n-C5 | 0.0029 | 0.0103 | Density (g/cc) | 0.7752 |
| 309.3 - 342 | Hexanes | C6 | 0.0033 | 0.0137 | | |
| 342 - 371.4 | Heptanes | C7 | 0.0019 | 0.0093 | | |
| 371.4 - 398.8 | Octanes | C8 | 0.0015 | 0.0082 | **C7+ Fraction** | |
| 398.8 - 423.8 | Nonanes | C9 | 0.0013 | 0.0082 | | |
| 423.8 - 447 | Decanes | C10 | 0.0011 | 0.0074 | Molecular Weight | 104.10 |
| 447 - 469.3 | Undecanes | C11 | 0.0008 | 0.0059 | Mole Fraction | 0.0185 |
| 469.3 - 488.2 | Dodecanes | C12 | 0.0009 | 0.0069 | Density (g/cc) | 0.7880 |
| 488.2 - 508.2 | Tridecanes | C13 | 0.0008 | 0.0069 | | |
| 508.2 - 525.4 | Tetradecanes | C14 | 0.0006 | 0.0054 | | |
| 525.4 - 543.8 | Pentadecanes | C15 | 0.0005 | 0.0045 | **C12+ Fraction** | |
| 543.8 - 560.9 | Hexadecanes | C16 | 0.0004 | 0.0041 | | |
| 560.9 - 564.8 | Heptadecanes | C17 | 0.0002 | 0.0027 | Molecular Weight | 203.48 |
| 564.8 - 590.4 | Octadecanes | C18 | 0.0002 | 0.0024 | Mole Fraction | 0.0038 |
| 590.4 - 603.2 | Nonadecanes | C19 | 0.0001 | 0.0012 | Density (g/cc) | 0.8326 |
| 603.2 - 617.5 | Eicosanes | C20 | 0.0000 | 0.0004 | | |
| 617.5 - 630.4 | Heneicosanes | C21 | 0.0000 | 0.0003 | | |
| 630.4 - 642.5 | Docosanes | C22 | 0.0000 | 0.0002 | | |
| 642.5 - 653.2 | Tricosanes | C23 | 0.0000 | 0.0002 | | |
| 653.2 - 664.3 | Tetracosanes | C24 | 0.0000 | 0.0002 | | |
| 664.3 - 674.9 | Pentacosanes | C25 | 0.0000 | 0.0002 | | |
| 674.9 - 685.4 | Hexacosanes | C26 | 0.0000 | 0.0002 | | |
| 685.4 - 695.4 | Heptacosanes | C27 | 0.0000 | 0.0002 | | |
| 695.4 - 704.9 | Octacosanes | C28 | 0.0000 | 0.0002 | | |
| 704.9 - 714.3 | Nonacosanes | C29 | 0.0000 | 0.0002 | | |
| Above 714.3 | Tricontanes Plus | C30+ | 0.0001 | 0.0019 | | |
| 322.0 | Cyclopentane | C5H10 | 0.0001 | 0.0002 | | |
| 345.4 | Methylcyclopentane | C6H12 | 0.0049 | 0.0199 | | |
| 354.3 | Cyclohexane | C6H12 | 0.0008 | 0.0032 | | |
| 374.3 | Methylcyclohexane | C7H14 | 0.0008 | 0.0039 | | |
| 353.2 | Benzene | C6H6 | 0.0005 | 0.0020 | | |
| 383.8 | Toluene | C7H8 | 0.0006 | 0.0027 | | |
| 409.3 - 412 | Ethylbenzene & p,m-Xylene | C8H10 | 0.0002 | 0.0008 | | |
| 417.5 | o-Xylene | C8H10 | 0.0001 | 0.0005 | | |
| 442.0 | 1, 2, 4-Trimethylbenzene | C9H12 | 0.0001 | 0.0005 | | |
| **Total** | | | **1.0000** | **1.0000** | | |

**TABLE 3**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**FLUID COMPRESSIBILITY @ 190.4 F (88.0 C)**

| Pressure Range From (psia) | Pressure Range To (psia) | Average Compressibility ($psi^{-1}$) |
|---|---|---|
| 5013 | 4763 | 1.3405E-04 |
| 4763 | 4513 | 1.4593E-04 |
| 4513 | 4263 | 1.5953E-04 |
| 4263 | 4013 | 1.7630E-04 |
| 4013 | 3763 | 1.9559E-04 |
| 3763 | 3513 | 2.2154E-04 |
| **3513** | **3186 Psat** | **2.5419E-04** |

| Pressure Range From (MPa) | Pressure Range To (MPa) | Average Compressibility ($MPa^{-1}$) |
|---|---|---|
| 34.56 | 32.84 | 1.9443E-02 |
| 32.84 | 31.11 | 2.1166E-02 |
| 31.11 | 29.39 | 2.3138E-02 |
| 29.39 | 27.67 | 2.5571E-02 |
| 27.67 | 25.94 | 2.8368E-02 |
| 25.94 | 24.22 | 3.2132E-02 |
| **24.22** | **21.97 Psat** | **3.6867E-02** |

Psat - Saturation Pressure

**TABLE 4**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT COMPOSITION EXPANSION @ 190.4 F (88.0 C)**

| Pressure (psia) | Pressure (MPa) | RelativeVolume [1] | Z-Factor (-) | Y-Function [2] | Liquid Volume (% of Vtot) | Fluid Density (g/cc) |
|---|---|---|---|---|---|---|
| 5013 | 34.56 | 0.70404 | 1.00192 | | | 0.2331 |
| 4763 | 32.84 | 0.72845 | 0.98496 | | | 0.2253 |
| 4513 | 31.11 | 0.75604 | 0.96860 | | | 0.2171 |
| 4263 | 29.39 | 0.78744 | 0.95294 | | | 0.2084 |
| 4013 | 27.67 | 0.82375 | 0.93842 | | | 0.1992 |
| 3763 | 25.94 | 0.86610 | 0.92519 | | | 0.1895 |
| 3513 | 24.22 | 0.91688 | 0.91436 | | | 0.1790 |
| **3186 Psat** | **21.97** | **1.00000** | **0.90442** | | **0.0000** | **0.1641** |
| 2978 | 20.53 | 1.06238 | 0.89810 | 1.1198 | 0.0364 | |
| 2768 | 19.08 | 1.13741 | 0.89373 | 1.0991 | 0.0772 | |
| 2676 | 18.45 | 1.17487 | 0.89247 | 1.0900 | 0.0968 | |
| 2439 | 16.81 | 1.28720 | 0.89119 | 1.0665 | 0.1403 | |
| 2187 | 15.08 | 1.43859 | 0.89309 | 1.0416 | 0.1904 | |
| 2083 | 14.36 | 1.51349 | 0.89491 | 1.0313 | 0.2101 | |
| 1903 | 13.12 | 1.66527 | 0.89956 | 1.0135 | 0.2465 | |
| 1752 | 12.08 | 1.81974 | 0.90499 | 0.9986 | 0.2785 | |
| 1686 | 11.62 | 1.89690 | 0.90782 | 0.9921 | 0.2869 | |
| 1442 | 9.94 | 2.24965 | 0.92081 | 0.9680 | 0.3202 | |
| 1365 | 9.41 | 2.38937 | 0.92576 | 0.9604 | 0.3191 | |
| 1109 | 7.64 | 3.00337 | 0.94538 | 0.9350 | 0.2969 | |
| 736 | 5.07 | 4.70735 | 0.98327 | 0.8982 | 0.2153 | |
| 619 | 4.27 | 5.67913 | 0.99763 | 0.8866 | 0.1748 | |
| 524 | 3.61 | 6.79376 | 1.01020 | 0.8772 | 0.1463 | |

[1] Volume at indicated pressure per volume at saturation pressure
[2] Y Function = ((Psat-P)/P)/(Relative Volume - 1)
Psat - Saturation Pressure

**TABLE 5**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT VOLUME DEPLETION FLUID RECOVERY@ 190.4 F (88.0 C)**

| Pressure | | Liquid Drop Out | Cumulative Produced Fluid | Cumulative Liquid Recovery | | Separator Condensate - Gas Ratio | |
|---|---|---|---|---|---|---|---|
| (psia) | (MPa) | (% of Vsat) | (mole %) | (STB/MMscf) | ($m^3/10^6m^3$) | (STB/MMscf) | ($m^3/10^6m^3$) |
| 5013 | 34.56 | | | 0.00 | 0.00 | 18.27 | 102.56 |
| 4763 | 32.84 | | | 0.00 | 0.00 | 18.27 | 102.56 |
| 4513 | 31.11 | | | 0.00 | 0.00 | 18.27 | 102.56 |
| 4263 | 29.39 | | | 0.00 | 0.00 | 18.27 | 102.56 |
| 4013 | 27.67 | | | 0.00 | 0.00 | 18.27 | 102.56 |
| 3763 | 25.94 | | | 0.00 | 0.00 | 18.27 | 102.56 |
| 3513 | 24.22 | | | 0.00 | 0.00 | 18.27 | 102.56 |
| **3186 Psat** | **21.97** | **0.0000** | **0.0000** | **0.00** | **0.00** | **18.27** | **102.56** |
| 2813 | 19.39 | 0.0653 | 8.9138 | 0.25 | 1.43 | 2.86 | 16.06 |
| 2513 | 17.32 | 0.1262 | 17.4089 | 0.46 | 2.57 | 2.40 | 13.47 |
| 2213 | 15.26 | 0.1902 | 27.2544 | 0.64 | 3.57 | 1.81 | 10.17 |
| 1913 | 13.19 | 0.2722 | 37.2194 | 0.80 | 4.48 | 1.64 | 9.18 |
| 1613 | 11.12 | 0.3492 | 47.5795 | 0.95 | 5.34 | 1.47 | 8.28 |
| 1313 | 9.05 | 0.4027 | 57.9676 | 1.08 | 6.07 | 1.25 | 7.02 |
| 1013 | 6.98 | 0.4196 | 68.0272 | 1.19 | 6.68 | 1.09 | 6.11 |
| 813 | 5.60 | 0.4181 | 74.5799 | 1.25 | 7.04 | 0.97 | 5.45 |
| 613 | 4.22 | 0.4009 | 80.9375 | 1.30 | 7.32 | 0.80 | 4.49 |
| 413 | 2.85 | 0.3752 | 87.1343 | 1.34 | 7.54 | 0.62 | 3.46 |

[1] Barrels (Cubic meters) of oil at indicated pressure and temperature per barrel (cubic meter) of residual oil @ 60 F (288.7 K).
[2] Total barrels (cubic meters) of oil and liberated gas at the indicated pressure and temperature per barrel (cubic meter) of residual oil @ 60 F (288.7 K).
Psat - Saturation Pressure
- Tank conditions: 60 F (288.7 K) @ 13 psia (0.0896 MPa); Standard conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa).

**TABLE 6**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT VOLUME DEPLETION PRODUCED WELLSTREAM PROPERTIES @ 190.4 F (88.0 C)**

| Pressure (psia) | Pressure (MPa) | Gas Density (g/cm³) | Gas Viscosity (cp=mPa.s) | Gas Deviation Factor (-) | Two-Phase Gas Deviation Factor ($Z_{2ph}$) | P/Z (psia) | P/Z (MPa) | $P/Z_{2ph}$ (psia) | $P/Z_{2ph}$ (MPa) |
|---|---|---|---|---|---|---|---|---|---|
| 5013 | 34.56 | | | | | | | | |
| 4763 | 32.84 | | | | | | | | |
| 4513 | 31.11 | | | | | | | | |
| 4263 | 29.39 | | | | | | | | |
| 4013 | 27.67 | | | | | | | | |
| 3763 | 25.94 | | | | | | | | |
| 3513 | 24.22 | | | | | | | | |
| **3186 Psat** | **21.97** | **0.1641** | **0.0201** | **0.9044** | **0.9044** | **3522** | **24.29** | **3522** | **24.29** |
| 2813 | 19.39 | 0.1438 | 0.0192 | 0.8814 | 0.8769 | 3191 | 22.00 | 3208 | 22.12 |
| 2513 | 17.33 | 0.1334 | 0.0184 | 0.8698 | 0.8642 | 2889 | 19.92 | 2907 | 20.05 |
| 2213 | 15.26 | 0.1178 | 0.0174 | 0.8686 | 0.8645 | 2548 | 17.56 | 2560 | 17.65 |
| 1913 | 13.19 | 0.1015 | 0.0165 | 0.8723 | 0.8664 | 2193 | 15.12 | 2208 | 15.22 |
| 1613 | 11.12 | 0.0846 | 0.0157 | 0.8815 | 0.8757 | 1830 | 12.61 | 1842 | 12.70 |
| 1313 | 9.05 | 0.0680 | 0.0150 | 0.8950 | 0.8902 | 1467 | 10.11 | 1475 | 10.17 |
| 1013 | 6.98 | 0.0514 | 0.0144 | 0.9135 | 0.9048 | 1109 | 7.64 | 1119 | 7.72 |
| 813 | 5.61 | 0.0407 | 0.0140 | 0.9278 | 0.9154 | 876 | 6.04 | 888 | 6.12 |
| 613 | 4.23 | 0.0300 | 0.0137 | 0.9442 | 0.9238 | 649 | 4.47 | 663 | 4.57 |
| 413 | 2.85 | 0.0193 | 0.0135 | 0.9631 | 0.9289 | 429 | 2.96 | 444 | 3.06 |

Psat - Saturation pressure
- Standard conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

**TABLE 7**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CVD - PRODUCED WELLSTREAM COMPOSITIONAL ANALYSIS @ 190.4 F (88.0 C)**

| Component Name | Chemical Symbol | Constant Volume Depletion Stage Pressure (psia/MPa) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2813 | 2513 | 2213 | 1913 | 1613 | 1313 | 1013 |
| | | 19.39 | 17.33 | 15.26 | 13.19 | 11.12 | 9.05 | 6.98 |
| Nitrogen | N2 | 0.0033 | 0.0042 | 0.0043 | 0.0041 | 0.0041 | 0.0040 | 0.0039 |
| Carbon Dioxide | CO2 | 0.0191 | 0.0164 | 0.0167 | 0.0169 | 0.0170 | 0.0173 | 0.0174 |
| Hydrogen Sulphide | H2S | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Methane | C1 | 0.8844 | 0.8782 | 0.8777 | 0.8775 | 0.8777 | 0.8763 | 0.8763 |
| Ethane | C2 | 0.0421 | 0.0426 | 0.0427 | 0.0430 | 0.0430 | 0.0436 | 0.0437 |
| Propane | C3 | 0.0201 | 0.0197 | 0.0200 | 0.0200 | 0.0199 | 0.0201 | 0.0200 |
| i-Butane | i-C4 | 0.0032 | 0.0033 | 0.0032 | 0.0032 | 0.0032 | 0.0033 | 0.0033 |
| n-Butane | n-C4 | 0.0080 | 0.0082 | 0.0080 | 0.0080 | 0.0080 | 0.0081 | 0.0081 |
| i-Pentane | i-C5 | 0.0031 | 0.0040 | 0.0037 | 0.0034 | 0.0034 | 0.0033 | 0.0034 |
| n-Pentane | n-C5 | 0.0040 | 0.0054 | 0.0050 | 0.0047 | 0.0045 | 0.0045 | 0.0045 |
| Hexanes | C6 | 0.0035 | 0.0049 | 0.0049 | 0.0048 | 0.0047 | 0.0046 | 0.0046 |
| Heptanes | C7 | 0.0087 | 0.0123 | 0.0131 | 0.0133 | 0.0136 | 0.0139 | 0.0139 |
| Octanes | C8 | 0.0004 | 0.0007 | 0.0007 | 0.0010 | 0.0007 | 0.0006 | 0.0006 |
| Nonanes | C9 | 0.0000 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| Decanes | C10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Undecanes | C11 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Dodecanes | C12 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Tridecanes | C13 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Tetradecanes | C14 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Pentadecanes | C15 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Hexadecanes | C16 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Heptadecanes | C17 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Octadecanes | C18 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Nonadecanes | C19 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Eicosanes | C20 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Heneicosanes | C21 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Docosanes | C22 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Tricosanes | C23 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Tetracosanes | C24 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Pentacosanes | C25 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Hexacosanes | C26 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Heptacosanes | C27 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Octacosanes | C28 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Nonacosanes | C29 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Tricontanes Plus | C30+ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| NAPHTHENES | | | | | | | | |
| Cyclopentane | C5H10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Methylcyclopentane | C6H12 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Cyclohexane | C6H12 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Methylcyclohexane | C7H14 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| AROMATICS | | | | | | | | |
| Benzene | C6H6 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Toluene | C7H8 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Ethylbenzene & p,m-Xylene | C8H10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| o-Xylene | C8H10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1, 2, 4-Trimethylbenzene | C9H12 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Total | | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| **Calculated Properties of C12+ Fraction** | | | | | | | | |
| Molecular Weight | | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| Mole Fraction | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Density (g/cc) | | n/a | n/a | n/a | n/a | n/a | n/a | n/a |

**TABLE 7 (Cont'd)**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT VOLUME DEPLETION WELLSTREAM COMPOSITIONS @ 190.4 F (88.0 C)**

| Component Name | Chemical Symbol | Constant Volume Depletion Stage Pressure (psia/MPa) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 813<br>5.61 | 613<br>4.23 | 413<br>2.85 | | | |
| Nitrogen | N2 | 0.0039 | 0.0036 | 0.0021 | | | |
| Carbon Dioxide | CO2 | 0.0177 | 0.0174 | 0.0163 | | | |
| Hydrogen Sulphide | H2S | 0.0000 | 0.0000 | 0.0000 | | | |
| Methane | C1 | 0.8749 | 0.8770 | 0.8890 | | | |
| Ethane | C2 | 0.0444 | 0.0438 | 0.0421 | | | |
| Propane | C3 | 0.0203 | 0.0203 | 0.0198 | | | |
| i-Butane | i-C4 | 0.0033 | 0.0033 | 0.0032 | | | |
| n-Butane | n-C4 | 0.0083 | 0.0082 | 0.0080 | | | |
| i-Pentane | i-C5 | 0.0035 | 0.0033 | 0.0022 | | | |
| n-Pentane | n-C5 | 0.0047 | 0.0048 | 0.0030 | | | |
| Hexanes | C6 | 0.0045 | 0.0044 | 0.0032 | | | |
| Heptanes | C7 | 0.0137 | 0.0130 | 0.0101 | | | |
| Octanes | C8 | 0.0007 | 0.0008 | 0.0009 | | | |
| Nonanes | C9 | 0.0001 | 0.0002 | 0.0002 | | | |
| Decanes | C10 | 0.0000 | 0.0000 | 0.0000 | | | |
| Undecanes | C11 | 0.0000 | 0.0000 | 0.0000 | | | |
| Dodecanes | C12 | 0.0000 | 0.0000 | 0.0000 | | | |
| Tridecanes | C13 | 0.0000 | 0.0000 | 0.0000 | | | |
| Tetradecanes | C14 | 0.0000 | 0.0000 | 0.0000 | | | |
| Pentadecanes | C15 | 0.0000 | 0.0000 | 0.0000 | | | |
| Hexadecanes | C16 | 0.0000 | 0.0000 | 0.0000 | | | |
| Heptadecanes | C17 | 0.0000 | 0.0000 | 0.0000 | | | |
| Octadecanes | C18 | 0.0000 | 0.0000 | 0.0000 | | | |
| Nonadecanes | C19 | 0.0000 | 0.0000 | 0.0000 | | | |
| Eicosanes | C20 | 0.0000 | 0.0000 | 0.0000 | | | |
| Heneicosanes | C21 | 0.0000 | 0.0000 | 0.0000 | | | |
| Docosanes | C22 | 0.0000 | 0.0000 | 0.0000 | | | |
| Tricosanes | C23 | 0.0000 | 0.0000 | 0.0000 | | | |
| Tetracosanes | C24 | 0.0000 | 0.0000 | 0.0000 | | | |
| Pentacosanes | C25 | 0.0000 | 0.0000 | 0.0000 | | | |
| Hexacosanes | C26 | 0.0000 | 0.0000 | 0.0000 | | | |
| Heptacosanes | C27 | 0.0000 | 0.0000 | 0.0000 | | | |
| Octacosanes | C28 | 0.0000 | 0.0000 | 0.0000 | | | |
| Nonacosanes | C29 | 0.0000 | 0.0000 | 0.0000 | | | |
| Tricontanes Plus | C30+ | 0.0000 | 0.0000 | 0.0000 | | | |
| NAPHTHENES | | | | | | | |
| Cyclopentane | C5H10 | 0.0000 | 0.0000 | 0.0000 | | | |
| Methylcyclopentane | C6H12 | 0.0000 | 0.0000 | 0.0000 | | | |
| Cyclohexane | C6H12 | 0.0000 | 0.0000 | 0.0000 | | | |
| Methylcyclohexane | C7H14 | 0.0000 | 0.0000 | 0.0000 | | | |
| AROMATICS | | | | | | | |
| Benzene | C6H6 | 0.0000 | 0.0000 | 0.0000 | | | |
| Toluene | C7H8 | 0.0000 | 0.0000 | 0.0000 | | | |
| Ethylbenzene & p,m-Xylene | C8H10 | 0.0000 | 0.0000 | 0.0000 | | | |
| o-Xylene | C8H10 | 0.0000 | 0.0000 | 0.0000 | | | |
| 1, 2, 4-Trimethylbenzene | C9H12 | 0.0000 | 0.0000 | 0.0000 | | | |
| Total | | 1.0000 | 1.0000 | 1.0000 | | | |
| **Calculated Properties of C12+ Fraction** | | | | | | | |
| Molecular Weight | | n/a | n/a | n/a | | | |
| Mole Fraction | | 0.0000 | 0.0000 | 0.0000 | | | |
| Density (g/cc) | | n/a | n/a | n/a | | | |

**TABLE 8**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT VOLUME DEPLETION COMPOSITIONAL YIELDS @ 190.4 F (88.0 C)**

| Pressure | | Separator Liquid Yield | | | | | |
|---|---|---|---|---|---|---|---|
| | | $C_{3+}$ | | $C_{4+}$ | | $C_{5+}$ | |
| (psia) | (MPa) | (STB/MMscf) | $(m^3/10^6m^3)$ | (STB/MMscf) | $(m^3/10^6m^3)$ | (STB/MMscf) | $(m^3/10^6m^3)$ |
| 5013 | 34.56 | 50.77 | 285.06 | 37.64 | 211.33 | 29.39 | 165.03 |
| 4763 | 32.84 | 50.77 | 285.06 | 37.64 | 211.33 | 29.39 | 165.03 |
| 4513 | 31.11 | 50.77 | 285.06 | 37.64 | 211.33 | 29.39 | 165.03 |
| 4263 | 29.39 | 50.77 | 285.06 | 37.64 | 211.33 | 29.39 | 165.03 |
| 4013 | 27.67 | 50.77 | 285.06 | 37.64 | 211.33 | 29.39 | 165.03 |
| 3763 | 25.94 | 50.77 | 285.06 | 37.64 | 211.33 | 29.39 | 165.03 |
| 3513 | 24.22 | 50.77 | 285.06 | 37.64 | 211.33 | 29.39 | 165.03 |
| **3186 Psat** | **21.97** | **50.77** | **285.06** | **37.64** | **211.33** | **29.39** | **165.03** |
| 2813 | 19.39 | 40.92 | 229.74 | 27.59 | 154.91 | 19.00 | 106.68 |
| 2513 | 17.32 | 48.37 | 271.58 | 35.30 | 198.22 | 26.50 | 148.80 |
| 2213 | 15.26 | 48.52 | 272.44 | 35.31 | 198.23 | 26.77 | 150.33 |
| 1913 | 13.19 | 48.51 | 272.39 | 35.30 | 198.19 | 26.73 | 150.10 |
| 1613 | 11.12 | 48.21 | 270.68 | 35.07 | 196.91 | 26.48 | 148.68 |
| 1313 | 9.05 | 48.65 | 273.15 | 35.37 | 198.57 | 26.63 | 149.53 |
| 1013 | 6.98 | 48.64 | 273.10 | 35.37 | 198.61 | 26.67 | 149.74 |
| 813 | 5.60 | 48.92 | 274.65 | 35.50 | 199.34 | 26.64 | 149.58 |
| 613 | 4.22 | 48.09 | 270.04 | 34.67 | 194.68 | 25.87 | 145.28 |
| 413 | 2.85 | 40.99 | 230.17 | 27.90 | 156.65 | 19.31 | 108.40 |

[1] Barrels (Cubic meters) of oil at indicated pressure and temperature per barrel (cubic meter) of residual oil @ 60 F (288.7 K).
[2] Total barrels (cubic meters) of oil and liberated gas at the indicated pressure and temperature per barrel (cubic meter) of residual oil @ 60 F (288.7 K).
Psat - Saturation Pressure
- Tank conditions: 60 F (288.7 K) @ 13 psia (0.0896 MPa); Standard conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa).

**TABLE 9**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT VOLUME DEPLETION COMPOSITIONAL RECOVERY @ 190.4 F (88.0 C)**

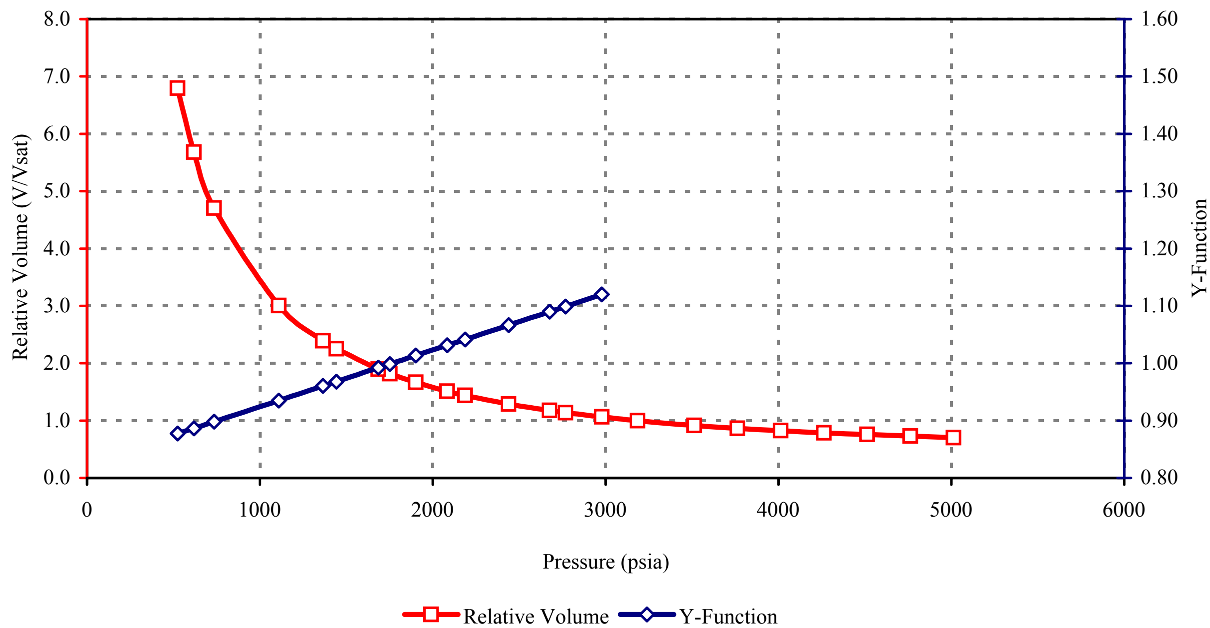
| Pressure | | Cumulative Liquid Recovery | | | | | |
|---|---|---|---|---|---|---|---|
| | | $C_{3+}$ | | $C_{4+}$ | | $C_{5+}$ | |
| (psia) | (MPa) | (STB/MMscf) | ($m^3/10^6m^3$) | (STB/MMscf) | ($m^3/10^6m^3$) | (STB/MMscf) | ($m^3/10^6m^3$) |
| 5013 | 34.56 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4763 | 32.84 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4513 | 31.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4263 | 29.39 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4013 | 27.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3763 | 25.94 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3513 | 24.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **3186 Psat** | **21.97** | **0.00** | **0.0000** | **0.00** | **0.0000** | **0.00** | **0.0000** |
| 2813 | 19.39 | 3.65 | 20.48 | 2.46 | 13.81 | 1.69 | 9.51 |
| 2513 | 17.32 | 7.76 | 43.55 | 5.46 | 30.65 | 3.94 | 22.15 |
| 2213 | 15.26 | 12.53 | 70.37 | 8.93 | 50.16 | 6.58 | 36.95 |
| 1913 | 13.19 | 17.37 | 97.52 | 12.45 | 69.91 | 9.24 | 51.91 |
| 1613 | 11.12 | 22.36 | 125.56 | 16.08 | 90.31 | 11.99 | 67.31 |
| 1313 | 9.05 | 27.42 | 153.93 | 19.76 | 110.94 | 14.75 | 82.85 |
| 1013 | 6.98 | 32.31 | 181.41 | 23.32 | 130.92 | 17.44 | 97.91 |
| 813 | 5.60 | 35.51 | 199.40 | 25.64 | 143.98 | 19.18 | 107.71 |
| 613 | 4.22 | 38.57 | 216.57 | 27.85 | 156.36 | 20.83 | 116.95 |
| 413 | 2.85 | 41.11 | 230.83 | 29.58 | 166.07 | 22.02 | 123.66 |

[1] Barrels (Cubic meters) of oil at indicated pressure and temperature per barrel (cubic meter) of residual oil @ 60 F (288.7 K).
[2] Total barrels (cubic meters) of oil and liberated gas at the indicated pressure and temperature per barrel (cubic meter) of residual oil @ 60 F (288.7 K).
Psat - Saturation Pressure
- Tank conditions: 60 F (288.7 K) @ 13 psia (0.0896 MPa); Standard conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa).

# TABLE 10
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## CVD -WELLSTREAM GAS COMPOSITION SUMMARY @ 190.4 F (88.0 C)

| Component | Constant Volume Stage Pressure (psia/MPa) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2813 | 2513 | 2213 | 1913 | 1613 | 1313 | 1013 | 813 | 613 | 413 |
| | 19.39 | 17.33 | 15.26 | 13.19 | 11.12 | 9.05 | 6.98 | 5.61 | 4.23 | 2.85 |
| **N2** | 0.0033 | 0.0042 | 0.0043 | 0.0041 | 0.0041 | 0.0040 | 0.0039 | 0.0039 | 0.0036 | 0.0021 |
| **CO2** | 0.0191 | 0.0164 | 0.0167 | 0.0169 | 0.0170 | 0.0173 | 0.0174 | 0.0177 | 0.0174 | 0.0163 |
| **H2S** | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **C1** | 0.8844 | 0.8782 | 0.8777 | 0.8775 | 0.8777 | 0.8763 | 0.8763 | 0.8749 | 0.8770 | 0.8890 |
| **C2** | 0.0421 | 0.0426 | 0.0427 | 0.0430 | 0.0430 | 0.0436 | 0.0437 | 0.0444 | 0.0438 | 0.0421 |
| **C3** | 0.0201 | 0.0197 | 0.0200 | 0.0200 | 0.0199 | 0.0201 | 0.0200 | 0.0203 | 0.0203 | 0.0198 |
| **i-C4** | 0.0032 | 0.0033 | 0.0032 | 0.0032 | 0.0032 | 0.0033 | 0.0033 | 0.0033 | 0.0033 | 0.0032 |
| **n-C4** | 0.0080 | 0.0082 | 0.0080 | 0.0080 | 0.0080 | 0.0081 | 0.0081 | 0.0083 | 0.0082 | 0.0080 |
| **i-C5** | 0.0031 | 0.0040 | 0.0037 | 0.0034 | 0.0034 | 0.0033 | 0.0034 | 0.0035 | 0.0033 | 0.0022 |
| **n-C5** | 0.0040 | 0.0054 | 0.0050 | 0.0047 | 0.0045 | 0.0045 | 0.0045 | 0.0047 | 0.0048 | 0.0030 |
| **C6** | 0.0035 | 0.0049 | 0.0049 | 0.0048 | 0.0047 | 0.0046 | 0.0046 | 0.0045 | 0.0044 | 0.0032 |
| **C7** | 0.0087 | 0.0123 | 0.0131 | 0.0133 | 0.0136 | 0.0139 | 0.0139 | 0.0137 | 0.0130 | 0.0101 |
| **C8** | 0.0004 | 0.0007 | 0.0007 | 0.0010 | 0.0007 | 0.0006 | 0.0006 | 0.0007 | 0.0008 | 0.0009 |
| **C9** | 0.0000 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0002 | 0.0002 |
| **C10** | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **C11** | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **C12+** | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **Total** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** | **1.0000** |
| **Calculated Properties of Total Sample @ Standard Conditions** | | | | | | | | | | |
| **MW (g/mol)** | 19.62 | 20.11 | 20.14 | 20.16 | 20.14 | 20.18 | 20.18 | 20.21 | 20.13 | 19.56 |
| **Gravity (Air=1.0)** | 0.6774 | 0.6943 | 0.6954 | 0.6959 | 0.6953 | 0.6968 | 0.6969 | 0.6978 | 0.6950 | 0.6754 |
| **Calculated Properties of C7+ @ Standard Conditions** | | | | | | | | | | |
| **MW (g/mol)** | 96.55 | 96.74 | 96.72 | 96.95 | 96.75 | 96.69 | 96.71 | 96.75 | 96.91 | 97.29 |
| **Density (g/cc)** | 0.7231 | 0.7235 | 0.7235 | 0.7239 | 0.7235 | 0.7233 | 0.7234 | 0.7235 | 0.7238 | 0.7245 |

**FIGURE 1**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT COMPOSITION EXPANSION @ 190.4 F (88.0 C)**



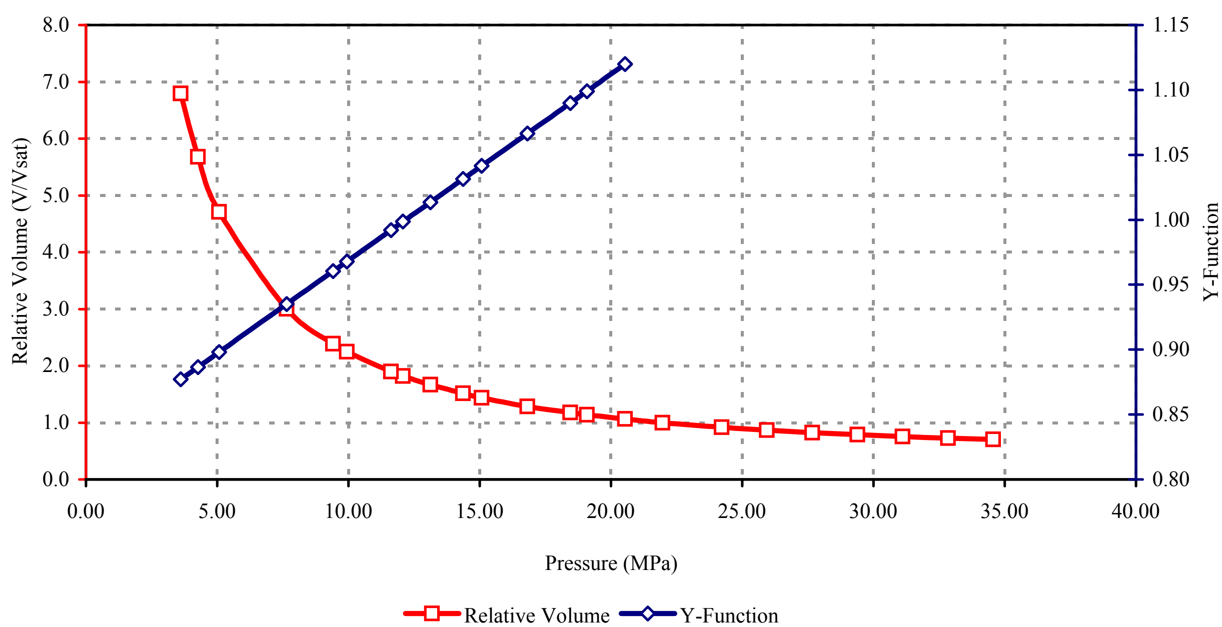
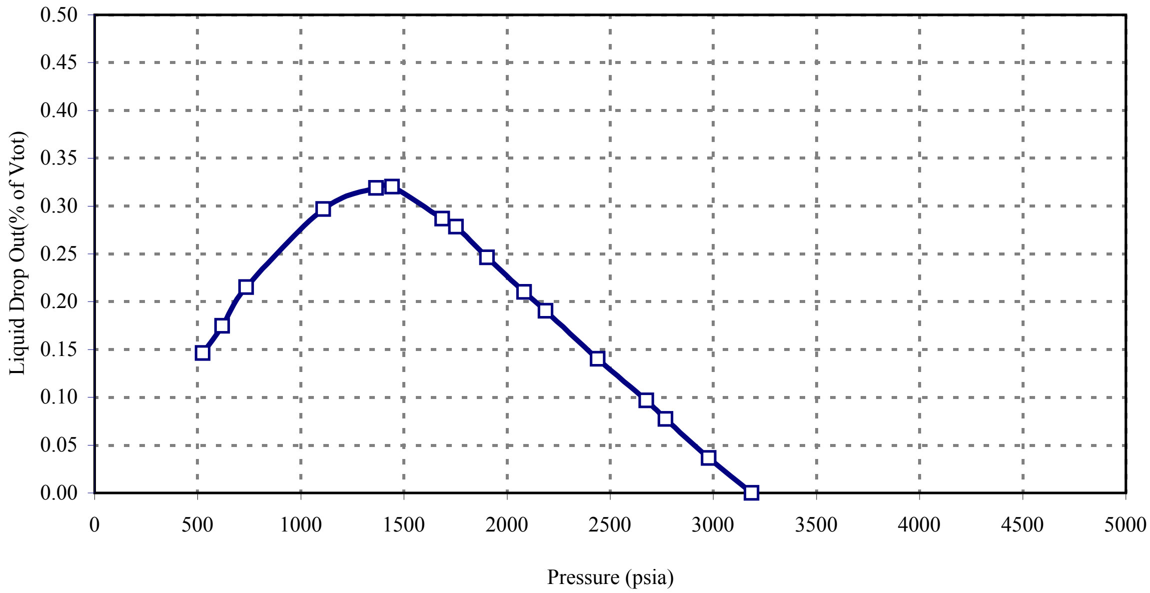



**FIGURE 2**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT COMPOSITION EXPANSION - LIQUID DROPOUT @ 190.4 F (88.0 C)**



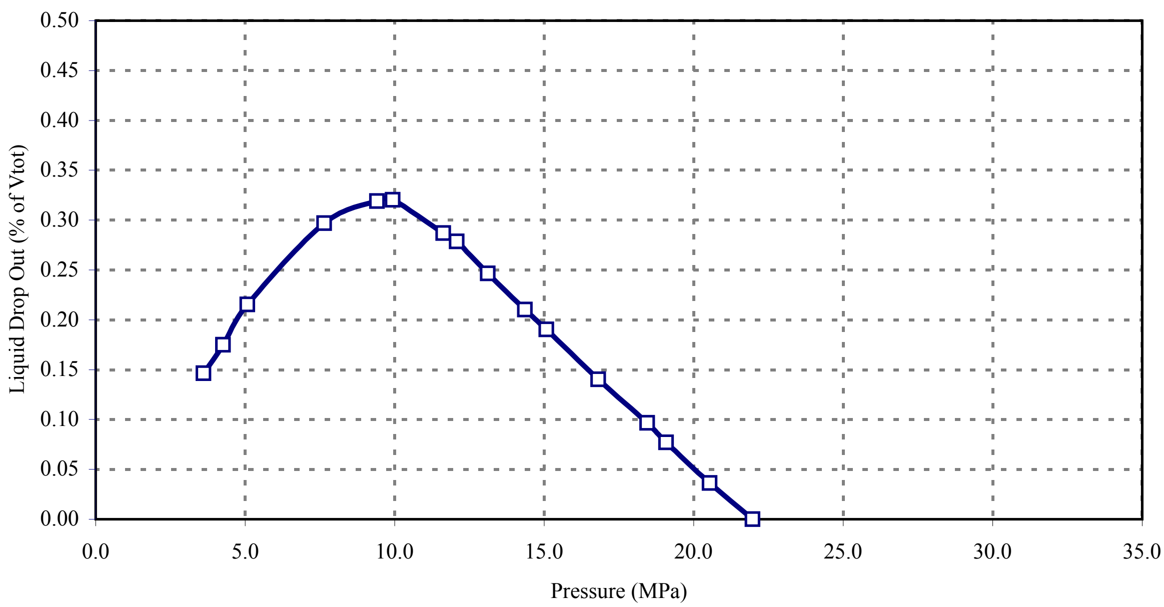
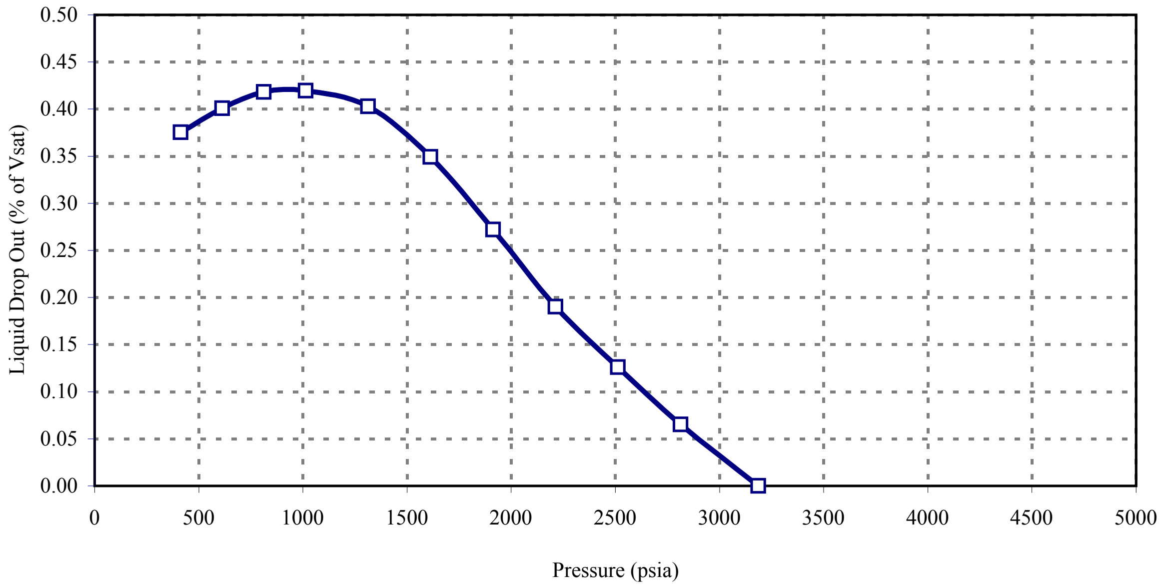



**FIGURE 3**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT VOLUME DEPLETION - LIQUID DROPOUT @ 190.4 F (88.0 C)**



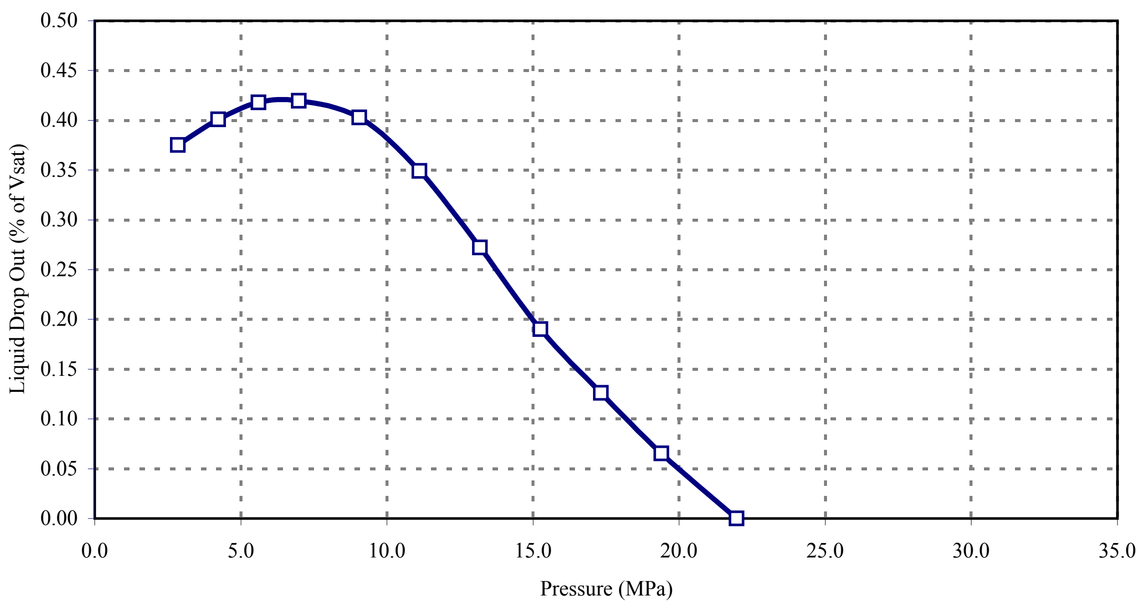
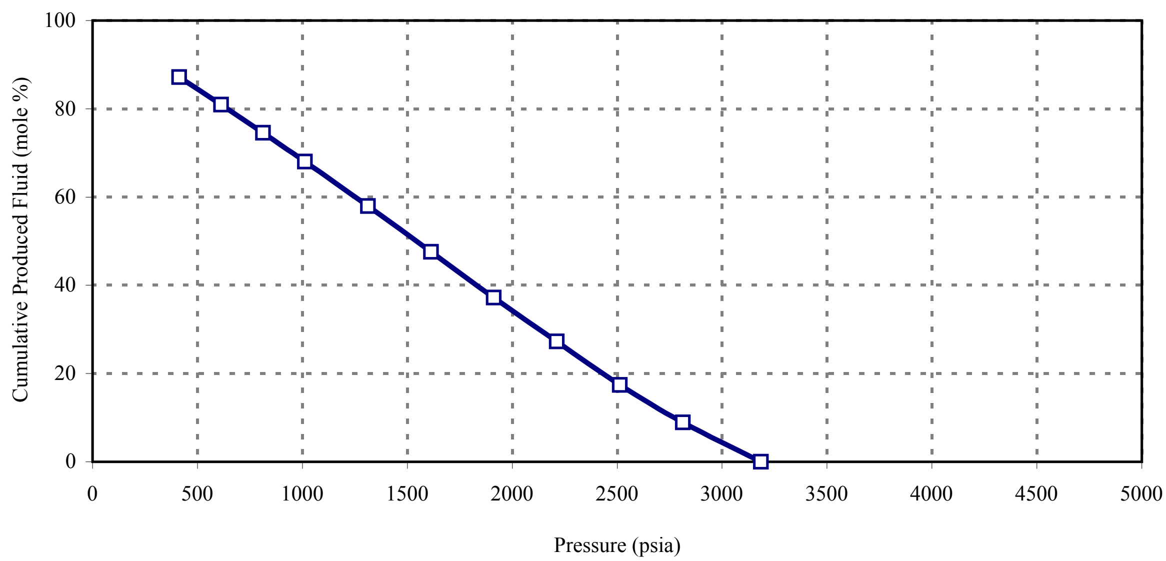



**FIGURE 4**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT VOLUME DEPLETION CUMULATIVE PRODUCED FLUID @ 190.4 F (88.0 C)**



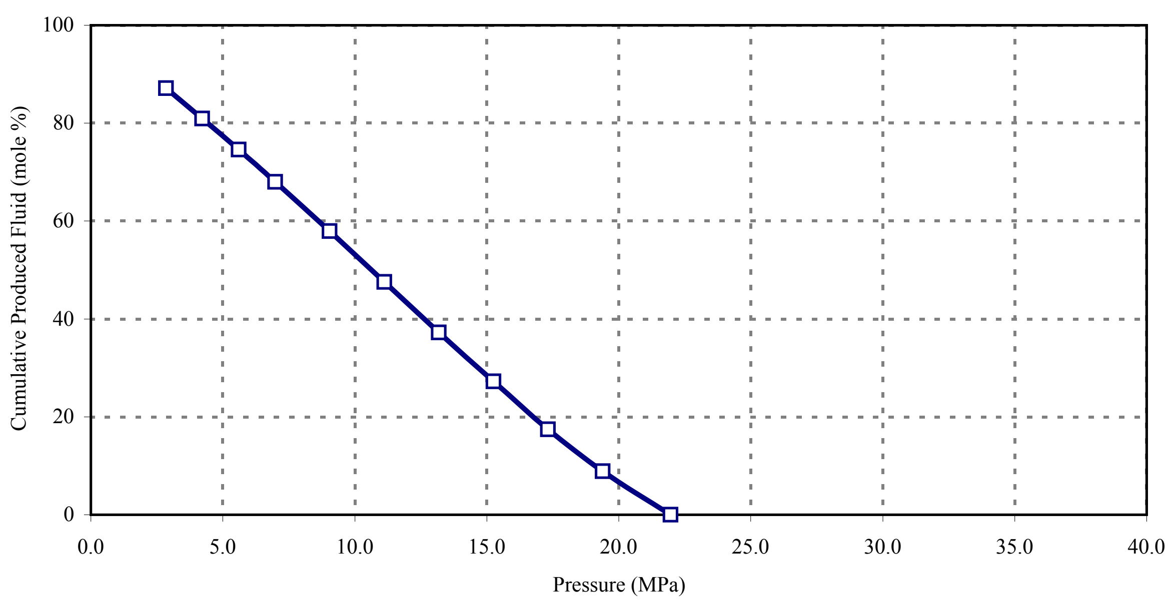
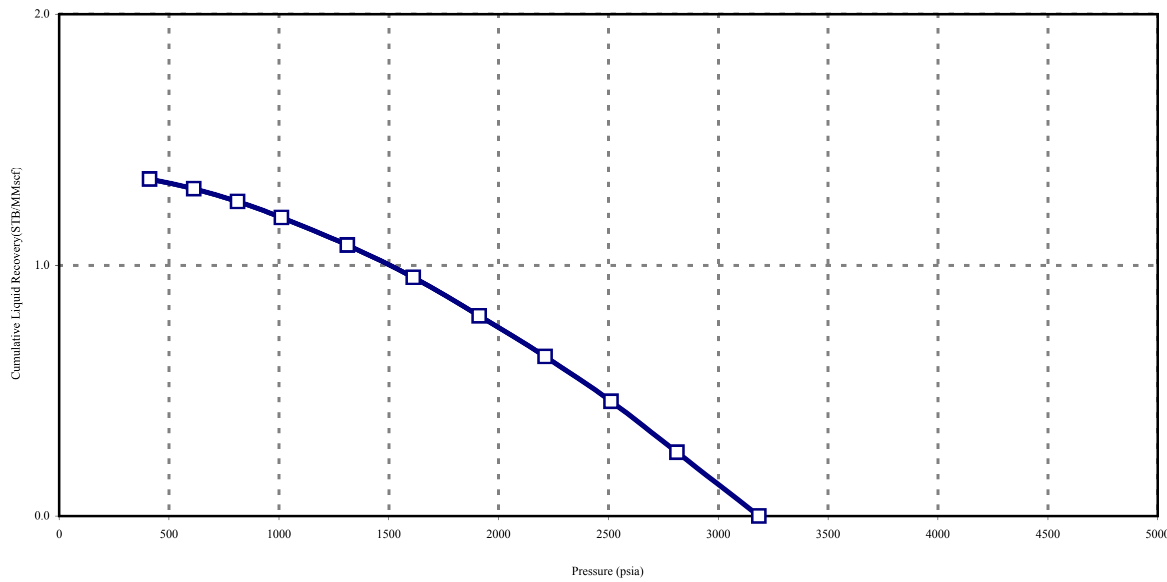



**FIGURE 5**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT VOLUME DEPLETION CUMULATIVE PRODUCED FLUID @ 190.4 F (88.0 C)**



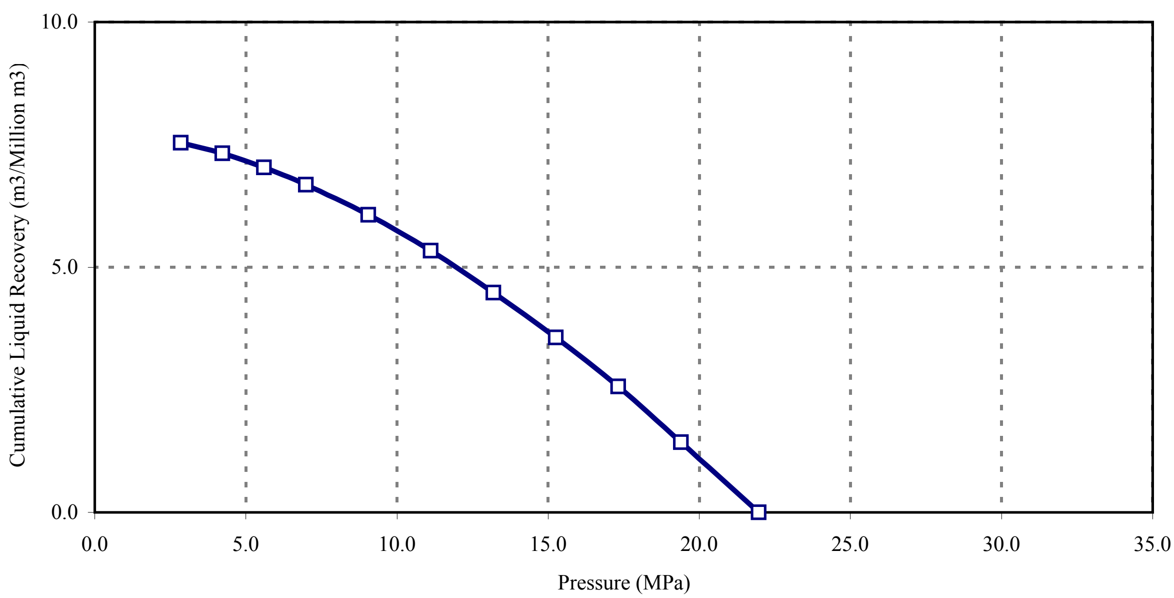
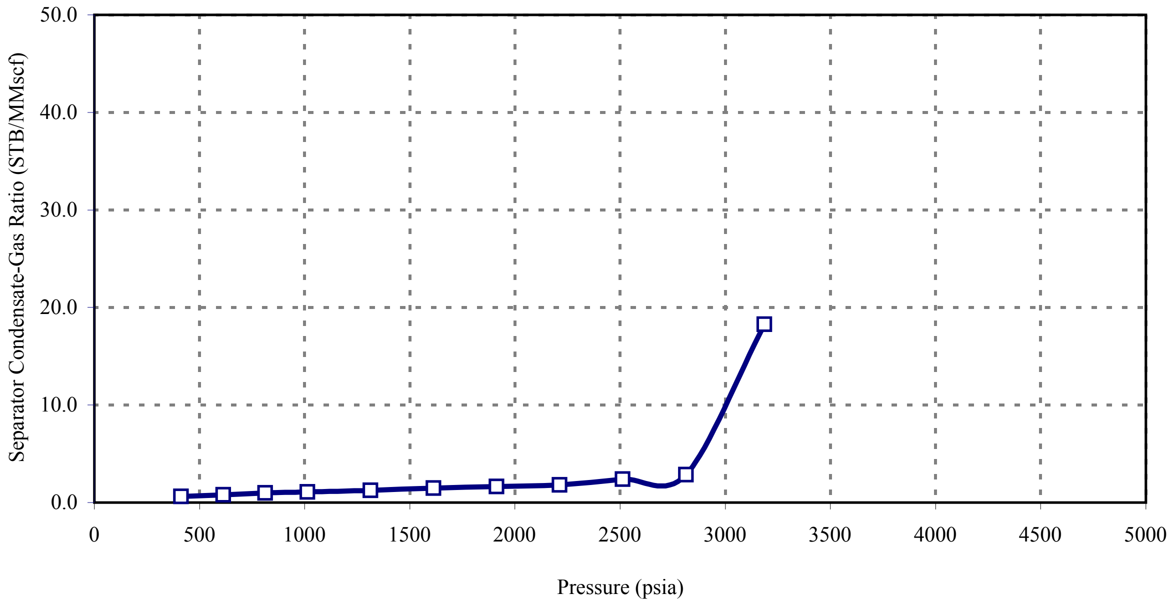



**FIGURE 6**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT VOLUME DEPLETION CONDENSATE-GAS RATIO @ 190.4 F (88.0 C)**



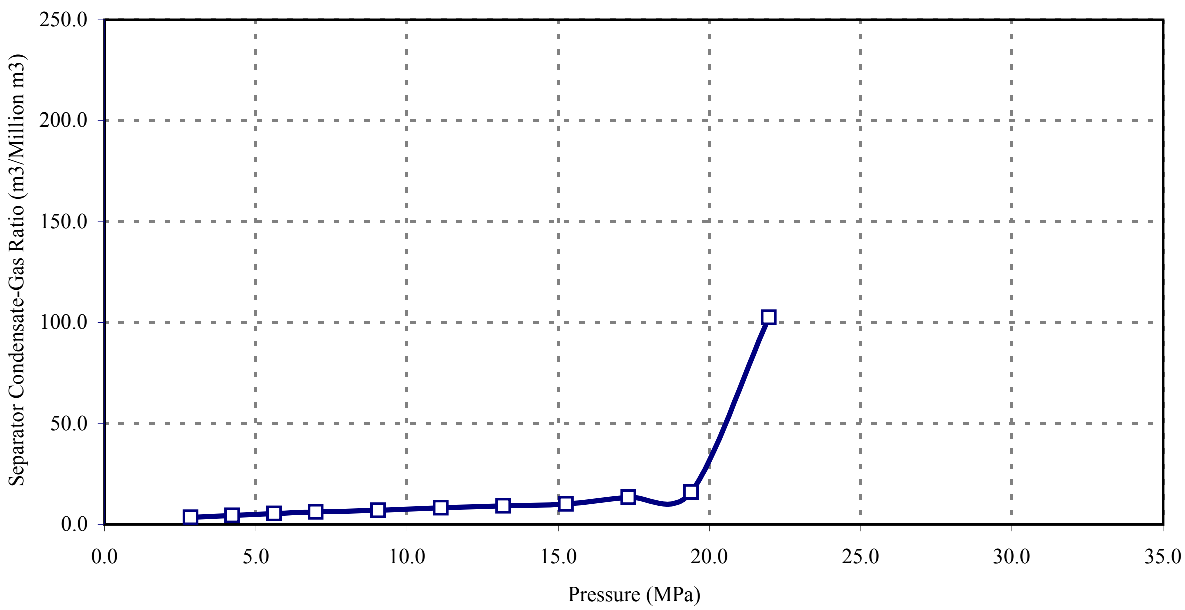
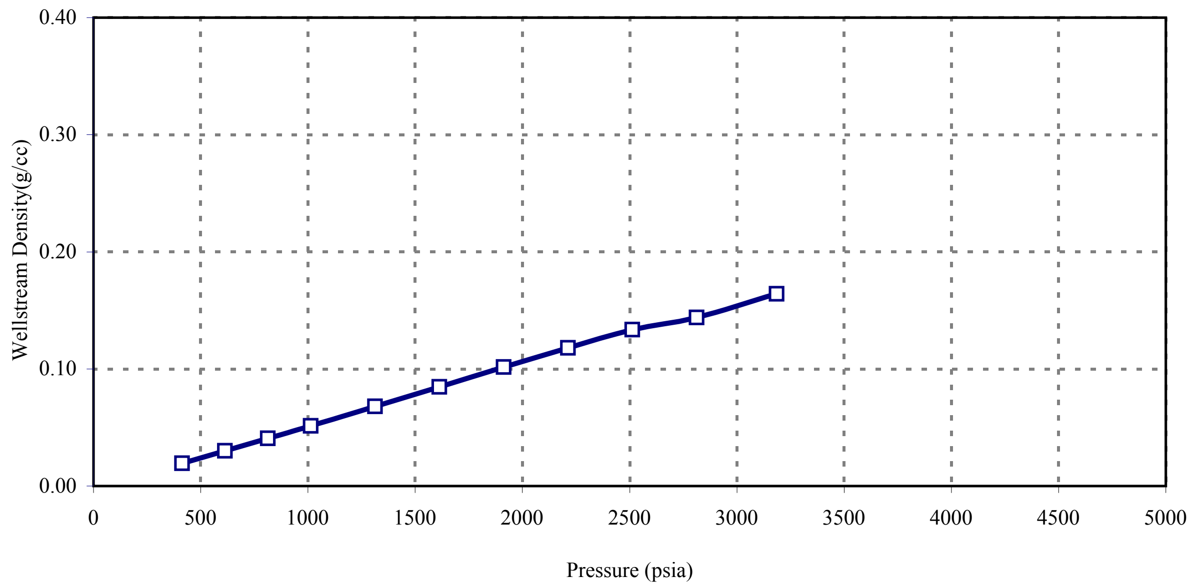



**FIGURE 7**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT VOLUME DEPLETION WELLSTREAM DENSITY @ 190.4 F (88.0 C)**



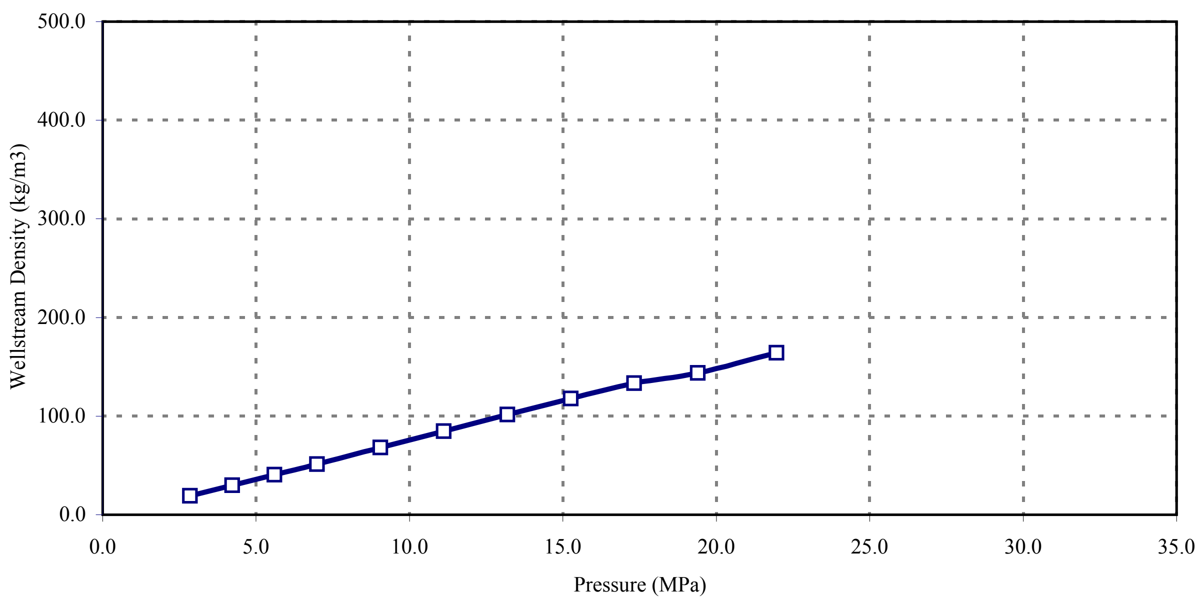
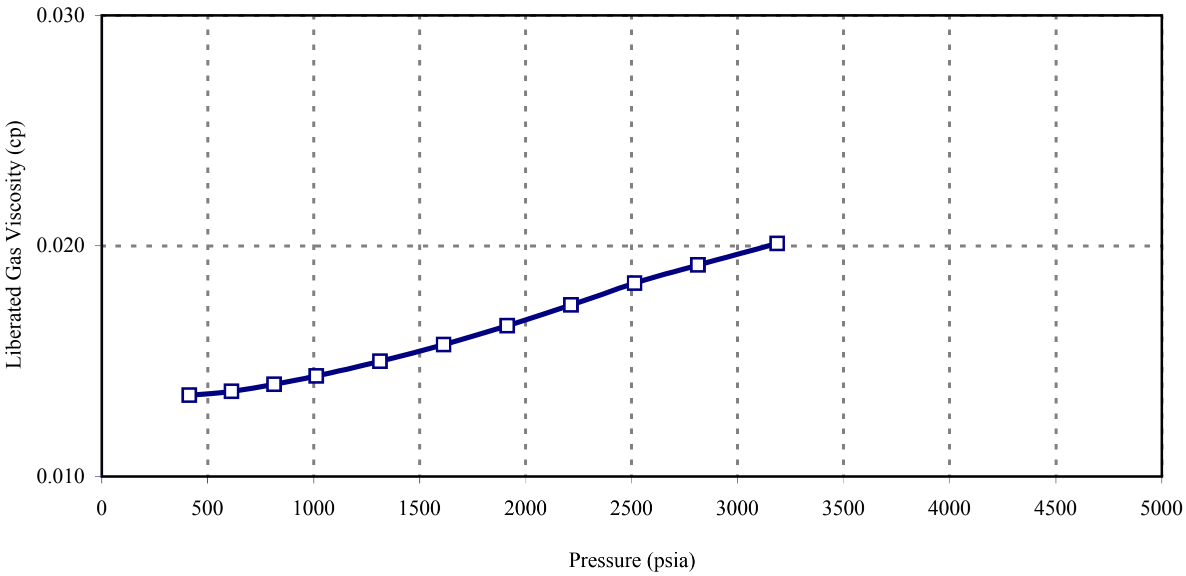



**FIGURE 8**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT VOLUME DEPLETION WELLSTREAM VISCOSITY @ 190.4 F (88.0 C)**



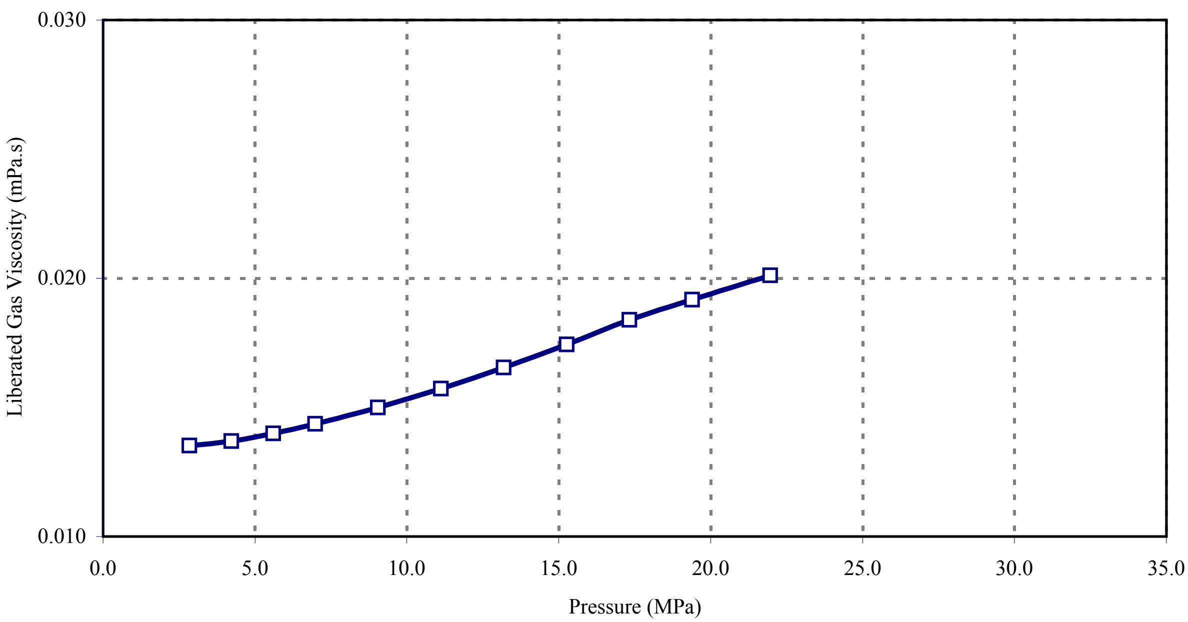
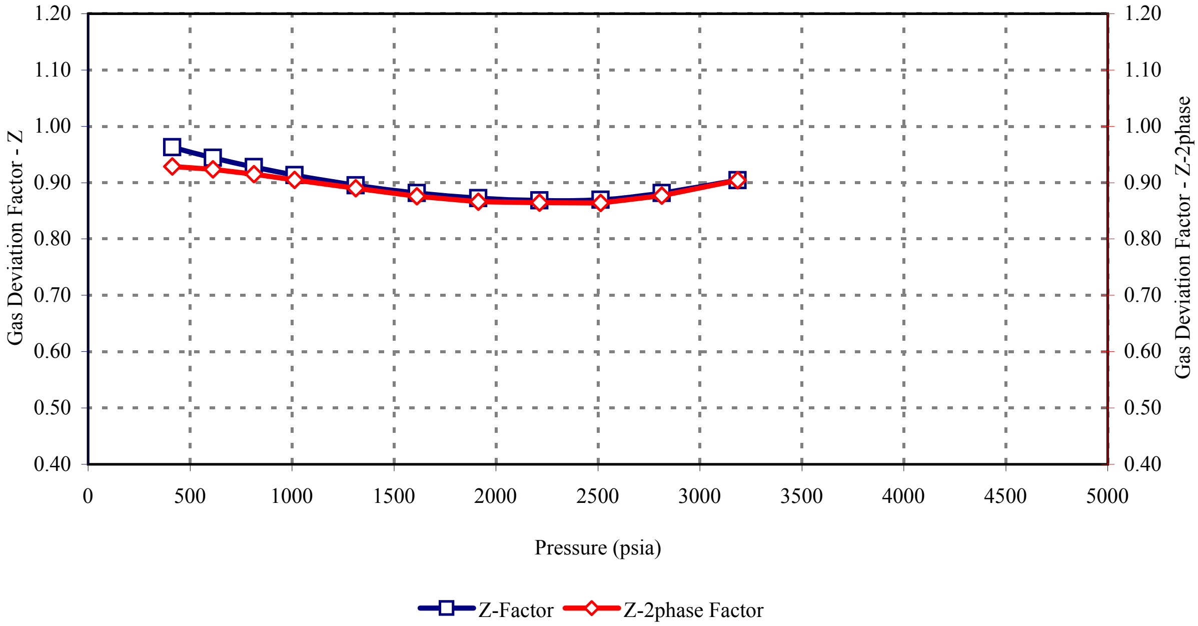



**FIGURE 9**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT VOLUME DEPLETION GAS DEVIATION FACTORS @ 190.4 F (88.0 C)**



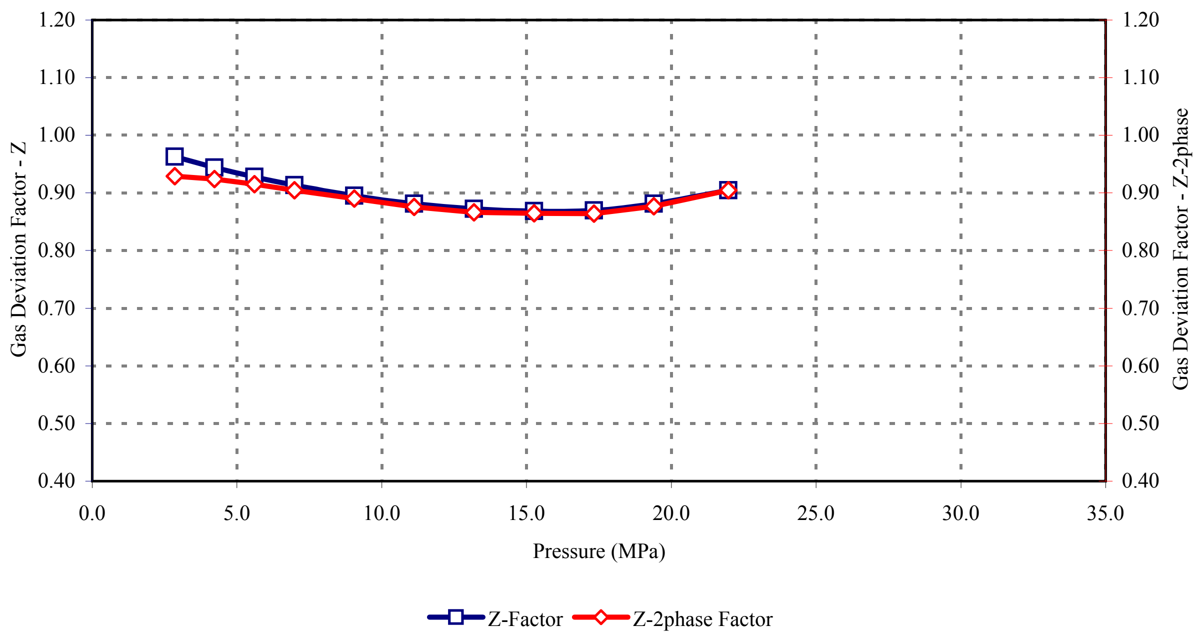
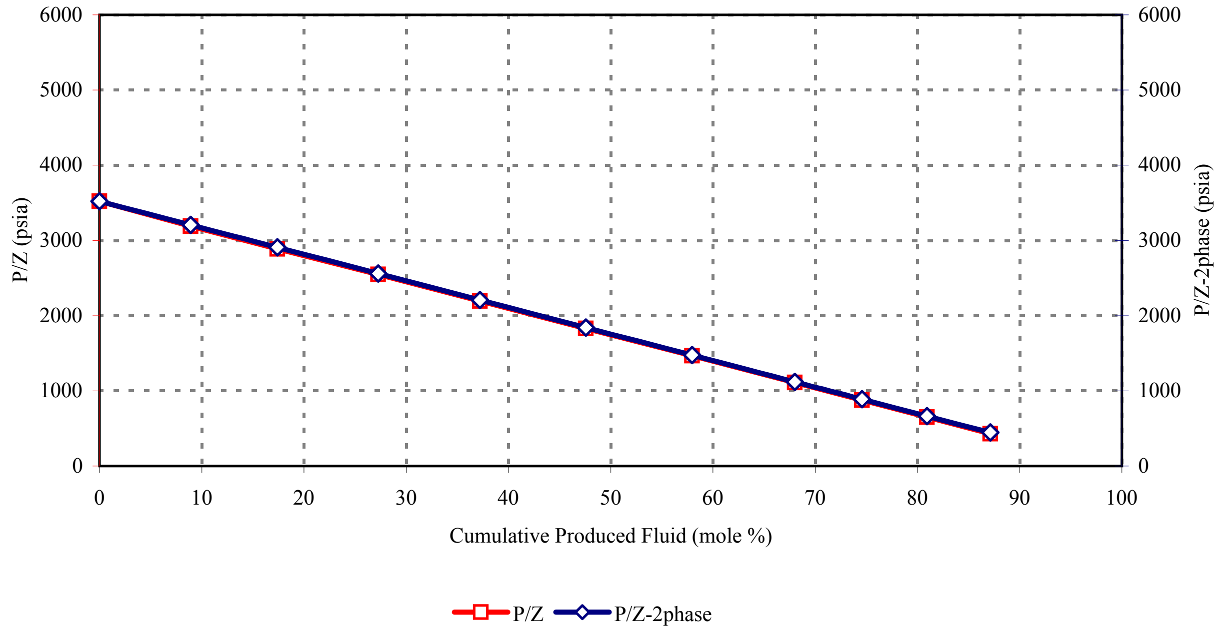



**FIGURE 10**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT VOLUME DEPLETION P/Z PARAMETERS @ 190.4 F (88.0 C)**



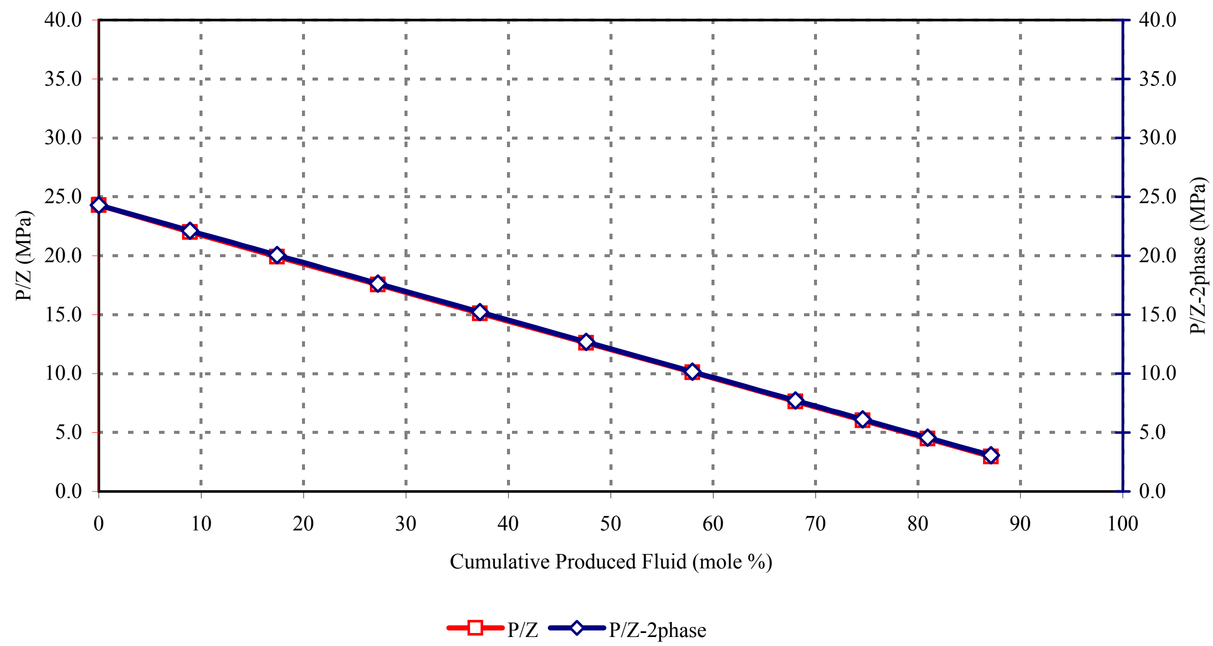
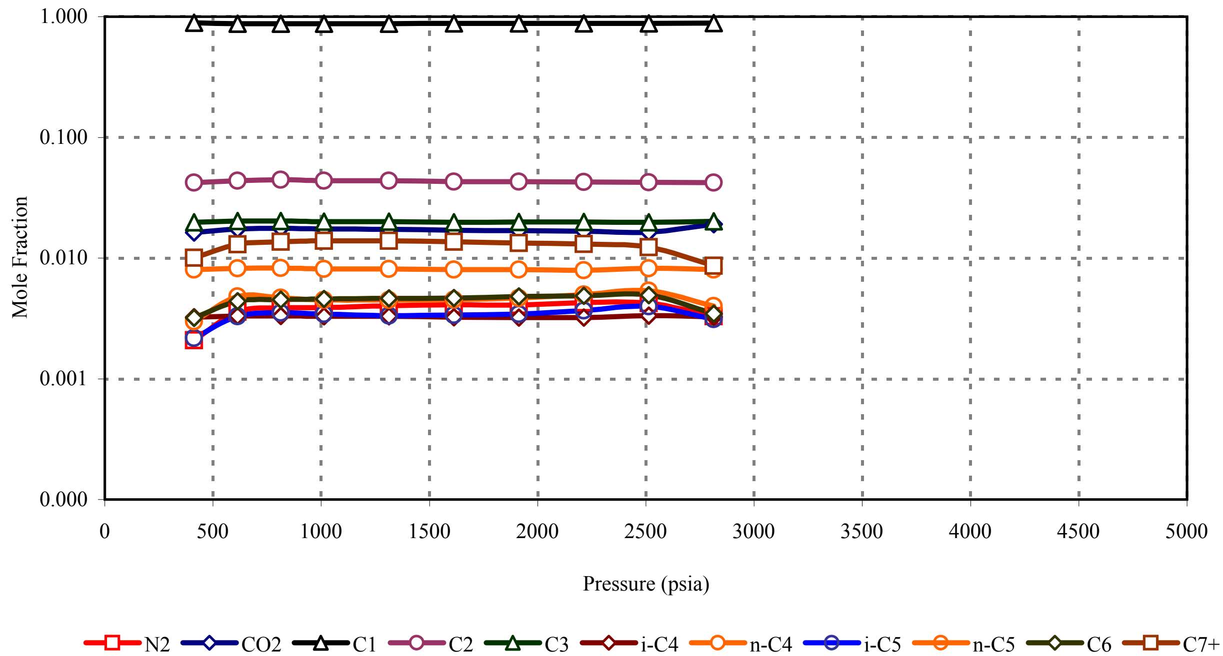
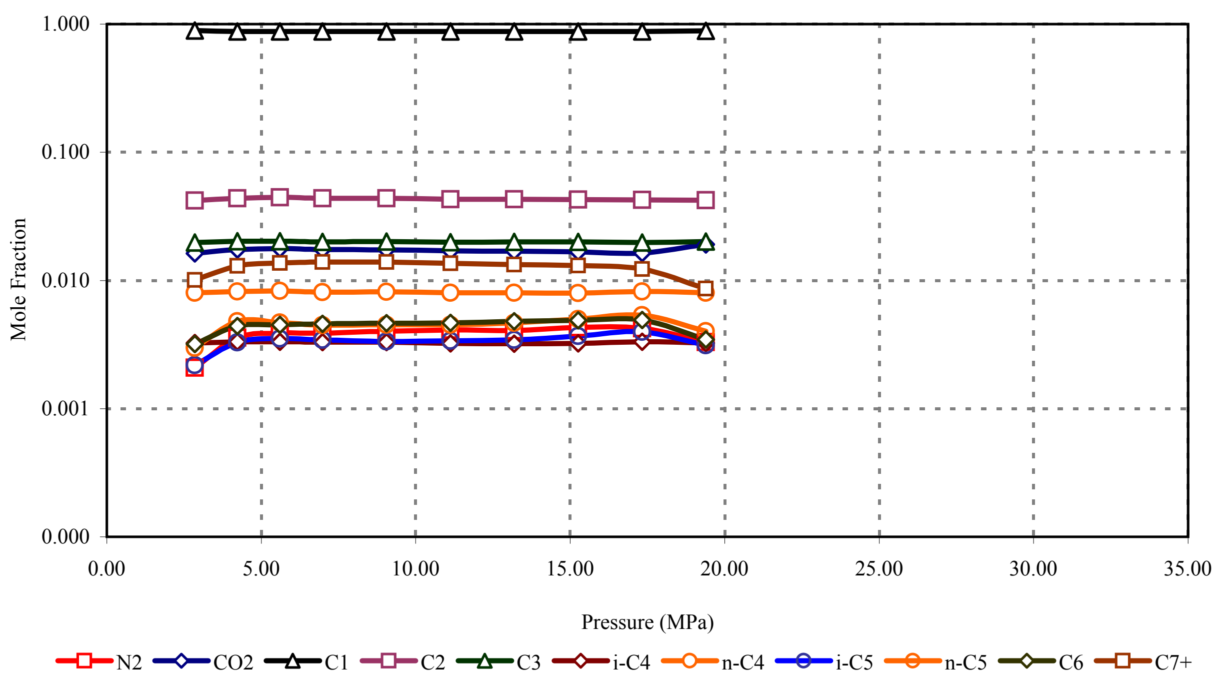



**FIGURE 11**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**CONSTANT VOLUME DEPLETION WELLSTREAM COMPOSITION @ 190.4 F (88.0 C)**



# APPENDIX A

**SAMPLE VALIDATION**

## TABLE A1
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF RESERVOIR FLUID

| Boiling Point (F) | Component Name | Chemical Symbol | Mole Fraction | Mass Fraction | Calculated Properties | |
|---|---|---|---|---|---|---|
| -320.4 | Nitrogen | $N_2$ | 0.0052 | 0.0070 | **Total Sample** | |
| -109.3 | Carbon Dioxide | $CO_2$ | 0.0161 | 0.0344 | | |
| -76.6 | Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | Molecular Weight | 20.64 |
| -259.1 | Methane | $C_1$ | 0.8813 | 0.6853 | Density (g/cc) | 0.3321 |
| -128.0 | Ethane | $C_2$ | 0.0398 | 0.0580 | | |
| -44.0 | Propane | $C_3$ | 0.0198 | 0.0424 | **$C_{6+}$ Fraction** | |
| 10.9 | i-Butane | i-$C_4$ | 0.0031 | 0.0089 | | |
| 30.9 | n-Butane | n-$C_4$ | 0.0077 | 0.0216 | Molecular Weight | 117.88 |
| 82.0 | i-Pentane | i-$C_5$ | 0.0022 | 0.0076 | Mole Fraction | 0.0218 |
| 97.0 | n-Pentane | n-$C_5$ | 0.0029 | 0.0103 | Density (g/cc) | 0.7752 |
| 97 - 156 | Hexanes | $C_6$ | 0.0033 | 0.0137 | | |
| 156 - 208.9 | Heptanes | $C_7$ | 0.0019 | 0.0093 | **$C_{7+}$ Fraction** | |
| 208.9 - 258.1 | Octanes | $C_8$ | 0.0015 | 0.0082 | | |
| 258.1 - 303.1 | Nonanes | $C_9$ | 0.0013 | 0.0082 | Molecular Weight | 104.10 |
| 303.1 - 345 | Decanes | $C_{10}$ | 0.0011 | 0.0074 | Mole Fraction | 0.0185 |
| 345 - 385 | Undecanes | $C_{11}$ | 0.0008 | 0.0059 | Density (g/cc) | 0.7880 |
| 385 - 419 | Dodecanes | $C_{12}$ | 0.0009 | 0.0069 | | |
| 419 - 455 | Tridecanes | $C_{13}$ | 0.0008 | 0.0069 | **$C_{12+}$ Fraction** | |
| 455 - 486 | Tetradecanes | $C_{14}$ | 0.0006 | 0.0054 | | |
| 486 - 519.1 | Pentadecanes | $C_{15}$ | 0.0005 | 0.0045 | Molecular Weight | 203.48 |
| 519.1 - 550 | Hexadecanes | $C_{16}$ | 0.0004 | 0.0041 | Mole Fraction | 0.0038 |
| 550 - 557 | Heptadecanes | $C_{17}$ | 0.0002 | 0.0027 | Density (g/cc) | 0.8326 |
| 557 - 603 | Octadecanes | $C_{18}$ | 0.0002 | 0.0024 | | |
| 603 - 626 | Nonadecanes | $C_{19}$ | 0.0001 | 0.0012 | | |
| 626 - 651.9 | Eicosanes | $C_{20}$ | 0.0000 | 0.0004 | | |
| 651.9 - 675 | Heneicosanes | $C_{21}$ | 0.0000 | 0.0003 | | |
| 675 - 696.9 | Docosanes | $C_{22}$ | 0.0000 | 0.0002 | | |
| 696.9 - 716 | Tricosanes | $C_{23}$ | 0.0000 | 0.0002 | | |
| 716 - 736 | Tetracosanes | $C_{24}$ | 0.0000 | 0.0002 | | |
| 736 - 755.1 | Pentacosanes | $C_{25}$ | 0.0000 | 0.0002 | | |
| 755.1 - 774 | Hexacosanes | $C_{26}$ | 0.0000 | 0.0002 | **Recombination Parameters** | |
| 774.1 - 792 | Heptacosanes | $C_{27}$ | 0.0000 | 0.0002 | | |
| 792.1 - 809.1 | Octacosanes | $C_{28}$ | 0.0000 | 0.0002 | Gas-Oil Ratio (cc/cc) | 9750.19 |
| 809.1 - 826 | Nonacosanes | $C_{29}$ | 0.0000 | 0.0002 | Dead Oil Density (g/cc) | 0.7700 |
| Above 826 | Tricontanes Plus | $C_{30+}$ | 0.0001 | 0.0019 | Dead Oil MW (g/mol) | 136.70 |
| | NAPHTHENES | | | | | |
| 120.0 | Cyclopentane | $C_5H_{10}$ | 0.0001 | 0.0002 | | |
| 162.0 | Methylcyclopentane | $C_6H_{12}$ | 0.0049 | 0.0199 | | |
| 178.0 | Cyclohexane | $C_6H_{12}$ | 0.0008 | 0.0032 | | |
| 214.0 | Methylcyclohexane | $C_7H_{14}$ | 0.0008 | 0.0039 | | |
| | AROMATICS | | | | | |
| 176.0 | Benzene | $C_6H_6$ | 0.0005 | 0.0020 | | |
| 231.1 | Toluene | $C_7H_8$ | 0.0006 | 0.0027 | | |
| 277 - 282 | Ethylbenzene & p,m-Xylene | $C_8H_{10}$ | 0.0002 | 0.0008 | | |
| 291.9 | o-Xylene | $C_8H_{10}$ | 0.0001 | 0.0005 | | |
| 336.0 | 1, 2, 4-Trimethylbenzene | $C_9H_{12}$ | 0.0001 | 0.0005 | | |
| **Total** | | | **1.0000** | **1.0000** | | |

Note: Physical Properties calculated based GPA 2145-00 physical constants

## TABLE A2
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF FLASHED OIL

| Boiling Point (F) | Component Name | Chemical Symbol | Mole Fraction | Mass Fraction | Calculated Properties | |
|---|---|---|---|---|---|---|
| -320.4 | Nitrogen | $N_2$ | 0.0000 | 0.0000 | **Total Sample** | |
| -109.3 | Carbon Dioxide | $CO_2$ | 0.0000 | 0.0000 | | |
| -76.6 | Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | Molecular Weight | 136.70 |
| -259.1 | Methane | $C_1$ | 0.0000 | 0.0000 | Density (g/cc) | 0.7880 |
| -128.0 | Ethane | $C_2$ | 0.0000 | 0.0000 | | |
| -44.0 | Propane | $C_3$ | 0.0002 | 0.0001 | **$C_{6+}$ Fraction** | |
| 10.9 | i-Butane | $i\text{-}C_4$ | 0.0005 | 0.0002 | | |
| 30.9 | n-Butane | $n\text{-}C_4$ | 0.0034 | 0.0015 | Molecular Weight | 139.04 |
| 82.0 | i-Pentane | $i\text{-}C_5$ | 0.0089 | 0.0048 | Mole Fraction | 0.9660 |
| 97.0 | n-Pentane | $n\text{-}C_5$ | 0.0210 | 0.0113 | Density (g/cc) | 0.7919 |
| 97 - 156 | Hexanes | $C_6$ | 0.0706 | 0.0455 | | |
| 156 - 208.9 | Heptanes | $C_7$ | 0.0919 | 0.0688 | **$C_{7+}$ Fraction** | |
| 208.9 - 258.1 | Octanes | $C_8$ | 0.1066 | 0.0910 | | |
| 258.1 - 303.1 | Nonanes | $C_9$ | 0.0979 | 0.0938 | Molecular Weight | 143.63 |
| 303.1 - 345 | Decanes | $C_{10}$ | 0.0799 | 0.0849 | Mole Fraction | 0.8902 |
| 345 - 385 | Undecanes | $C_{11}$ | 0.0616 | 0.0677 | Density (g/cc) | 0.7979 |
| 385 - 419 | Dodecanes | $C_{12}$ | 0.0651 | 0.0783 | | |
| 419 - 455 | Tridecanes | $C_{13}$ | 0.0607 | 0.0794 | **$C_{12+}$ Fraction** | |
| 455 - 486 | Tetradecanes | $C_{14}$ | 0.0435 | 0.0617 | | |
| 486 - 519.1 | Pentadecanes | $C_{15}$ | 0.0336 | 0.0518 | Molecular Weight | 203.48 |
| 519.1 - 550 | Hexadecanes | $C_{16}$ | 0.0283 | 0.0469 | Mole Fraction | 0.2852 |
| 550 - 557 | Heptadecanes | $C_{17}$ | 0.0171 | 0.0303 | Density (g/cc) | 0.8326 |
| 557 - 603 | Octadecanes | $C_{18}$ | 0.0144 | 0.0271 | | |
| 603 - 626 | Nonadecanes | $C_{19}$ | 0.0067 | 0.0132 | | |
| 626 - 651.9 | Eicosanes | $C_{20}$ | 0.0024 | 0.0050 | | |
| 651.9 - 675 | Heneicosanes | $C_{21}$ | 0.0013 | 0.0029 | | |
| 675 - 696.9 | Docosanes | $C_{22}$ | 0.0009 | 0.0021 | | |
| 696.9 - 716 | Tricosanes | $C_{23}$ | 0.0008 | 0.0020 | | |
| 716 - 736 | Tetracosanes | $C_{24}$ | 0.0007 | 0.0019 | | |
| 736 - 755.1 | Pentacosanes | $C_{25}$ | 0.0007 | 0.0018 | | |
| 755.1 - 774 | Hexacosanes | $C_{26}$ | 0.0007 | 0.0018 | | |
| 774.1 - 792 | Heptacosanes | $C_{27}$ | 0.0007 | 0.0019 | | |
| 792.1 - 809.1 | Octacosanes | $C_{28}$ | 0.0007 | 0.0021 | | |
| 809.1 - 826 | Nonacosanes | $C_{29}$ | 0.0007 | 0.0022 | | |
| Above 826 | Tricontanes Plus | $C_{30+}$ | 0.0060 | 0.0209 | | |
| | NAPHTHENES | | | | | |
| 120.0 | Cyclopentane | $C_5H_{10}$ | 0.0052 | 0.0027 | | |
| 162.0 | Methylcyclopentane | $C_6H_{12}$ | 0.0202 | 0.0127 | | |
| 178.0 | Cyclohexane | $C_6H_{12}$ | 0.0255 | 0.0160 | | |
| 214.0 | Methylcyclohexane | $C_7H_{14}$ | 0.0414 | 0.0303 | | |
| | AROMATICS | | | | | |
| 176.0 | Benzene | $C_6H_6$ | 0.0187 | 0.0109 | | |
| 231.1 | Toluene | $C_7H_8$ | 0.0359 | 0.0247 | | |
| 277 - 282 | Ethylbenzene & p,m-Xylene | $C_8H_{10}$ | 0.0114 | 0.0091 | | |
| 291.9 | o-Xylene | $C_8H_{10}$ | 0.0076 | 0.0060 | | |
| 336.0 | 1, 2, 4-Trimethylbenzene | $C_9H_{12}$ | 0.0064 | 0.0058 | | |
| **Total** | | | **1.0000** | **1.0209** | | |

Note: Physical Properties calculated based GPA 2145-00 physical constants

## TABLE A3
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF FLASHED GAS

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume (STB/MMscf) | Liquid Volume (mL/m$^3$) |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0052 | 0.0053 | | |
| Carbon Dioxide | $CO_2$ | 0.0163 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.8933 | 0.9082 | | |
| Ethane | $C_2$ | 0.0404 | 0.0411 | | |
| Propane | $C_3$ | 0.0201 | 0.0204 | 13.135 | 73.746 |
| i-Butane | i-$C_4$ | 0.0032 | 0.0032 | 2.469 | 13.860 |
| n-Butane | n-$C_4$ | 0.0077 | 0.0078 | 5.772 | 32.410 |
| i-Pentane | i-$C_5$ | 0.0021 | 0.0021 | 1.821 | 10.222 |
| n-Pentane | n-$C_5$ | 0.0027 | 0.0027 | 2.310 | 12.968 |
| Hexanes | $C_6$ | 0.0024 | 0.0024 | 2.295 | 12.885 |
| Heptanes | $C_7$ | 0.0007 | 0.0007 | 0.746 | 4.190 |
| Octanes | $C_8$ | 0.0000 | 0.0000 | 0.052 | 0.289 |
| Nonanes | $C_9$ | 0.0000 | 0.0000 | 0.007 | 0.040 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **0.9942** | **0.9941** | **28.606** | **160.611** |
| Propanes Plus | $C_{3+}$ | 0.0389 | 0.0395 | 28.606 | 160.611 |
| Butanes Plus | $C_{4+}$ | 0.0188 | 0.0191 | 15.471 | 86.865 |
| Pentanes Plus | $C_{5+}$ | 0.0079 | 0.0080 | 7.230 | 40.594 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 18.55 kg/kmol | 18.55 lb/lb-mol | Ppc | 667.2 psia | 4.60 MPa |
| Specific Gravity | 0.6405 (Air = 1) | 0.6405 (Air = 1) | Tpc | 370.0 R | 205.5 K |
| MW of C7+ | 0.07 kg/kmol | 0.07 lb/lbmol | Ppc* | 662.2 psia | 4.57 MPa |
| Density of C7+ | 0.7236 g/cc | 723.6 kg/m3 | Tpc* | 367.2 R | 204.0 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,094.1 Btu/scf | 40.84 MJ/m3 | Dry | 988.7 Btu/scf | 36.91 MJ/m3 |
| Wet | 1,075.0 Btu/scf | 40.13 MJ/m3 | Wet | 971.5 Btu/scf | 36.26 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 7682

# HUSKY ENERGY - NORTH AMETHYST
# MULTI-STAGE SEPARATOR TEST

## F I N A L   R E P O R T

Prepared for

HUSKY ENERGY

By

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Calgary, Alberta
Canada T2E 6T6
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April 26, 2007

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# MULTI-STAGE SEPARATOR TEST

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## RESULTS AND DISCUSSION

The multi-stage separator test was conducted on a BOTTOMHOLE sample prepared from separator oil and separator gas collected from Well K-15 of NORTH AMETHYST reservoir.

The sample collection data is provided in Table 1 and the sample validation data is given in Appendix A.

Table 2 provides the compositional analysis of the BOTTOMHOLE sample.

Table 3 contains various oil property measurements performed on the multi-stage separator test including live oil density, oil formation volume factor and gas-oil ratios.

Table 4 contains a summary of the gas properties including gas gravities, deviation factors, gas formation volume factors and gas expansion factors.

Table 5 presents the compositional analysis of the residual oil at completion of the experiment.

Appendix B contains the material balance check performed for this experiment. It is displayed as formation volume factors so that the balance can be checked on a point by point basis. Appendix C contains the compositional analyses of the liberated gases from the multi-stage separator test.

## SUMMARY

**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**MAIN PVT RESULTS**

### INITIAL RESERVOIR CONDITIONS

| | | | | |
|---|---|---|---|---|
| Reservoir Pressure | 3459.6 | psia | 23.85 | MPa |
| Reservoir Temperature: | 190.6 | F | 88.1 | C |

### MULTI-STAGE SEPARATOR TEST

| | | | | |
|---|---|---|---|---|
| Saturation Pressure | 3022 | psia | 20.83 | MPa |
| At Saturation Pressure | | | | |
| Oil Formation Volume Factor | 1.2775 | res.bbl/STB | 1.2775 | res.$m^3/m^3$ |
| Solution Gas-Oil Ratio | 548.31 | scf/STB | 97.65 | $m^3/m^3$ |
| Oil Density | 0.7331 | $g/cm^3$ | 733.1 | $kg/m^3$ |
| At Ambient Pressure | | | | |
| Residual Oil Density | 0.8509 | $g/cm^3$ | 850.9 | $kg/m^3$ |
| At Tank Conditions | | | | |
| Residual Oil Density | 0.8508 | $g/cm^3$ | 850.8 | $kg/m^3$ |
| API Gravity | 34.8 | | 34.8 | |

### SINGLE-STAGE SEPARATOR TEST

| | | | | |
|---|---|---|---|---|
| At Saturation Pressure | | | | |
| Oil Formation Volume Factor | 1.2710 | res.bbl/STB | 1.2710 | res.$m^3/m^3$ |
| Solution Gas-Oil Ratio | 575.58 | scf/STB | 102.51 | $m^3/m^3$ |
| At Tank Conditions | | | | |
| Residual Oil Density | 0.8417 | $g/cm^3$ | 841.7 | $kg/m^3$ |
| API Gravity | 36.6 | | 36.6 | |

**TABLE 1**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**SAMPLE COLLECTION DATA**

| | | | | |
|---|---|---|---|---|
| Project File: | 2006-147 | | | |
| Operator Name: | HUSKY ENERGY | | | |
| Pool or Zone: | BEN NEVIS - AVALON | | | |
| Field or Area: | NORTH AMETHYST | | | |
| Well Location: | K-15 | | | |
| Fluid Sample: | BOTTOMHOLE | | | |
| Sampling Company: | Schlumberger | | | |
| Name of Sampler: | N/A | | | |
| Sampling Date: | 39023 | | | |
| Sampling Point: | SUBSURFACE | | | |
| Sampling Temperature: | 190.6 | F | 88.1 | C |
| Sampling Pressure: | 3459.6 | psia | 23.85 | MPa |
| Reservoir Temperature: | 190.6 | F | 88.1 | C |
| Reservoir Pressure: | 3459.6 | psia | 23.85 | MPa |
| Initial Reservoir Pressure (Pi) | 3459.6 | psia | 23.85 | MPa |
| Depth of Reported Pi | 2390.0 | mMD | N/A | mss |

## TABLE 2
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF RESERVOIR FLUID

| Boiling Point (K) | | | Mole Fraction | Mass Fraction | Calculated Properties | |
|---|---|---|---|---|---|---|
| 77.4 | Nitrogen | N2 | 0.0028 | 0.0007 | **Total Sample** | |
| 194.6 | Carbon Dioxide | CO2 | 0.0116 | 0.0044 | | |
| 212.8 | Hydrogen Sulphide | H2S | 0.0000 | 0.0000 | Molecular Weight | 114.39 |
| 111.5 | Methane | C1 | 0.4361 | 0.0612 | | |
| 184.3 | Ethane | C2 | 0.0393 | 0.0103 | | |
| 231.0 | Propane | C3 | 0.0271 | 0.0104 | **C6+ Fraction** | |
| 261.5 | i-Butane | i-C4 | 0.0056 | 0.0028 | | |
| 272.6 | n-Butane | n-C4 | 0.0161 | 0.0082 | Molecular Weight | 229.51 |
| 301.0 | i-Pentane | i-C5 | 0.0068 | 0.0043 | Mole Fraction | 0.4440 |
| 309.3 | n-Pentane | n-C5 | 0.0107 | 0.0068 | Density (g/cc) | 0.8660 |
| 309.3 - 342 | Hexanes | C6 | 0.0165 | 0.0124 | | |
| 342 - 371.4 | Heptanes | C7 | 0.0179 | 0.0157 | | |
| 371.4 - 398.8 | Octanes | C8 | 0.0224 | 0.0224 | **C7+ Fraction** | |
| 398.8 - 423.8 | Nonanes | C9 | 0.0262 | 0.0293 | | |
| 423.8 - 447 | Decanes | C10 | 0.0261 | 0.0325 | Molecular Weight | 235.43 |
| 447 - 469.3 | Undecanes | C11 | 0.0256 | 0.0329 | Mole Fraction | 0.4256 |
| 469.3 - 488.2 | Dodecanes | C12 | 0.0271 | 0.0382 | Density (g/cc) | 0.8695 |
| 488.2 - 508.2 | Tridecanes | C13 | 0.0265 | 0.0405 | | |
| 508.2 - 525.4 | Tetradecanes | C14 | 0.0212 | 0.0352 | | |
| 525.4 - 543.8 | Pentadecanes | C15 | 0.0174 | 0.0314 | **C12+ Fraction** | |
| 543.8 - 560.9 | Hexadecanes | C16 | 0.0161 | 0.0312 | | |
| 560.9 - 564.8 | Heptadecanes | C17 | 0.0134 | 0.0278 | Molecular Weight | 309.59 |
| 564.8 - 590.4 | Octadecanes | C18 | 0.0135 | 0.0295 | Mole Fraction | 0.2615 |
| 590.4 - 603.2 | Nonadecanes | C19 | 0.0116 | 0.0267 | Density (g/cc) | 0.8956 |
| 603.2 - 617.5 | Eicosanes | C20 | 0.0090 | 0.0217 | | |
| 617.5 - 630.4 | Heneicosanes | C21 | 0.0080 | 0.0205 | | |
| 630.4 - 642.5 | Docosanes | C22 | 0.0074 | 0.0198 | | |
| 642.5 - 653.2 | Tricosanes | C23 | 0.0069 | 0.0192 | | |
| 653.2 - 664.3 | Tetracosanes | C24 | 0.0062 | 0.0180 | | |
| 664.3 - 674.9 | Pentacosanes | C25 | 0.0060 | 0.0182 | | |
| 674.9 - 685.4 | Hexacosanes | C26 | 0.0055 | 0.0172 | | |
| 685.4 - 695.4 | Heptacosanes | C27 | 0.0051 | 0.0167 | | |
| 695.4 - 704.9 | Octacosanes | C28 | 0.0051 | 0.0173 | | |
| 704.9 - 714.3 | Nonacosanes | C29 | 0.0048 | 0.0169 | | |
| Above 714.3 | Tricontanes Plus | C30+ | 0.0506 | 0.2619 | | |
| | | | | | | |
| 322.0 | Cyclopentane | C5H10 | 0.0019 | 0.0012 | | |
| 345.4 | Methylcyclopentane | C6H12 | 0.0076 | 0.0056 | | |
| 354.3 | Cyclohexane | C6H12 | 0.0069 | 0.0051 | | |
| 374.3 | Methylcyclohexane | C7H14 | 0.0102 | 0.0087 | | |
| | | | | | | |
| 353.2 | Benzene | C6H6 | 0.0064 | 0.0043 | | |
| 383.8 | Toluene | C7H8 | 0.0084 | 0.0068 | | |
| 409.3 - 412 | Ethylbenzene & p,m-Xylene | C8H10 | 0.0028 | 0.0026 | | |
| 417.5 | o-Xylene | C8H10 | 0.0019 | 0.0017 | | |
| 442.0 | 1, 2, 4-Trimethylbenzene | C9H12 | 0.0017 | 0.0017 | | |
| **Total** | | | **1.0000** | **1.0000** | | |

**TABLE 3**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**MULTI-STAGE SEPARATOR OIL PROPERTIES**

| Pressure | | Temperature | | Oil | Oil Formation | Total Formation | Gas-Oil Ratio | | Gas-Oil Ratio | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Density | Volume Factor | Volume Factor | Solution | Liberated | Solution | Liberated |
| (psia) | (MPa) | (F) | (C) | (g/cm³) | [1] | [2] | (scf/STB) | (scf/STB) | (m³/m³) | (m³/m³) |
| **3022 Psat** | **20.83** | **191** | **88.1** | **0.7331** | **1.2775** | **1.2775** | **548.31** | **0.00** | **97.65** | **0.00** |
| 580 | 4.00 | 185 | 85.0 | 0.8127 | 1.0714 | 3.3795 | 102.79 | 445.52 | 18.31 | 79.35 |
| 348 | 2.40 | 136 | 58.0 | 0.8293 | 1.0448 | 4.8201 | 74.01 | 474.30 | 13.18 | 84.47 |
| 180 | 1.24 | 131 | 55.0 | 0.8322 | 1.0354 | 8.6240 | 44.61 | 503.69 | 7.95 | 89.71 |
| 29 | 0.20 | 122 | 50.0 | 0.8409 | 1.0155 | 38.8752 | 5.50 | 542.80 | 0.98 | 96.67 |
| 13 | 0.09 | 60 | 15.6 | 0.8509 | 1.0000 | 56.6359 | 0.00 | 548.31 | 0.00 | 97.65 |

Density of Residual Oil = 0.8508 g/cm3 (850.8 kg/m3) @ 60 F (288.7K)
API Gravity of Residual Oil = 34.8

[1] Barrels (Cubic meters) of oil at indicated pressure and temperature per barrel (cubic meter) of residual oil @ 60 F (288.7 K).
[2] Total barrels (cubic meters) of oil and liberated gas at the indicated pressure and temperature per barrel (cubic meter) of residual oil @ 60 F (288.7 K).
Psat - Saturation Pressure
- Tank conditions: 60 F (288.7 K) @ 13 psia (0.0896 MPa); Standard conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa).

**TABLE 4**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**MULTI-STAGE SEPARATOR GAS PROPERTIES @ 190.6 F (88.1 C)**

| Pressure | | Temperature | | Gas Gravity | | Gas | Gas Deviation | Gas Formation | Gas Expansion |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Incremental | Cumulative | Density | Factor | Volume Factor | Factor |
| (psia) | (MPa) | (F) | (C) | (Air = 1) | (Air = 1) | (g/cm³) | (-) | [1] | [2] |
| **3022 Psat** | **20.83** | **191** | **88.1** | | | | | | |
| 580 | 4.00 | 185 | 85.0 | 0.6861 | 0.6861 | 0.0282 | 0.9458 | 0.0291 | 34.377 |
| 348 | 2.40 | 136 | 58.0 | 0.6837 | 0.6859 | 0.0180 | 0.9563 | 0.0447 | 22.375 |
| 180 | 1.24 | 131 | 55.0 | 0.7394 | 0.6891 | 0.0100 | 0.9727 | 0.0846 | 11.821 |
| 29 | 0.20 | 122 | 50.0 | 1.0321 | 0.7138 | 0.0022 | 0.9910 | 0.3916 | 2.553 |
| 13 | 0.09 | 60 | 15.6 | 1.1304 | 0.7179 | 0.0012 | 0.9930 | 0.5697 | 1.755 |

[1] Cubic feet (meters) of gas at indicated pressure and temperature per cubic feet (meter) @ standard conditions
[2] Cubic feet (meters) of gas @ standard conditions per cubic feet (meter) @ indicated pressure and temperature.
Psat - Saturation pressure
- Standard conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

## TABLE 5
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF RESIDUAL OIL

| Boiling Point (K) | | | Mole Fraction | Mass Fraction | Calculated Properties | |
|---|---|---|---|---|---|---|
| 77.4 | Nitrogen | N2 | 0.0000 | 0.0000 | **Total Sample** | |
| 194.6 | Carbon Dioxide | CO2 | 0.0000 | 0.0000 | | |
| 212.8 | Hydrogen Sulphide | H2S | 0.0000 | 0.0000 | Molecular Weight | 223.02 |
| 111.5 | Methane | C1 | 0.0000 | 0.0000 | | |
| 184.3 | Ethane | C2 | 0.0000 | 0.0000 | | |
| 231.0 | Propane | C3 | 0.0101 | 0.0020 | **C6+ Fraction** | |
| 261.5 | i-Butane | i-C4 | 0.0047 | 0.0012 | | |
| 272.6 | n-Butane | n-C4 | 0.0176 | 0.0046 | Molecular Weight | 233.51 |
| 301.0 | i-Pentane | i-C5 | 0.0109 | 0.0035 | Mole Fraction | 0.9387 |
| 309.3 | n-Pentane | n-C5 | 0.0181 | 0.0058 | Density (g/cc) | 0.8313 |
| 309.3 - 342 | Hexanes | C6 | 0.0314 | 0.0121 | | |
| 342 - 371.4 | Heptanes | C7 | 0.0361 | 0.0162 | | |
| 371.4 - 398.8 | Octanes | C8 | 0.0451 | 0.0231 | **C7+ Fraction** | |
| 398.8 - 423.8 | Nonanes | C9 | 0.0538 | 0.0310 | | |
| 423.8 - 447 | Decanes | C10 | 0.0531 | 0.0339 | Molecular Weight | 239.32 |
| 447 - 469.3 | Undecanes | C11 | 0.0516 | 0.0340 | Mole Fraction | 0.9034 |
| 469.3 - 488.2 | Dodecanes | C12 | 0.0554 | 0.0400 | Density (g/cc) | 0.8367 |
| 488.2 - 508.2 | Tridecanes | C13 | 0.0560 | 0.0439 | | |
| 508.2 - 525.4 | Tetradecanes | C14 | 0.0475 | 0.0405 | | |
| 525.4 - 543.8 | Pentadecanes | C15 | 0.0408 | 0.0377 | **C12+ Fraction** | |
| 543.8 - 560.9 | Hexadecanes | C16 | 0.0379 | 0.0377 | | |
| 560.9 - 564.8 | Heptadecanes | C17 | 0.0305 | 0.0324 | Molecular Weight | 308.27 |
| 564.8 - 590.4 | Octadecanes | C18 | 0.0319 | 0.0359 | Mole Fraction | 0.5749 |
| 590.4 - 603.2 | Nonadecanes | C19 | 0.0266 | 0.0313 | Density (g/cc) | 0.8701 |
| 603.2 - 617.5 | Eicosanes | C20 | 0.0204 | 0.0251 | | |
| 617.5 - 630.4 | Heneicosanes | C21 | 0.0183 | 0.0238 | | |
| 630.4 - 642.5 | Docosanes | C22 | 0.0168 | 0.0229 | | |
| 642.5 - 653.2 | Tricosanes | C23 | 0.0149 | 0.0213 | | |
| 653.2 - 664.3 | Tetracosanes | C24 | 0.0135 | 0.0201 | | |
| 664.3 - 674.9 | Pentacosanes | C25 | 0.0132 | 0.0204 | | |
| 674.9 - 685.4 | Hexacosanes | C26 | 0.0114 | 0.0184 | | |
| 685.4 - 695.4 | Heptacosanes | C27 | 0.0105 | 0.0176 | | |
| 695.4 - 704.9 | Octacosanes | C28 | 0.0104 | 0.0182 | | |
| 704.9 - 714.3 | Nonacosanes | C29 | 0.0098 | 0.0177 | | |
| Above 714.3 | Tricontanes Plus | C30+ | 0.1093 | 0.2899 | | |
| 322.0 | Cyclopentane | C5H10 | 0.0039 | 0.0012 | | |
| 345.4 | Methylcyclopentane | C6H12 | 0.0104 | 0.0039 | | |
| 354.3 | Cyclohexane | C6H12 | 0.0138 | 0.0052 | | |
| 374.3 | Methylcyclohexane | C7H14 | 0.0207 | 0.0091 | | |
| 353.2 | Benzene | C6H6 | 0.0127 | 0.0044 | | |
| 383.8 | Toluene | C7H8 | 0.0176 | 0.0073 | | |
| 409.3 - 412 | Ethylbenzene & p,m-Xylene | C8H10 | 0.0060 | 0.0028 | | |
| 417.5 | o-Xylene | C8H10 | 0.0039 | 0.0018 | | |
| 442.0 | 1, 2, 4-Trimethylbenzene | C9H12 | 0.0037 | 0.0020 | | |
| **Total** | | | **1.0000** | **1.0000** | | |

# APPENDIX A

**SAMPLE VALIDATION**

# TABLE A1
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF RESERVOIR FLUID

| Boiling Point (F) | Component Name | Chemical Symbol | Mole Fraction | Mass Fraction | Calculated Properties | |
|---|---|---|---|---|---|---|
| -320.4 | Nitrogen | $N_2$ | 0.0028 | 0.0007 | **Total Sample** | |
| -109.3 | Carbon Dioxide | $CO_2$ | 0.0116 | 0.0044 | | |
| -76.6 | Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | Molecular Weight | 114.39 |
| -259.1 | Methane | $C_1$ | 0.4361 | 0.0612 | Density (g/cc) | 0.7544 |
| -128.0 | Ethane | $C_2$ | 0.0393 | 0.0103 | | |
| -44.0 | Propane | $C_3$ | 0.0271 | 0.0104 | **$C_{6+}$ Fraction** | |
| 10.9 | i-Butane | i-$C_4$ | 0.0056 | 0.0028 | | |
| 30.9 | n-Butane | n-$C_4$ | 0.0161 | 0.0082 | Molecular Weight | 229.51 |
| 82.0 | i-Pentane | i-$C_5$ | 0.0068 | 0.0043 | Mole Fraction | 0.4440 |
| 97.0 | n-Pentane | n-$C_5$ | 0.0107 | 0.0068 | Density (g/cc) | 0.8660 |
| 97 - 156 | Hexanes | $C_6$ | 0.0165 | 0.0124 | | |
| 156 - 208.9 | Heptanes | $C_7$ | 0.0179 | 0.0157 | **$C_{7+}$ Fraction** | |
| 208.9 - 258.1 | Octanes | $C_8$ | 0.0224 | 0.0224 | | |
| 258.1 - 303.1 | Nonanes | $C_9$ | 0.0262 | 0.0293 | Molecular Weight | 235.43 |
| 303.1 - 345 | Decanes | $C_{10}$ | 0.0261 | 0.0325 | Mole Fraction | 0.4256 |
| 345 - 385 | Undecanes | $C_{11}$ | 0.0256 | 0.0329 | Density (g/cc) | 0.8695 |
| 385 - 419 | Dodecanes | $C_{12}$ | 0.0271 | 0.0382 | | |
| 419 - 455 | Tridecanes | $C_{13}$ | 0.0265 | 0.0405 | **$C_{12+}$ Fraction** | |
| 455 - 486 | Tetradecanes | $C_{14}$ | 0.0212 | 0.0352 | | |
| 486 - 519.1 | Pentadecanes | $C_{15}$ | 0.0174 | 0.0314 | Molecular Weight | 309.59 |
| 519.1 - 550 | Hexadecanes | $C_{16}$ | 0.0161 | 0.0312 | Mole Fraction | 0.2615 |
| 550 - 557 | Heptadecanes | $C_{17}$ | 0.0134 | 0.0278 | Density (g/cc) | 0.8956 |
| 557 - 603 | Octadecanes | $C_{18}$ | 0.0135 | 0.0295 | | |
| 603 - 626 | Nonadecanes | $C_{19}$ | 0.0116 | 0.0267 | **$C_{30+}$ Fraction** | |
| 626 - 651.9 | Eicosanes | $C_{20}$ | 0.0090 | 0.0217 | | |
| 651.9 - 675 | Heneicosanes | $C_{21}$ | 0.0080 | 0.0205 | Molecular Weight | 591.63 |
| 675 - 696.9 | Docosanes | $C_{22}$ | 0.0074 | 0.0198 | Mole Fraction | 0.0506 |
| 696.9 - 716 | Tricosanes | $C_{23}$ | 0.0069 | 0.0192 | Density (g/cc) | 0.9851 |
| 716 - 736 | Tetracosanes | $C_{24}$ | 0.0062 | 0.0180 | | |
| 736 - 755.1 | Pentacosanes | $C_{25}$ | 0.0060 | 0.0182 | | |
| 755.1 - 774 | Hexacosanes | $C_{26}$ | 0.0055 | 0.0172 | **Recombination Parameters** | |
| 774.1 - 792 | Heptacosanes | $C_{27}$ | 0.0051 | 0.0167 | | |
| 792.1 - 809.1 | Octacosanes | $C_{28}$ | 0.0051 | 0.0173 | Gas-Oil Ratio (cc/cc) | 102.51 |
| 809.1 - 826 | Nonacosanes | $C_{29}$ | 0.0048 | 0.0169 | Dead Oil Density (g/cc) | 0.8417 |
| Above 826 | Tricontanes Plus | $C_{30+}$ | 0.0506 | 0.2619 | Dead Oil MW (g/mol) | 220.56 |
| | NAPHTHENES | | | | | |
| 120.0 | Cyclopentane | $C_5H_{10}$ | 0.0019 | 0.0012 | | |
| 162.0 | Methylcyclopentane | $C_6H_{12}$ | 0.0076 | 0.0056 | | |
| 178.0 | Cyclohexane | $C_6H_{12}$ | 0.0069 | 0.0051 | | |
| 214.0 | Methylcyclohexane | $C_7H_{14}$ | 0.0102 | 0.0087 | | |
| | AROMATICS | | | | | |
| 176.0 | Benzene | $C_6H_6$ | 0.0064 | 0.0043 | | |
| 231.1 | Toluene | $C_7H_8$ | 0.0084 | 0.0068 | | |
| 277 - 282 | Ethylbenzene & p,m-Xylene | $C_8H_{10}$ | 0.0028 | 0.0026 | | |
| 291.9 | o-Xylene | $C_8H_{10}$ | 0.0019 | 0.0017 | | |
| 336.0 | 1, 2, 4-Trimethylbenzene | $C_9H_{12}$ | 0.0017 | 0.0017 | | |
| **Total** | | | **1.0000** | **1.0000** | | |

Note: Physical Properties calculated based on GPA 2145-00 physical constants

GC No.: 6162-7649

# TABLE A2
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF FLASHED OIL

| Boiling Point (F) | Component Name | Chemical Symbol | Mole Fraction | Mass Fraction |
|---|---|---|---|---|
| -320.4 | Nitrogen | $N_2$ | 0.0000 | 0.0000 |
| -109.3 | Carbon Dioxide | $CO_2$ | 0.0000 | 0.0000 |
| -76.6 | Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 |
| -259.1 | Methane | $C_1$ | 0.0000 | 0.0000 |
| -128.0 | Ethane | $C_2$ | 0.0000 | 0.0000 |
| -44.0 | Propane | $C_3$ | 0.0088 | 0.0025 |
| 10.9 | i-Butane | $i\text{-}C_4$ | 0.0047 | 0.0018 |
| 30.9 | n-Butane | $n\text{-}C_4$ | 0.0178 | 0.0066 |
| 82.0 | i-Pentane | $i\text{-}C_5$ | 0.0114 | 0.0053 |
| 97.0 | n-Pentane | $n\text{-}C_5$ | 0.0193 | 0.0089 |
| 97 - 156 | Hexanes | $C_6$ | 0.0328 | 0.0180 |
| 156 - 208.9 | Heptanes | $C_7$ | 0.0376 | 0.0240 |
| 208.9 - 258.1 | Octanes | $C_8$ | 0.0478 | 0.0349 |
| 258.1 - 303.1 | Nonanes | $C_9$ | 0.0558 | 0.0457 |
| 303.1 - 345 | Decanes | $C_{10}$ | 0.0558 | 0.0507 |
| 345 - 385 | Undecanes | $C_{11}$ | 0.0546 | 0.0513 |
| 385 - 419 | Dodecanes | $C_{12}$ | 0.0579 | 0.0595 |
| 419 - 455 | Tridecanes | $C_{13}$ | 0.0565 | 0.0631 |
| 455 - 486 | Tetradecanes | $C_{14}$ | 0.0452 | 0.0548 |
| 486 - 519.1 | Pentadecanes | $C_{15}$ | 0.0372 | 0.0489 |
| 519.1 - 550 | Hexadecanes | $C_{16}$ | 0.0343 | 0.0486 |
| 550 - 557 | Heptadecanes | $C_{17}$ | 0.0286 | 0.0433 |
| 557 - 603 | Octadecanes | $C_{18}$ | 0.0287 | 0.0460 |
| 603 - 626 | Nonadecanes | $C_{19}$ | 0.0247 | 0.0415 |
| 626 - 651.9 | Eicosanes | $C_{20}$ | 0.0193 | 0.0339 |
| 651.9 - 675 | Heneicosanes | $C_{21}$ | 0.0172 | 0.0319 |
| 675 - 696.9 | Docosanes | $C_{22}$ | 0.0158 | 0.0309 |
| 696.9 - 716 | Tricosanes | $C_{23}$ | 0.0147 | 0.0299 |
| 716 - 736 | Tetracosanes | $C_{24}$ | 0.0133 | 0.0280 |
| 736 - 755.1 | Pentacosanes | $C_{25}$ | 0.0129 | 0.0284 |
| 755.1 - 774 | Hexacosanes | $C_{26}$ | 0.0117 | 0.0269 |
| 774.1 - 792 | Heptacosanes | $C_{27}$ | 0.0109 | 0.0261 |
| 792.1 - 809.1 | Octacosanes | $C_{28}$ | 0.0109 | 0.0269 |
| 809.1 - 826 | Nonacosanes | $C_{29}$ | 0.0103 | 0.0263 |
| Above 826 | Tricontanes Plus | $C_{30+}$ | 0.1081 | 0.2899 |
| | NAPHTHENES | | | |
| 120.0 | Cyclopentane | $C_5H_{10}$ | 0.0041 | 0.0018 |
| 162.0 | Methylcyclopentane | $C_6H_{12}$ | 0.0110 | 0.0059 |
| 178.0 | Cyclohexane | $C_6H_{12}$ | 0.0143 | 0.0077 |
| 214.0 | Methylcyclohexane | $C_7H_{14}$ | 0.0215 | 0.0135 |
| | AROMATICS | | | |
| 176.0 | Benzene | $C_6H_6$ | 0.0132 | 0.0066 |
| 231.1 | Toluene | $C_7H_8$ | 0.0179 | 0.0106 |
| 277 - 282 | Ethylbenzene & p,m-Xylene | $C_8H_{10}$ | 0.0059 | 0.0040 |
| 291.9 | o-Xylene | $C_8H_{10}$ | 0.0040 | 0.0027 |
| 336.0 | 1, 2, 4-Trimethylbenzene | $C_9H_{12}$ | 0.0035 | 0.0027 |
| **Total** | | | **1.0000** | **1.2899** |

| Calculated Properties | |
|---|---|
| **Total Sample** | |
| Molecular Weight | 220.56 |
| Density (g/cc) | 0.8595 |
| **$C_{6+}$ Fraction** | |
| Molecular Weight | 230.98 |
| Mole Fraction | 0.9380 |
| Density (g/cc) | 0.8666 |
| **$C_{7+}$ Fraction** | |
| Molecular Weight | 236.97 |
| Mole Fraction | 0.9011 |
| Density (g/cc) | 0.8698 |
| **$C_{12+}$ Fraction** | |
| Molecular Weight | 309.59 |
| Mole Fraction | 0.5581 |
| Density (g/cc) | 0.8956 |
| **$C_{30+}$ Fraction** | |
| Molecular Weight | 591.63 |
| Mole Fraction | 0.0506 |
| Density (g/cc) | 0.9851 |

Note: Physical Properties calculated based on GPA 2145-00 physical constants

GC No.: 6162

# TABLE A3
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF FLASHED GAS

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0053 | 0.0054 | | |
| Carbon Dioxide | $CO_2$ | 0.0217 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.8206 | 0.8388 | | |
| Ethane | $C_2$ | 0.0740 | 0.0756 | | |
| Propane | $C_3$ | 0.0432 | 0.0442 | 28.210 | 158.387 |
| i-Butane | $i\text{-}C_4$ | 0.0063 | 0.0064 | 4.868 | 27.329 |
| n-Butane | $n\text{-}C_4$ | 0.0146 | 0.0149 | 10.895 | 61.168 |
| i-Pentane | $i\text{-}C_5$ | 0.0027 | 0.0028 | 2.368 | 13.293 |
| n-Pentane | $n\text{-}C_5$ | 0.0032 | 0.0033 | 2.743 | 15.398 |
| Hexanes | $C_6$ | 0.0022 | 0.0022 | 2.125 | 11.930 |
| Heptanes | $C_7$ | 0.0060 | 0.0061 | 6.544 | 36.742 |
| Octanes | $C_8$ | 0.0003 | 0.0003 | 0.371 | 2.083 |
| Nonanes | $C_9$ | 0.0000 | 0.0000 | 0.023 | 0.131 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **58.146** | **326.461** |
| Propanes Plus | $C_{3+}$ | 1.1524 | 1.1558 | 116.292 | 652.922 |
| Butanes Plus | $C_{4+}$ | 1.0784 | 1.0802 | 116.292 | 652.922 |
| Pentanes Plus | $C_{5+}$ | 1.0290 | 1.0296 | 83.214 | 467.206 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 20.83 kg/kmol | 20.83 lb/lb-mol | Ppc | 670.5 psia | 4.62 MPa |
| Specific Gravity | 0.7193 (Air = 1) | 0.7193 (Air = 1) | Tpc | 392.9 R | 218.3 K |
| MW of C7+ | 0.61 kg/kmol | 0.61 lb/lbmol | Ppc* | 664.4 psia | 4.58 MPa |
| Density of C7+ | 0.7232 g/cc | 723.2 kg/m3 | Tpc* | 389.3 R | 216.3 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,205.1 Btu/scf | 44.98 MJ/m3 | Dry | 1,092.3 Btu/scf | 40.77 MJ/m3 |
| Wet | 1,184.2 Btu/scf | 44.20 MJ/m3 | Wet | 1,073.3 Btu/scf | 40.06 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 7649

# APPENDIX B

**MULTI-STAGE SEPARATOR TEST - MATERIAL BALANCE**

**TABLE B1**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**MULTI-STAGE SEPARATOR @ 190.6 F (88.1 C) - MATERIAL BALANCE**

| Pressure (psia) | Pressure (MPa) | Measured Oil FVF [1] | Calculated Oil FVF [1] | Absolute Relative Error (%) |
|---|---|---|---|---|
| **3022 Psat** | **20.83** | **1.2775** | **1.2775** | **0.0000** |
| 580 | 4.00 | 1.0714 | 1.0705 | 0.0808 |
| 348 | 2.40 | 1.0448 | 1.0438 | 0.0907 |
| 180 | 1.24 | 1.0354 | 1.0346 | 0.0771 |
| 29 | 0.20 | 1.0155 | 1.0134 | 0.2065 |
| 13 | 0.09 | 1.0000 | 0.9999 | 0.0080 |

[1] (res bbl/STB) (res m3/m3)
Psat - Saturation Pressure
- Tank conditions: 60 F (288.7 K) @ 13 psia (0.09 MPa)

# APPENDIX C

**MULTI-STAGE SEPARATOR TEST - LIBERATED GAS ANALYSES**

**TABLE C1**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**MULTI-STAGE SEPARATOR GAS COMPOSITION @ 580 psia (4.00 MPa) AND 185.0 F (85.0 C)**

| Component Name | Chemical Symbol | Mole Fraction | | Liquid Volume | |
|---|---|---|---|---|---|
| | | As Analyzed | Acid Gas Free | STB/MMscf | mL/m3 |
| Nitrogen | $N_2$ | 0.0037 | 0.0038 | | |
| Carbon Dioxide | $CO_2$ | 0.0195 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.8630 | 0.8802 | | |
| Ethane | $C_2$ | 0.0574 | 0.0585 | | |
| Propane | $C_3$ | 0.0274 | 0.0280 | 17.921 | 100.616 |
| i-Butane | $i\text{-}C_4$ | 0.0038 | 0.0038 | 2.923 | 16.411 |
| n-Butane | $n\text{-}C_4$ | 0.0090 | 0.0091 | 6.703 | 37.634 |
| i-Pentane | $i\text{-}C_5$ | 0.0027 | 0.0028 | 2.364 | 13.274 |
| n-Pentane | $n\text{-}C_5$ | 0.0034 | 0.0035 | 2.911 | 16.344 |
| Hexanes | $C_6$ | 0.0026 | 0.0026 | 2.504 | 14.061 |
| Heptanes | $C_7$ | 0.0069 | 0.0071 | 7.605 | 42.698 |
| Octanes | $C_8$ | 0.0005 | 0.0005 | 0.603 | 3.387 |
| Nonanes | $C_9$ | 0.0000 | 0.0001 | 0.067 | 0.375 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **43.601** | **244.799** |
| Propanes Plus | $C_{3+}$ | 0.0563 | 0.0575 | 43.601 | 244.799 |
| Butanes Plus | $C_{4+}$ | 0.0289 | 0.0295 | 25.680 | 144.183 |
| Pentanes Plus | $C_{5+}$ | 0.0162 | 0.0165 | 16.054 | 90.138 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 19.87 kg/kmol | 19.87 lb/lb-mol | Ppc | 670.6 psia | 4.62 MPa |
| Specific Gravity | 0.6861 (Air = 1) | 0.6861 (Air = 1) | Tpc | 381.8 R | 212.1 K |
| MW of C7+ | 96.90 kg/kmol | 96.90 lb/lbmol | Ppc* | 664.9 psia | 4.58 MPa |
| Density of C7+ | 0.7238 g/cc | 723.8 kg/m3 | Tpc* | 378.6 R | 210.3 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,161.9 Btu/scf | 43.37 MJ/m3 | Dry | 1,051.8 Btu/scf | 39.26 MJ/m3 |
| Wet | 1,141.7 Btu/scf | 42.62 MJ/m3 | Wet | 1,033.5 Btu/scf | 38.58 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 8148

# TABLE C2
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## MULTI-STAGE SEPARATOR GAS COMPOSITION @ 348 psia (2.40 MPa) AND 136.4 F (58.0 C)

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0047 | 0.0048 | | |
| Carbon Dioxide | $CO_2$ | 0.0229 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.8515 | 0.8715 | | |
| Ethane | $C_2$ | 0.0660 | 0.0676 | | |
| Propane | $C_3$ | 0.0312 | 0.0319 | 20.374 | 114.388 |
| i-Butane | $i\text{-}C_4$ | 0.0041 | 0.0042 | 3.168 | 17.785 |
| n-Butane | $n\text{-}C_4$ | 0.0096 | 0.0099 | 7.213 | 40.500 |
| i-Pentane | $i\text{-}C_5$ | 0.0019 | 0.0020 | 1.670 | 9.378 |
| n-Pentane | $n\text{-}C_5$ | 0.0022 | 0.0023 | 1.896 | 10.644 |
| Hexanes | $C_6$ | 0.0015 | 0.0015 | 1.476 | 8.287 |
| Heptanes | $C_7$ | 0.0039 | 0.0040 | 4.244 | 23.827 |
| Octanes | $C_8$ | 0.0004 | 0.0004 | 0.429 | 2.408 |
| Nonanes | $C_9$ | 0.0000 | 0.0000 | 0.055 | 0.309 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **40.525** | **227.527** |
| Propanes Plus | $C_{3+}$ | 0.0548 | 0.0561 | 40.525 | 227.527 |
| Butanes Plus | $C_{4+}$ | 0.0236 | 0.0242 | 20.151 | 113.139 |
| Pentanes Plus | $C_{5+}$ | 0.0099 | 0.0101 | 9.770 | 54.854 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 19.80 kg/kmol | 19.80 lb/lb-mol | Ppc | 673.3 psia | 4.64 MPa |
| Specific Gravity | 0.6837 (Air = 1) | 0.6837 (Air = 1) | Tpc | 382.2 R | 212.3 K |
| MW of C7+ | 97.15 kg/kmol | 97.15 lb/lbmol | Ppc* | 666.7 psia | 4.60 MPa |
| Density of C7+ | 0.7243 g/cc | 724.3 kg/m3 | Tpc* | 378.5 R | 210.3 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,147.4 Btu/scf | 42.83 MJ/m3 | Dry | 1,038.5 Btu/scf | 38.76 MJ/m3 |
| Wet | 1,127.5 Btu/scf | 42.08 MJ/m3 | Wet | 1,020.4 Btu/scf | 38.09 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 8154

# TABLE C3
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## MULTI-STAGE SEPARATOR GAS COMPOSITION @ 180 psia (1.24 MPa) AND 131.0 F (55.0 C)

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0036 | 0.0037 | | |
| Carbon Dioxide | $CO_2$ | 0.0244 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.7957 | 0.8156 | | |
| Ethane | $C_2$ | 0.0940 | 0.0964 | | |
| Propane | $C_3$ | 0.0448 | 0.0459 | 29.225 | 164.086 |
| i-Butane | $i\text{-}C_4$ | 0.0058 | 0.0060 | 4.532 | 25.443 |
| n-Butane | $n\text{-}C_4$ | 0.0129 | 0.0132 | 9.646 | 54.159 |
| i-Pentane | $i\text{-}C_5$ | 0.0038 | 0.0039 | 3.294 | 18.492 |
| n-Pentane | $n\text{-}C_5$ | 0.0044 | 0.0045 | 3.793 | 21.296 |
| Hexanes | $C_6$ | 0.0030 | 0.0030 | 2.904 | 16.306 |
| Heptanes | $C_7$ | 0.0071 | 0.0073 | 7.765 | 43.596 |
| Octanes | $C_8$ | 0.0005 | 0.0005 | 0.602 | 3.377 |
| Nonanes | $C_9$ | 0.0001 | 0.0001 | 0.077 | 0.435 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **61.838** | **347.191** |
| Propanes Plus | $C_{3+}$ | 0.0823 | 0.0844 | 61.838 | 347.191 |
| Butanes Plus | $C_{4+}$ | 0.0376 | 0.0385 | 32.613 | 183.105 |
| Pentanes Plus | $C_{5+}$ | 0.0188 | 0.0193 | 18.435 | 103.503 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 21.42 kg/kmol | 21.42 lb/lb-mol | Ppc | 671.9 psia | 4.63 MPa |
| Specific Gravity | 0.7394 (Air = 1) | 0.7394 (Air = 1) | Tpc | 399.9 R | 222.1 K |
| MW of C7+ | 96.90 kg/kmol | 96.90 lb/lbmol | Ppc* | 665.3 psia | 4.59 MPa |
| Density of C7+ | 0.7238 g/cc | 723.8 kg/m3 | Tpc* | 395.9 R | 220.0 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,233.0 Btu/scf | 46.02 MJ/m3 | Dry | 1,118.4 Btu/scf | 41.75 MJ/m3 |
| Wet | 1,211.6 Btu/scf | 45.22 MJ/m3 | Wet | 1,098.9 Btu/scf | 41.02 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 8164

# TABLE C4
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## MULTI-STAGE SEPARATOR GAS COMPOSITION @ 29 psia (0.20 MPa) AND 122.0 F (50.0 C)

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0006 | 0.0006 | | |
| Carbon Dioxide | $CO_2$ | 0.0314 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.5155 | 0.5322 | | |
| Ethane | $C_2$ | 0.1875 | 0.1936 | | |
| Propane | $C_3$ | 0.1414 | 0.1460 | 92.357 | 518.538 |
| i-Butane | $i\text{-}C_4$ | 0.0221 | 0.0228 | 17.173 | 96.419 |
| n-Butane | $n\text{-}C_4$ | 0.0530 | 0.0547 | 39.668 | 222.716 |
| i-Pentane | $i\text{-}C_5$ | 0.0116 | 0.0120 | 10.067 | 56.521 |
| n-Pentane | $n\text{-}C_5$ | 0.0136 | 0.0140 | 11.664 | 65.485 |
| Hexanes | $C_6$ | 0.0076 | 0.0079 | 7.441 | 41.779 |
| Heptanes | $C_7$ | 0.0151 | 0.0156 | 16.520 | 92.751 |
| Octanes | $C_8$ | 0.0005 | 0.0005 | 0.634 | 3.562 |
| Nonanes | $C_9$ | 0.0000 | 0.0000 | 0.058 | 0.324 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **195.582** | **1098.094** |
| Propanes Plus | $C_{3+}$ | 0.2650 | 0.2736 | 195.582 | 1098.094 |
| Butanes Plus | $C_{4+}$ | 0.1236 | 0.1276 | 103.225 | 579.556 |
| Pentanes Plus | $C_{5+}$ | 0.0484 | 0.0500 | 46.384 | 260.422 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 29.89 kg/kmol | 29.89 lb/lb-mol | Ppc | 660.8 psia | 4.56 MPa |
| Specific Gravity | 1.0321 (Air = 1) | 1.0321 (Air = 1) | Tpc | 491.6 R | 273.1 K |
| MW of C7+ | 96.44 kg/kmol | 96.44 lb/lbmol | Ppc* | 654.3 psia | 4.51 MPa |
| Density of C7+ | 0.7229 g/cc | 722.9 kg/m3 | Tpc* | 486.8 R | 270.4 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,676.8 Btu/scf | 62.59 MJ/m3 | Dry | 1,532.6 Btu/scf | 57.21 MJ/m3 |
| Wet | 1,647.6 Btu/scf | 61.50 MJ/m3 | Wet | 1,505.9 Btu/scf | 56.21 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 8168

# TABLE C5
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## MULTI-STAGE SEPARATOR GAS COMPOSITION @ 13 psia (0.09 MPa) AND 60.0 F (15.6 C)

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0003 | 0.0003 | | |
| Carbon Dioxide | $CO_2$ | 0.0276 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.4430 | 0.4556 | | |
| Ethane | $C_2$ | 0.2120 | 0.2180 | | |
| Propane | $C_3$ | 0.1593 | 0.1639 | 104.051 | 584.197 |
| i-Butane | i-$C_4$ | 0.0241 | 0.0248 | 18.684 | 104.903 |
| n-Butane | n-$C_4$ | 0.0557 | 0.0572 | 41.638 | 233.777 |
| i-Pentane | i-$C_5$ | 0.0197 | 0.0203 | 17.135 | 96.205 |
| n-Pentane | n-$C_5$ | 0.0226 | 0.0232 | 19.399 | 108.915 |
| Hexanes | $C_6$ | 0.0117 | 0.0120 | 11.432 | 64.183 |
| Heptanes | $C_7$ | 0.0233 | 0.0240 | 25.531 | 143.343 |
| Octanes | $C_8$ | 0.0007 | 0.0007 | 0.813 | 4.562 |
| Nonanes | $C_9$ | 0.0001 | 0.0001 | 0.070 | 0.391 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **238.752** | **1340.477** |
| Propanes Plus | $C_{3+}$ | 0.3171 | 0.3261 | 238.752 | 1340.477 |
| Butanes Plus | $C_{4+}$ | 0.1578 | 0.1622 | 134.701 | 756.280 |
| Pentanes Plus | $C_{5+}$ | 0.0780 | 0.0802 | 74.379 | 417.600 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 32.74 kg/kmol | 32.74 lb/lb-mol | Ppc | 652.5 psia | 4.50 MPa |
| Specific Gravity | 1.1304 (Air = 1) | 1.1304 (Air = 1) | Tpc | 519.7 R | 288.7 K |
| MW of C7+ | 96.36 kg/kmol | 96.36 lb/lbmol | Ppc* | 647.0 psia | 4.46 MPa |
| Density of C7+ | 0.7227 g/cc | 722.7 kg/m3 | Tpc* | 515.3 R | 286.3 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,841.2 Btu/scf | 68.73 MJ/m3 | Dry | 1,685.8 Btu/scf | 62.93 MJ/m3 |
| Wet | 1,809.2 Btu/scf | 67.53 MJ/m3 | Wet | 1,656.5 Btu/scf | 61.83 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 8170

# HUSKY ENERGY - NORTH AMETHYST
# MULTI-STAGE SEPARATOR TEST

## F I N A L  R E P O R T

Prepared for

HUSKY ENERGY

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# MULTI-STAGE SEPARATOR TEST

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## RESULTS AND DISCUSSION

The multi-stage separator test was conducted on a BOTTOMHOLE sample prepared from separator oil and separator gas collected from Well K-15 of NORTH AMETHYST reservoir.

The sample collection data is provided in Table 1 and the sample validation data is given in Appendix A.

Table 2 provides the compositional analysis of the BOTTOMHOLE sample.

Table 3 contains various oil property measurements performed on the multi-stage separator test including live oil density, oil formation volume factor and gas-oil ratios.

Table 4 contains a summary of the gas properties including gas gravities, deviation factors, gas formation volume factors and gas expansion factors.

Table 5 presents the compositional analysis of the residual oil at completion of the experiment.

Appendix B contains the material balance check performed for this experiment. It is displayed as formation volume factors so that the balance can be checked on a point by point basis. Appendix C contains the compositional analyses of the liberated gases from the multi-stage separator test.

## SUMMARY

**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**MAIN PVT RESULTS**

### INITIAL RESERVOIR CONDITIONS

| | | | | |
|---|---|---|---|---|
| Reservoir Pressure | 3485 | psia | 24.03 | MPa |
| Reservoir Temperature: | 191.1 | F | 88.4 | C |

### MULTI-STAGE SEPARATOR TEST

| | | | | |
|---|---|---|---|---|
| Saturation Pressure | 3060 | psia | 21.10 | MPa |
| At Saturation Pressure | | | | |
| Oil Formation Volume Factor | 1.2966 | res.bbl/STB | 1.2966 | res.$m^3/m^3$ |
| Solution Gas-Oil Ratio | 566.93 | scf/STB | 100.97 | $m^3/m^3$ |
| Oil Density | 0.7241 | $g/cm^3$ | 724.1 | $kg/m^3$ |
| At Ambient Pressure | | | | |
| Residual Oil Density | 0.8502 | $g/cm^3$ | 850.2 | $kg/m^3$ |
| At Tank Conditions | | | | |
| Residual Oil Density | 0.8501 | $g/cm^3$ | 850.1 | $kg/m^3$ |
| API Gravity | 35.0 | | 35.0 | |

### SINGLE-STAGE SEPARATOR TEST

| | | | | |
|---|---|---|---|---|
| At Saturation Pressure | | | | |
| Oil Formation Volume Factor | 1.3048 | res.bbl/STB | 1.3048 | res.$m^3/m^3$ |
| Solution Gas-Oil Ratio | 594.93 | scf/STB | 105.96 | $m^3/m^3$ |
| At Tank Conditions | | | | |
| Residual Oil Density | 0.8468 | $g/cm^3$ | 846.8 | $kg/m^3$ |
| API Gravity | 35.6 | | 35.6 | |

## TABLE 1
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## SAMPLE COLLECTION DATA

| | | | | |
|---|---|---|---|---|
| Project File: | 2006-147 | | | |
| Operator Name: | HUSKY ENERGY | | | |
| Pool or Zone: | BEN NEVIS - AVALON | | | |
| Field or Area: | NORTH AMETHYST | | | |
| Well Location: | K-15 | | | |
| Fluid Sample: | BOTTOMHOLE | | | |
| | | | | |
| Sampling Company: | Schlumberger | | | |
| Name of Sampler: | N/A | | | |
| Sampling Date: | 2-Nov-06 | | | |
| Sampling Point: | SUBSURFACE | | | |
| Sampling Temperature: | 191.1 | F | 88.4 | C |
| Sampling Pressure: | 3484.7 | psia | 24.03 | MPa |
| | | | | |
| Reservoir Temperature: | 191.1 | F | 88.4 | C |
| Reservoir Pressure: | 3484.7 | psia | 24.03 | MPa |
| | | | | |
| Initial Reservoir Pressure (Pi) | 3484.7 | psia | 24.03 | MPa |
| Depth of Reported Pi | 2415.0 | mMD | N/A | mss |

## TABLE 2
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF RESERVOIR FLUID

| Boiling Point (K) | | | Mole Fraction | Mass Fraction | Calculated Properties | |
|---|---|---|---|---|---|---|
| 77.4 | Nitrogen | N2 | 0.0137 | 0.0034 | **Total Sample** | |
| 194.6 | Carbon Dioxide | CO2 | 0.0150 | 0.0058 | | |
| 212.8 | Hydrogen Sulphide | H2S | 0.0000 | 0.0000 | Molecular Weight | 113.45 |
| 111.5 | Methane | C1 | 0.4307 | 0.0609 | | |
| 184.3 | Ethane | C2 | 0.0382 | 0.0101 | | |
| 231.0 | Propane | C3 | 0.0270 | 0.0105 | **C6+ Fraction** | |
| 261.5 | i-Butane | i-C4 | 0.0056 | 0.0029 | | |
| 272.6 | n-Butane | n-C4 | 0.0162 | 0.0083 | Molecular Weight | 230.86 |
| 301.0 | i-Pentane | i-C5 | 0.0069 | 0.0044 | Mole Fraction | 0.4358 |
| 309.3 | n-Pentane | n-C5 | 0.0109 | 0.0069 | Density (g/cc) | 0.8673 |
| 309.3 - 342 | Hexanes | C6 | 0.0169 | 0.0128 | | |
| 342 - 371.4 | Heptanes | C7 | 0.0179 | 0.0158 | | |
| 371.4 - 398.8 | Octanes | C8 | 0.0225 | 0.0226 | **C7+ Fraction** | |
| 398.8 - 423.8 | Nonanes | C9 | 0.0256 | 0.0290 | | |
| 423.8 - 447 | Decanes | C10 | 0.0237 | 0.0298 | Molecular Weight | 237.09 |
| 447 - 469.3 | Undecanes | C11 | 0.0234 | 0.0303 | Mole Fraction | 0.4169 |
| 469.3 - 488.2 | Dodecanes | C12 | 0.0248 | 0.0351 | Density (g/cc) | 0.8709 |
| 488.2 - 508.2 | Tridecanes | C13 | 0.0245 | 0.0378 | | |
| 508.2 - 525.4 | Tetradecanes | C14 | 0.0212 | 0.0355 | | |
| 525.4 - 543.8 | Pentadecanes | C15 | 0.0188 | 0.0341 | **C12+ Fraction** | |
| 543.8 - 560.9 | Hexadecanes | C16 | 0.0174 | 0.0340 | | |
| 560.9 - 564.8 | Heptadecanes | C17 | 0.0139 | 0.0290 | Molecular Weight | 311.47 |
| 564.8 - 590.4 | Octadecanes | C18 | 0.0141 | 0.0312 | Mole Fraction | 0.2580 |
| 590.4 - 603.2 | Nonadecanes | C19 | 0.0117 | 0.0272 | Density (g/cc) | 0.8967 |
| 603.2 - 617.5 | Eicosanes | C20 | 0.0088 | 0.0213 | | |
| 617.5 - 630.4 | Heneicosanes | C21 | 0.0077 | 0.0198 | | |
| 630.4 - 642.5 | Docosanes | C22 | 0.0070 | 0.0189 | | |
| 642.5 - 653.2 | Tricosanes | C23 | 0.0065 | 0.0182 | | |
| 653.2 - 664.3 | Tetracosanes | C24 | 0.0058 | 0.0168 | | |
| 664.3 - 674.9 | Pentacosanes | C25 | 0.0056 | 0.0170 | | |
| 674.9 - 685.4 | Hexacosanes | C26 | 0.0050 | 0.0160 | | |
| 685.4 - 695.4 | Heptacosanes | C27 | 0.0047 | 0.0154 | | |
| 695.4 - 704.9 | Octacosanes | C28 | 0.0046 | 0.0158 | | |
| 704.9 - 714.3 | Nonacosanes | C29 | 0.0043 | 0.0153 | | |
| Above 714.3 | Tricontanes Plus | C30+ | 0.0516 | 0.2698 | | |
| | | | | | | |
| 322.0 | Cyclopentane | C5H10 | 0.0019 | 0.0012 | | |
| 345.4 | Methylcyclopentane | C6H12 | 0.0076 | 0.0056 | | |
| 354.3 | Cyclohexane | C6H12 | 0.0070 | 0.0052 | | |
| 374.3 | Methylcyclohexane | C7H14 | 0.0102 | 0.0088 | | |
| | | | | | | |
| 353.2 | Benzene | C6H6 | 0.0063 | 0.0043 | | |
| 383.8 | Toluene | C7H8 | 0.0083 | 0.0067 | | |
| 409.3 - 412 | Ethylbenzene & p,m-Xylene | C8H10 | 0.0028 | 0.0027 | | |
| 417.5 | o-Xylene | C8H10 | 0.0019 | 0.0018 | | |
| 442.0 | 1, 2, 4-Trimethylbenzene | C9H12 | 0.0016 | 0.0017 | | |
| **Total** | | | **1.0000** | **1.0000** | | |

**TABLE 3**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**MULTI-STAGE SEPARATOR OIL PROPERTIES**

| Pressure | | Temperature | | Oil Density | Oil Formation Volume Factor | Total Formation Volume Factor | Gas-Oil Ratio | | Gas-Oil Ratio | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Solution | Liberated | Solution | Liberated |
| (psia) | (MPa) | (F) | (C) | ($g/cm^3$) | [1] | [2] | (scf/STB) | (scf/STB) | ($m^3/m^3$) | ($m^3/m^3$) |
| **3060 Psat** | **21.10** | **191** | **88.4** | **0.7241** | **1.2966** | **1.2966** | **566.93** | **0.00** | **100.97** | **0.00** |
| 580 | 4.00 | 185 | 85.0 | 0.7985 | 1.0879 | 3.4740 | 106.15 | 460.78 | 18.90 | 82.07 |
| 348 | 2.40 | 136 | 58.0 | 0.8206 | 1.0541 | 4.9422 | 77.79 | 489.14 | 13.85 | 87.12 |
| 180 | 1.24 | 131 | 55.0 | 0.8301 | 1.0354 | 8.9442 | 41.92 | 525.01 | 7.47 | 93.50 |
| 29 | 0.20 | 122 | 50.0 | 0.8424 | 1.0122 | 40.2329 | 4.95 | 561.98 | 0.88 | 100.09 |
| 13 | 0.09 | 60 | 15.6 | 0.8502 | 1.0000 | 58.4935 | 0.00 | 566.93 | 0.00 | 100.97 |

Density of Residual Oil = 0.8501 g/cm3 (850.1 kg/m3) @ 60 F (288.7K)
API Gravity of Residual Oil = 35.0

[1] Barrels (Cubic meters) of oil at indicated pressure and temperature per barrel (cubic meter) of residual oil @ 60 F (288.7 K).
[2] Total barrels (cubic meters) of oil and liberated gas at the indicated pressure and temperature per barrel (cubic meter) of residual oil @ 60 F (288.7 K).
Psat - Saturation Pressure
- Tank conditions: 60 F (288.7 K) @ 13 psia (0.0896 MPa); Standard conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa).

**TABLE 4**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**MULTI-STAGE SEPARATOR GAS PROPERTIES @ 191.1 F (88.4 C)**

| Pressure | | Temperature | | Gas Gravity | | Gas | Gas Deviation | Gas Formation | Gas Expansion |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Incremental | Cumulative | Density | Factor | Volume Factor | Factor |
| (psia) | (MPa) | (F) | (C) | (Air = 1) | (Air = 1) | ($g/cm^3$) | (-) | [1] | [2] |
| **3060 Psat** | **21.10** | **191** | **88.4** | | | | | | |
| 580 | 4.00 | 185 | 85.0 | 0.6908 | 0.6908 | 0.0284 | 0.9453 | 0.0291 | 34.393 |
| 348 | 2.40 | 136 | 58.0 | 0.6973 | 0.6912 | 0.0184 | 0.9550 | 0.0446 | 22.406 |
| 180 | 1.24 | 131 | 55.0 | 0.7423 | 0.6947 | 0.0100 | 0.9726 | 0.0846 | 11.823 |
| 29 | 0.20 | 122 | 50.0 | 0.9990 | 0.7147 | 0.0022 | 0.9916 | 0.3919 | 2.552 |
| 13 | 0.09 | 60 | 15.6 | 1.1986 | 0.7189 | 0.0013 | 0.9924 | 0.5694 | 1.756 |

[1] Cubic feet (meters) of gas at indicated pressure and temperature per cubic feet (meter) @ standard conditions
[2] Cubic feet (meters) of gas @ standard conditions per cubic feet (meter) @ indicated pressure and temperature.
Psat - Saturation pressure
- Standard conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

## TABLE 5
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF RESIDUAL OIL

| Boiling Point (K) | | | Mole Fraction | Mass Fraction | Calculated Properties | |
|---|---|---|---|---|---|---|
| 77.4 | Nitrogen | N2 | 0.0000 | 0.0000 | **Total Sample** | |
| 194.6 | Carbon Dioxide | CO2 | 0.0000 | 0.0000 | | |
| 212.8 | Hydrogen Sulphide | H2S | 0.0000 | 0.0000 | Molecular Weight | 222.55 |
| 111.5 | Methane | C1 | 0.0000 | 0.0000 | | |
| 184.3 | Ethane | C2 | 0.0000 | 0.0000 | | |
| 231.0 | Propane | C3 | 0.0114 | 0.0023 | **C6+ Fraction** | |
| 261.5 | i-Butane | i-C4 | 0.0051 | 0.0013 | | |
| 272.6 | n-Butane | n-C4 | 0.0186 | 0.0049 | Molecular Weight | 233.67 |
| 301.0 | i-Pentane | i-C5 | 0.0111 | 0.0036 | Mole Fraction | 0.9352 |
| 309.3 | n-Pentane | n-C5 | 0.0185 | 0.0060 | Density (g/cc) | 0.8310 |
| 309.3 - 342 | Hexanes | C6 | 0.0314 | 0.0122 | | |
| 342 - 371.4 | Heptanes | C7 | 0.0364 | 0.0164 | | |
| 371.4 - 398.8 | Octanes | C8 | 0.0457 | 0.0235 | **C7+ Fraction** | |
| 398.8 - 423.8 | Nonanes | C9 | 0.0550 | 0.0317 | | |
| 423.8 - 447 | Decanes | C10 | 0.0554 | 0.0354 | Molecular Weight | 239.51 |
| 447 - 469.3 | Undecanes | C11 | 0.0554 | 0.0366 | Mole Fraction | 0.8999 |
| 469.3 - 488.2 | Dodecanes | C12 | 0.0596 | 0.0431 | Density (g/cc) | 0.8363 |
| 488.2 - 508.2 | Tridecanes | C13 | 0.0569 | 0.0448 | | |
| 508.2 - 525.4 | Tetradecanes | C14 | 0.0448 | 0.0383 | | |
| 525.4 - 543.8 | Pentadecanes | C15 | 0.0362 | 0.0335 | **C12+ Fraction** | |
| 543.8 - 560.9 | Hexadecanes | C16 | 0.0331 | 0.0330 | | |
| 560.9 - 564.8 | Heptadecanes | C17 | 0.0277 | 0.0295 | Molecular Weight | 312.13 |
| 564.8 - 590.4 | Octadecanes | C18 | 0.0286 | 0.0323 | Mole Fraction | 0.5615 |
| 590.4 - 603.2 | Nonadecanes | C19 | 0.0245 | 0.0289 | Density (g/cc) | 0.8713 |
| 603.2 - 617.5 | Eicosanes | C20 | 0.0193 | 0.0238 | | |
| 617.5 - 630.4 | Heneicosanes | C21 | 0.0175 | 0.0228 | | |
| 630.4 - 642.5 | Docosanes | C22 | 0.0162 | 0.0222 | | |
| 642.5 - 653.2 | Tricosanes | C23 | 0.0146 | 0.0209 | | |
| 653.2 - 664.3 | Tetracosanes | C24 | 0.0133 | 0.0198 | | |
| 664.3 - 674.9 | Pentacosanes | C25 | 0.0132 | 0.0205 | | |
| 674.9 - 685.4 | Hexacosanes | C26 | 0.0115 | 0.0186 | | |
| 685.4 - 695.4 | Heptacosanes | C27 | 0.0107 | 0.0180 | | |
| 695.4 - 704.9 | Octacosanes | C28 | 0.0108 | 0.0188 | | |
| 704.9 - 714.3 | Nonacosanes | C29 | 0.0103 | 0.0187 | | |
| Above 714.3 | Tricontanes Plus | C30+ | 0.1125 | 0.2999 | | |
| 322.0 | Cyclopentane | C5H10 | 0.0039 | 0.0012 | | |
| 345.4 | Methylcyclopentane | C6H12 | 0.0106 | 0.0040 | | |
| 354.3 | Cyclohexane | C6H12 | 0.0140 | 0.0053 | | |
| 374.3 | Methylcyclohexane | C7H14 | 0.0210 | 0.0093 | | |
| 353.2 | Benzene | C6H6 | 0.0128 | 0.0045 | | |
| 383.8 | Toluene | C7H8 | 0.0184 | 0.0076 | | |
| 409.3 - 412 | Ethylbenzene & p,m-Xylene | C8H10 | 0.0061 | 0.0029 | | |
| 417.5 | o-Xylene | C8H10 | 0.0040 | 0.0019 | | |
| 442.0 | 1, 2, 4-Trimethylbenzene | C9H12 | 0.0036 | 0.0020 | | |
| **Total** | | | **1.0000** | **1.0000** | | |

# APPENDIX A

**SAMPLE VALIDATION**

## TABLE A1
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF RESERVOIR FLUID

| Boiling Point (F) | Component Name | Chemical Symbol | Mole Fraction | Mass Fraction |
|---|---|---|---|---|
| -320.4 | Nitrogen | $N_2$ | 0.0137 | 0.0034 |
| -109.3 | Carbon Dioxide | $CO_2$ | 0.0150 | 0.0058 |
| -76.6 | Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 |
| -259.1 | Methane | $C_1$ | 0.4307 | 0.0609 |
| -128.0 | Ethane | $C_2$ | 0.0382 | 0.0101 |
| -44.0 | Propane | $C_3$ | 0.0270 | 0.0105 |
| 10.9 | i-Butane | i-$C_4$ | 0.0056 | 0.0029 |
| 30.9 | n-Butane | n-$C_4$ | 0.0162 | 0.0083 |
| 82.0 | i-Pentane | i-$C_5$ | 0.0069 | 0.0044 |
| 97.0 | n-Pentane | n-$C_5$ | 0.0109 | 0.0069 |
| 97 - 156 | Hexanes | $C_6$ | 0.0169 | 0.0128 |
| 156 - 208.9 | Heptanes | $C_7$ | 0.0179 | 0.0158 |
| 208.9 - 258.1 | Octanes | $C_8$ | 0.0225 | 0.0226 |
| 258.1 - 303.1 | Nonanes | $C_9$ | 0.0256 | 0.0290 |
| 303.1 - 345 | Decanes | $C_{10}$ | 0.0237 | 0.0298 |
| 345 - 385 | Undecanes | $C_{11}$ | 0.0234 | 0.0303 |
| 385 - 419 | Dodecanes | $C_{12}$ | 0.0248 | 0.0351 |
| 419 - 455 | Tridecanes | $C_{13}$ | 0.0245 | 0.0378 |
| 455 - 486 | Tetradecanes | $C_{14}$ | 0.0212 | 0.0355 |
| 486 - 519.1 | Pentadecanes | $C_{15}$ | 0.0188 | 0.0341 |
| 519.1 - 550 | Hexadecanes | $C_{16}$ | 0.0174 | 0.0340 |
| 550 - 557 | Heptadecanes | $C_{17}$ | 0.0139 | 0.0290 |
| 557 - 603 | Octadecanes | $C_{18}$ | 0.0141 | 0.0312 |
| 603 - 626 | Nonadecanes | $C_{19}$ | 0.0117 | 0.0272 |
| 626 - 651.9 | Eicosanes | $C_{20}$ | 0.0088 | 0.0213 |
| 651.9 - 675 | Heneicosanes | $C_{21}$ | 0.0077 | 0.0198 |
| 675 - 696.9 | Docosanes | $C_{22}$ | 0.0070 | 0.0189 |
| 696.9 - 716 | Tricosanes | $C_{23}$ | 0.0065 | 0.0182 |
| 716 - 736 | Tetracosanes | $C_{24}$ | 0.0058 | 0.0168 |
| 736 - 755.1 | Pentacosanes | $C_{25}$ | 0.0056 | 0.0170 |
| 755.1 - 774 | Hexacosanes | $C_{26}$ | 0.0050 | 0.0160 |
| 774.1 - 792 | Heptacosanes | $C_{27}$ | 0.0047 | 0.0154 |
| 792.1 - 809.1 | Octacosanes | $C_{28}$ | 0.0046 | 0.0158 |
| 809.1 - 826 | Nonacosanes | $C_{29}$ | 0.0043 | 0.0153 |
| Above 826 | Tricontanes Plus | $C_{30+}$ | 0.0516 | 0.2698 |
| | NAPHTHENES | | | |
| 120.0 | Cyclopentane | $C_5H_{10}$ | 0.0019 | 0.0012 |
| 162.0 | Methylcyclopentane | $C_6H_{12}$ | 0.0076 | 0.0056 |
| 178.0 | Cyclohexane | $C_6H_{12}$ | 0.0070 | 0.0052 |
| 214.0 | Methylcyclohexane | $C_7H_{14}$ | 0.0102 | 0.0088 |
| | AROMATICS | | | |
| 176.0 | Benzene | $C_6H_6$ | 0.0063 | 0.0043 |
| 231.1 | Toluene | $C_7H_8$ | 0.0083 | 0.0067 |
| 277 - 282 | Ethylbenzene & p,m-Xylene | $C_8H_{10}$ | 0.0028 | 0.0027 |
| 291.9 | o-Xylene | $C_8H_{10}$ | 0.0019 | 0.0018 |
| 336.0 | 1, 2, 4-Trimethylbenzene | $C_9H_{12}$ | 0.0016 | 0.0017 |
| **Total** | | | **1.0000** | **1.0000** |

| Calculated Properties | |
|---|---|
| **Total Sample** | |
| Molecular Weight | 113.45 |
| Density (g/cc) | 0.7554 |
| **$C_{6+}$ Fraction** | |
| Molecular Weight | 230.86 |
| Mole Fraction | 0.4358 |
| Density (g/cc) | 0.8673 |
| **$C_{7+}$ Fraction** | |
| Molecular Weight | 237.09 |
| Mole Fraction | 0.4169 |
| Density (g/cc) | 0.8709 |
| **$C_{12+}$ Fraction** | |
| Molecular Weight | 311.47 |
| Mole Fraction | 0.2580 |
| Density (g/cc) | 0.8967 |
| **$C_{30+}$ Fraction** | |
| Molecular Weight | 593.25 |
| Mole Fraction | 0.0516 |
| Density (g/cc) | 0.9853 |
| **Recombination Parameters** | |
| Gas-Oil Ratio (cc/cc) | 105.96 |
| Dead Oil Density (g/cc) | 0.8468 |
| Dead Oil MW (g/mol) | 221.51 |

Note: Physical Properties calculated based on GPA 2145-00 physical constants

GC No.: 6161-7647

## TABLE A2
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF FLASHED OIL

| Boiling Point (F) | Component Name | Chemical Symbol | Mole Fraction | Mass Fraction | Calculated Properties | |
|---|---|---|---|---|---|---|
| -320.4 | Nitrogen | $N_2$ | 0.0000 | 0.0000 | **Total Sample** | |
| -109.3 | Carbon Dioxide | $CO_2$ | 0.0000 | 0.0000 | | |
| -76.6 | Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | Molecular Weight | 221.51 |
| -259.1 | Methane | $C_1$ | 0.0000 | 0.0000 | Density (g/cc) | 0.8606 |
| -128.0 | Ethane | $C_2$ | 0.0000 | 0.0000 | | |
| -44.0 | Propane | $C_3$ | 0.0095 | 0.0027 | **$C_{6+}$ Fraction** | |
| 10.9 | i-Butane | i-$C_4$ | 0.0049 | 0.0018 | | |
| 30.9 | n-Butane | n-$C_4$ | 0.0184 | 0.0069 | Molecular Weight | 232.37 |
| 82.0 | i-Pentane | i-$C_5$ | 0.0115 | 0.0054 | Mole Fraction | 0.9359 |
| 97.0 | n-Pentane | n-$C_5$ | 0.0197 | 0.0092 | Density (g/cc) | 0.8679 |
| 97 - 156 | Hexanes | $C_6$ | 0.0340 | 0.0189 | | |
| 156 - 208.9 | Heptanes | $C_7$ | 0.0383 | 0.0248 | **$C_{7+}$ Fraction** | |
| 208.9 - 258.1 | Octanes | $C_8$ | 0.0487 | 0.0359 | | |
| 258.1 - 303.1 | Nonanes | $C_9$ | 0.0556 | 0.0460 | Molecular Weight | 238.66 |
| 303.1 - 345 | Decanes | $C_{10}$ | 0.0515 | 0.0473 | Mole Fraction | 0.8977 |
| 345 - 385 | Undecanes | $C_{11}$ | 0.0508 | 0.0482 | Density (g/cc) | 0.8713 |
| 385 - 419 | Dodecanes | $C_{12}$ | 0.0537 | 0.0558 | | |
| 419 - 455 | Tridecanes | $C_{13}$ | 0.0532 | 0.0600 | **$C_{12+}$ Fraction** | |
| 455 - 486 | Tetradecanes | $C_{14}$ | 0.0460 | 0.0564 | | |
| 486 - 519.1 | Pentadecanes | $C_{15}$ | 0.0407 | 0.0541 | Molecular Weight | 311.47 |
| 519.1 - 550 | Hexadecanes | $C_{16}$ | 0.0377 | 0.0540 | Mole Fraction | 0.5598 |
| 550 - 557 | Heptadecanes | $C_{17}$ | 0.0301 | 0.0460 | Density (g/cc) | 0.8967 |
| 557 - 603 | Octadecanes | $C_{18}$ | 0.0307 | 0.0496 | | |
| 603 - 626 | Nonadecanes | $C_{19}$ | 0.0254 | 0.0432 | **$C_{30+}$ Fraction** | |
| 626 - 651.9 | Eicosanes | $C_{20}$ | 0.0191 | 0.0339 | | |
| 651.9 - 675 | Heneicosanes | $C_{21}$ | 0.0167 | 0.0314 | Molecular Weight | 593.25 |
| 675 - 696.9 | Docosanes | $C_{22}$ | 0.0153 | 0.0301 | Mole Fraction | 0.0516 |
| 696.9 - 716 | Tricosanes | $C_{23}$ | 0.0141 | 0.0289 | Density (g/cc) | 0.9853 |
| 716 - 736 | Tetracosanes | $C_{24}$ | 0.0125 | 0.0267 | | |
| 736 - 755.1 | Pentacosanes | $C_{25}$ | 0.0121 | 0.0270 | | |
| 755.1 - 774 | Hexacosanes | $C_{26}$ | 0.0110 | 0.0254 | | |
| 774.1 - 792 | Heptacosanes | $C_{27}$ | 0.0101 | 0.0244 | | |
| 792.1 - 809.1 | Octacosanes | $C_{28}$ | 0.0100 | 0.0250 | | |
| 809.1 - 826 | Nonacosanes | $C_{29}$ | 0.0094 | 0.0244 | | |
| Above 826 | Tricontanes Plus | $C_{30+}$ | 0.1120 | 0.2999 | | |
| | NAPHTHENES | | | | | |
| 120.0 | Cyclopentane | $C_5H_{10}$ | 0.0042 | 0.0019 | | |
| 162.0 | Methylcyclopentane | $C_6H_{12}$ | 0.0112 | 0.0061 | | |
| 178.0 | Cyclohexane | $C_6H_{12}$ | 0.0148 | 0.0080 | | |
| 214.0 | Methylcyclohexane | $C_7H_{14}$ | 0.0219 | 0.0139 | | |
| | AROMATICS | | | | | |
| 176.0 | Benzene | $C_6H_6$ | 0.0134 | 0.0067 | | |
| 231.1 | Toluene | $C_7H_8$ | 0.0179 | 0.0106 | | |
| 277 - 282 | Ethylbenzene & p,m-Xylene | $C_8H_{10}$ | 0.0062 | 0.0042 | | |
| 291.9 | o-Xylene | $C_8H_{10}$ | 0.0041 | 0.0028 | | |
| 336.0 | 1, 2, 4-Trimethylbenzene | $C_9H_{12}$ | 0.0036 | 0.0028 | | |
| **Total** | | | **1.0000** | **1.2999** | | |

Note: Physical Properties calculated based on GPA 2145-00 physical constants GC No.: 6161

## TABLE A3
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## COMPOSITIONAL ANALYSIS OF FLASHED GAS

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0255 | 0.0262 | | |
| Carbon Dioxide | $CO_2$ | 0.0278 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.7988 | 0.8216 | | |
| Ethane | $C_2$ | 0.0709 | 0.0729 | | |
| Propane | $C_3$ | 0.0420 | 0.0432 | 27.405 | 153.866 |
| i-Butane | $i\text{-}C_4$ | 0.0061 | 0.0063 | 4.763 | 26.741 |
| n-Butane | $n\text{-}C_4$ | 0.0144 | 0.0148 | 10.769 | 60.462 |
| i-Pentane | $i\text{-}C_5$ | 0.0029 | 0.0030 | 2.506 | 14.070 |
| n-Pentane | $n\text{-}C_5$ | 0.0034 | 0.0035 | 2.892 | 16.238 |
| Hexanes | $C_6$ | 0.0023 | 0.0024 | 2.255 | 12.661 |
| Heptanes | $C_7$ | 0.0057 | 0.0059 | 6.274 | 35.227 |
| Octanes | $C_8$ | 0.0003 | 0.0003 | 0.349 | 1.960 |
| Nonanes | $C_9$ | 0.0000 | 0.0000 | 0.017 | 0.094 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **57.230** | **321.318** |
| Propanes Plus | $C_{3+}$ | 1.1480 | 1.1522 | 114.460 | 642.637 |
| Butanes Plus | $C_{4+}$ | 1.0771 | 1.0793 | 114.460 | 642.637 |
| Pentanes Plus | $C_{5+}$ | 1.0290 | 1.0298 | 82.292 | 462.030 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 21.16 kg/kmol | 21.16 lb/lb-mol | Ppc | 669.4 psia | 4.62 MPa |
| Specific Gravity | 0.7305 (Air = 1) | 0.7305 (Air = 1) | Tpc | 390.7 R | 217.1 K |
| MW of C7+ | 0.58 kg/kmol | 0.58 lb/lbmol | Ppc* | 661.9 psia | 4.56 MPa |
| Density of C7+ | 0.7232 g/cc | 723.2 kg/m3 | Tpc* | 386.3 R | 214.6 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,174.0 Btu/scf | 43.82 MJ/m3 | Dry | 1,064.2 Btu/scf | 39.72 MJ/m3 |
| Wet | 1,153.6 Btu/scf | 43.06 MJ/m3 | Wet | 1,045.6 Btu/scf | 39.03 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 7647

# APPENDIX B

**MULTI-STAGE SEPARATOR TEST - MATERIAL BALANCE**

**TABLE B1**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**MULTI-STAGE SEPARATOR @ 191.1 F (88.4 C) - MATERIAL BALANCE**

| Pressure (psia) | Pressure (MPa) | Measured Oil FVF [1] | Calculated Oil FVF [1] | Absolute Relative Error (%) |
|---|---|---|---|---|
| **3060 Psat** | **21.10** | **1.2966** | **1.2966** | **0.0000** |
| 580 | 4.00 | 1.0879 | 1.0890 | 0.1034 |
| 348 | 2.40 | 1.0541 | 1.0545 | 0.0368 |
| 180 | 1.24 | 1.0354 | 1.0353 | 0.0108 |
| 29 | 0.20 | 1.0122 | 1.0107 | 0.1492 |
| 13 | 0.09 | 1.0000 | 0.9999 | 0.0111 |

[1] (res bbl/STB) (res m3/m3)
Psat - Saturation Pressure
- Tank conditions: 60 F (288.7 K) @ 13 psia (0.09 MPa)

# APPENDIX C

**MULTI-STAGE SEPARATOR TEST - LIBERATED GAS ANALYSES**

## TABLE C1
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## MULTI-STAGE SEPARATOR GAS COMPOSITION @ 580 psia (4.00 MPa) AND 185.0 F (85.0 C)

| Component Name | Chemical Symbol | Mole Fraction | | Liquid Volume | |
|---|---|---|---|---|---|
| | | As Analyzed | Acid Gas Free | STB/MMscf | mL/m3 |
| Nitrogen | $N_2$ | 0.0052 | 0.0053 | | |
| Carbon Dioxide | $CO_2$ | 0.0202 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.8590 | 0.8767 | | |
| Ethane | $C_2$ | 0.0574 | 0.0586 | | |
| Propane | $C_3$ | 0.0278 | 0.0283 | 18.126 | 101.771 |
| i-Butane | $i\text{-}C_4$ | 0.0039 | 0.0040 | 3.040 | 17.071 |
| n-Butane | $n\text{-}C_4$ | 0.0094 | 0.0096 | 7.013 | 39.375 |
| i-Pentane | $i\text{-}C_5$ | 0.0029 | 0.0029 | 2.502 | 14.050 |
| n-Pentane | $n\text{-}C_5$ | 0.0036 | 0.0037 | 3.100 | 17.402 |
| Hexanes | $C_6$ | 0.0028 | 0.0029 | 2.729 | 15.320 |
| Heptanes | $C_7$ | 0.0072 | 0.0074 | 7.892 | 44.310 |
| Octanes | $C_8$ | 0.0006 | 0.0006 | 0.703 | 3.944 |
| Nonanes | $C_9$ | 0.0001 | 0.0001 | 0.091 | 0.511 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **45.196** | **253.753** |
| Propanes Plus | $C_{3+}$ | 0.0582 | 0.0594 | 45.196 | 253.753 |
| Butanes Plus | $C_{4+}$ | 0.0304 | 0.0311 | 27.070 | 151.982 |
| Pentanes Plus | $C_{5+}$ | 0.0171 | 0.0175 | 17.016 | 95.537 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 20.01 kg/kmol | 20.01 lb/lb-mol | Ppc | 670.3 psia | 4.62 MPa |
| Specific Gravity | 0.6908 (Air = 1) | 0.6908 (Air = 1) | Tpc | 382.7 R | 212.6 K |
| MW of C7+ | 97.03 kg/kmol | 97.03 lb/lbmol | Ppc* | 664.5 psia | 4.58 MPa |
| Density of C7+ | 0.7241 g/cc | 724.1 kg/m3 | Tpc* | 379.4 R | 210.8 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,165.2 Btu/scf | 43.49 MJ/m3 | Dry | 1,054.9 Btu/scf | 39.38 MJ/m3 |
| Wet | 1,144.9 Btu/scf | 42.74 MJ/m3 | Wet | 1,036.6 Btu/scf | 38.69 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 8149

## TABLE C2
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## MULTI-STAGE SEPARATOR GAS COMPOSITION @ 348 psia (2.40 MPa) AND 136.4 F (58.0 C)

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0046 | 0.0047 | | |
| Carbon Dioxide | $CO_2$ | 0.0213 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.8518 | 0.8704 | | |
| Ethane | $C_2$ | 0.0623 | 0.0637 | | |
| Propane | $C_3$ | 0.0288 | 0.0295 | 18.836 | 105.752 |
| i-Butane | i-$C_4$ | 0.0039 | 0.0040 | 3.021 | 16.964 |
| n-Butane | n-$C_4$ | 0.0092 | 0.0094 | 6.894 | 38.708 |
| i-Pentane | i-$C_5$ | 0.0029 | 0.0030 | 2.513 | 14.111 |
| n-Pentane | n-$C_5$ | 0.0036 | 0.0037 | 3.119 | 17.510 |
| Hexanes | $C_6$ | 0.0030 | 0.0030 | 2.890 | 16.223 |
| Heptanes | $C_7$ | 0.0079 | 0.0081 | 8.649 | 48.562 |
| Octanes | $C_8$ | 0.0006 | 0.0006 | 0.731 | 4.106 |
| Nonanes | $C_9$ | 0.0001 | 0.0001 | 0.090 | 0.508 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **46.744** | **262.446** |
| Propanes Plus | $C_{3+}$ | 0.0600 | 0.0613 | 46.744 | 262.446 |
| Butanes Plus | $C_{4+}$ | 0.0312 | 0.0318 | 27.909 | 156.693 |
| Pentanes Plus | $C_{5+}$ | 0.0180 | 0.0184 | 17.993 | 101.021 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 20.20 kg/kmol | 20.20 lb/lb-mol | Ppc | 670.8 psia | 4.62 MPa |
| Specific Gravity | 0.6973 (Air = 1) | 0.6973 (Air = 1) | Tpc | 384.9 R | 213.8 K |
| MW of C7+ | 96.97 kg/kmol | 96.97 lb/lbmol | Ppc* | 664.7 psia | 4.58 MPa |
| Density of C7+ | 0.7239 g/cc | 723.9 kg/m3 | Tpc* | 381.4 R | 211.9 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,173.5 Btu/scf | 43.80 MJ/m3 | Dry | 1,062.8 Btu/scf | 39.67 MJ/m3 |
| Wet | 1,153.1 Btu/scf | 43.04 MJ/m3 | Wet | 1,044.3 Btu/scf | 38.98 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 8152

**TABLE C3**
**HUSKY ENERGY - NORTH AMETHYST**
**WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE**
**RESERVOIR FLUID STUDY**
**MULTI-STAGE SEPARATOR GAS COMPOSITION @ 180 psia (1.24 MPa) AND 131.0 F (55.0 C)**

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0034 | 0.0035 | | |
| Carbon Dioxide | $CO_2$ | 0.0262 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.7924 | 0.8138 | | |
| Ethane | $C_2$ | 0.0940 | 0.0965 | | |
| Propane | $C_3$ | 0.0459 | 0.0471 | 29.959 | 168.205 |
| i-Butane | $i\text{-}C_4$ | 0.0061 | 0.0063 | 4.752 | 26.680 |
| n-Butane | $n\text{-}C_4$ | 0.0140 | 0.0144 | 10.489 | 58.890 |
| i-Pentane | $i\text{-}C_5$ | 0.0035 | 0.0036 | 3.047 | 17.106 |
| n-Pentane | $n\text{-}C_5$ | 0.0042 | 0.0043 | 3.595 | 20.186 |
| Hexanes | $C_6$ | 0.0028 | 0.0029 | 2.780 | 15.606 |
| Heptanes | $C_7$ | 0.0069 | 0.0071 | 7.554 | 42.412 |
| Octanes | $C_8$ | 0.0005 | 0.0005 | 0.549 | 3.082 |
| Nonanes | $C_9$ | 0.0001 | 0.0001 | 0.074 | 0.414 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **62.798** | **352.581** |
| Propanes Plus | $C_{3+}$ | 0.0840 | 0.0862 | 62.798 | 352.581 |
| Butanes Plus | $C_{4+}$ | 0.0381 | 0.0391 | 32.839 | 184.377 |
| Pentanes Plus | $C_{5+}$ | 0.0179 | 0.0184 | 17.598 | 98.807 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 21.50 kg/kmol | 21.50 lb/lb-mol | Ppc | 672.6 psia | 4.64 MPa |
| Specific Gravity | 0.7423 (Air = 1) | 0.7423 (Air = 1) | Tpc | 400.7 R | 222.6 K |
| MW of C7+ | 96.86 kg/kmol | 96.86 lb/lbmol | Ppc* | 665.6 psia | 4.59 MPa |
| Density of C7+ | 0.7237 g/cc | 723.7 kg/m3 | Tpc* | 396.5 R | 220.3 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,233.1 Btu/scf | 46.03 MJ/m3 | Dry | 1,118.5 Btu/scf | 41.75 MJ/m3 |
| Wet | 1,211.6 Btu/scf | 45.23 MJ/m3 | Wet | 1,099.0 Btu/scf | 41.02 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 8165

# TABLE C4
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## MULTI-STAGE SEPARATOR GAS COMPOSITION @ 29 psia (0.20 MPa) AND 122.0 F (50.0 C)

| Component Name | Chemical Symbol | Mole Fraction As Analyzed | Mole Fraction Acid Gas Free | Liquid Volume STB/MMscf | Liquid Volume mL/m3 |
|---|---|---|---|---|---|
| Nitrogen | $N_2$ | 0.0009 | 0.0010 | | |
| Carbon Dioxide | $CO_2$ | 0.0294 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.5564 | 0.5733 | | |
| Ethane | $C_2$ | 0.1687 | 0.1738 | | |
| Propane | $C_3$ | 0.1264 | 0.1303 | 82.568 | 463.581 |
| i-Butane | $i\text{-}C_4$ | 0.0198 | 0.0204 | 15.331 | 86.076 |
| n-Butane | $n\text{-}C_4$ | 0.0476 | 0.0491 | 35.626 | 200.021 |
| i-Pentane | $i\text{-}C_5$ | 0.0132 | 0.0136 | 11.458 | 64.330 |
| n-Pentane | $n\text{-}C_5$ | 0.0150 | 0.0155 | 12.927 | 72.578 |
| Hexanes | $C_6$ | 0.0075 | 0.0078 | 7.360 | 41.325 |
| Heptanes | $C_7$ | 0.0143 | 0.0147 | 15.666 | 87.959 |
| Octanes | $C_8$ | 0.0005 | 0.0005 | 0.627 | 3.518 |
| Nonanes | $C_9$ | 0.0001 | 0.0001 | 0.071 | 0.400 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **181.635** | **1019.790** |
| Propanes Plus | $C_{3+}$ | 0.2444 | 0.2519 | 181.635 | 1019.790 |
| Butanes Plus | $C_{4+}$ | 0.1180 | 0.1216 | 99.066 | 556.209 |
| Pentanes Plus | $C_{5+}$ | 0.0506 | 0.0522 | 48.110 | 270.111 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 28.94 kg/kmol | 28.94 lb/lb-mol | Ppc | 660.6 psia | 4.55 MPa |
| Specific Gravity | 0.9990 (Air = 1) | 0.9990 (Air = 1) | Tpc | 480.2 R | 266.8 K |
| MW of C7+ | 96.47 kg/kmol | 96.47 lb/lbmol | Ppc* | 654.3 psia | 4.51 MPa |
| Density of C7+ | 0.7229 g/cc | 722.9 kg/m3 | Tpc* | 475.6 R | 264.2 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,629.5 Btu/scf | 60.82 MJ/m3 | Dry | 1,488.4 Btu/scf | 55.56 MJ/m3 |
| Wet | 1,601.1 Btu/scf | 59.77 MJ/m3 | Wet | 1,462.5 Btu/scf | 54.59 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 8166

# TABLE C5
## HUSKY ENERGY - NORTH AMETHYST
## WELL K-15 - BEN NEVIS - AVALON - BOTTOMHOLE SAMPLE
## RESERVOIR FLUID STUDY
## MULTI-STAGE SEPARATOR GAS COMPOSITION @ 13 psia (0.09 MPa) AND 60.0 F (15.6 C)

| Component Name | Chemical Symbol | Mole Fraction | | Liquid Volume | |
|---|---|---|---|---|---|
| | | As Analyzed | Acid Gas Free | STB/MMscf | mL/m3 |
| Nitrogen | $N_2$ | 0.0006 | 0.0006 | | |
| Carbon Dioxide | $CO_2$ | 0.0474 | 0.0000 | | |
| Hydrogen Sulphide | $H_2S$ | 0.0000 | 0.0000 | | |
| Methane | $C_1$ | 0.3840 | 0.4031 | | |
| Ethane | $C_2$ | 0.2304 | 0.2419 | | |
| Propane | $C_3$ | 0.1693 | 0.1777 | 110.545 | 620.653 |
| i-Butane | i-$C_4$ | 0.0246 | 0.0258 | 19.080 | 107.127 |
| n-Butane | n-$C_4$ | 0.0586 | 0.0615 | 43.823 | 246.044 |
| i-Pentane | i-$C_5$ | 0.0149 | 0.0157 | 12.971 | 72.824 |
| n-Pentane | n-$C_5$ | 0.0194 | 0.0204 | 16.706 | 93.798 |
| Hexanes | $C_6$ | 0.0147 | 0.0154 | 14.332 | 80.468 |
| Heptanes | $C_7$ | 0.0349 | 0.0366 | 38.162 | 214.260 |
| Octanes | $C_8$ | 0.0012 | 0.0012 | 1.418 | 7.960 |
| Nonanes | $C_9$ | 0.0001 | 0.0001 | 0.127 | 0.712 |
| Decanes | $C_{10}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Undecane | $C_{11}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Dodecanes Plus | $C_{12+}$ | 0.0000 | 0.0000 | 0.000 | 0.000 |
| Total | | **1.0000** | **1.0000** | **257.164** | **1443.847** |
| Propanes Plus | $C_{3+}$ | 0.3376 | 0.3544 | 257.164 | 1443.847 |
| Butanes Plus | $C_{4+}$ | 0.1683 | 0.1767 | 146.619 | 823.194 |
| Pentanes Plus | $C_{5+}$ | 0.0852 | 0.0894 | 83.716 | 470.023 |

| Calculated Gas Properties @ Standard Conditions | | | Calculated Pseudocritical Properties | | |
|---|---|---|---|---|---|
| Molecular Weight | 34.72 kg/kmol | 34.72 lb/lb-mol | Ppc | 657.6 psia | 4.53 MPa |
| Specific Gravity | 1.1986 (Air = 1) | 1.1986 (Air = 1) | Tpc | 537.6 R | 298.7 K |
| MW of C7+ | 96.42 kg/kmol | 96.42 lb/lbmol | Ppc* | 649.3 psia | 4.48 MPa |
| Density of C7+ | 0.7229 g/cc | 722.9 kg/m3 | Tpc* | 530.8 R | 294.9 K |

| Calculated Gross Heating Value @ Standard Conditions | | | Calculated Net Heating Value @ Standard Conditions | | |
|---|---|---|---|---|---|
| Dry | 1,899.7 Btu/scf | 70.91 MJ/m3 | Dry | 1,741.1 Btu/scf | 64.99 MJ/m3 |
| Wet | 1,866.6 Btu/scf | 69.68 MJ/m3 | Wet | 1,710.8 Btu/scf | 63.86 MJ/m3 |

Standard Conditions: 60 F (288.7 K) @ 14.696 psia (0.101325 MPa)

GC No.: 8171