

# Oil & Natural Gas Technology

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## Quarterly Progress Report (January - March 2008)

### Characterization and Quantification of the Methane Hydrate Resource Potential Associated with the Barrow Gas Fields

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**SIXTH QUARTERLY PROGRESS REPORT**

**JANUARY – MARCH, 2008**

**CHARACTERIZATION AND QUANTIFICATION  
OF THE METHANE HYDRATE RESOURCE POTENTIAL ASSOCIATED WITH THE  
BARROW GAS FIELDS**

**DOE Project Number: DE-FC26-06NT42962**

*Awarded to*

**North Slope Borough, Alaska**

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## **EXECUTIVE SUMMARY**

Phase 1B of the project was completed in March, 2008, upon conclusion of the full-field history-matched reservoir simulation of the East Barrow and Walakpa Gas Fields. This work supports the earlier findings of the extended material balance (EMB) modeling, which indicate that hydrate dissociation must be a contributing factor in pressure support of the free gas production of both fields.

## **SUMMARY OF PROJECT**

The North Slope Borough (NSB) has established a team to characterize and quantify the methane hydrate resource potential associated with the Barrow Gas Fields (BGF), which are owned and operated by the NSB in a permafrost region of arctic Alaska. Currently, gas from these three producing fields provides heating and electricity for Barrow, which is the economic, transportation, and administrative center of the NSB. Other commercially-operated producing oil and gas fields within the NSB include Prudhoe Bay, Milne Point, Kuparuk, Alpine and Endicott. The results of this project will enhance the understanding of the nature and occurrence of methane hydrates in the arctic environment, and specifically in the Barrow Gas Fields, and will serve to evaluate the potential influence of gas hydrates on gas supply and production from producing gas fields. Findings of this project will contribute significantly to understanding the role of gas hydrate as a recharge mechanism in a producing gas field, and provide substantial commercial and social benefits for the NSB.

The characterization and quantification of methane hydrate resources in the Barrow Gas Fields (BGF) will be completed in three phases: IA, IB, and II. This approach will allow for timely evaluation and adjustment of methods and objectives as new findings are obtained. The Research Management Plan (RMP) lays the framework for all three phases, and it has been revised for Phase 1B based on input from the TAG.

Phase 1A concluded that methane hydrate stability zones exist in association with two of the BGF (Walakpa and East Barrow), validating the postulate that the gas fields in question are potentially being recharged by dissociation of adjacent methane hydrates. Based on these results, funding was approved for Phase 1B of the study.

In Phase 1B, the NSB will a) determine probability that the reservoir is continuous up-dip into the methane hydrate stability zone, and contained sufficient water to combine with available gas to form gas hydrate; b) determine the optimum well location for a dedicated methane hydrate well; and c) quantify reserves, expected production rates and depletion mechanisms for methane hydrate production.

The Project has been funded for \$609,859 for Phase 1B to accomplish the following four tasks:

- Task 5 — Revise RMP, Map Barrow Area and Walakpa Gas Fields
- Task 6 — Reservoir Characterization and Selection of Optimum Test Well Location
- Task 7 — Build methane hydrate reservoir simulator to model methane hydrate test well production
- Task 8 — Phase I Final Report

The results of Phase 1B will determine whether or not funding will be requested for Phase 2.

## **PROJECT TASKS COMPLETED LAST QUARTER**

### **TASK 5b: Map Barrow and Walakpa Gas Fields**

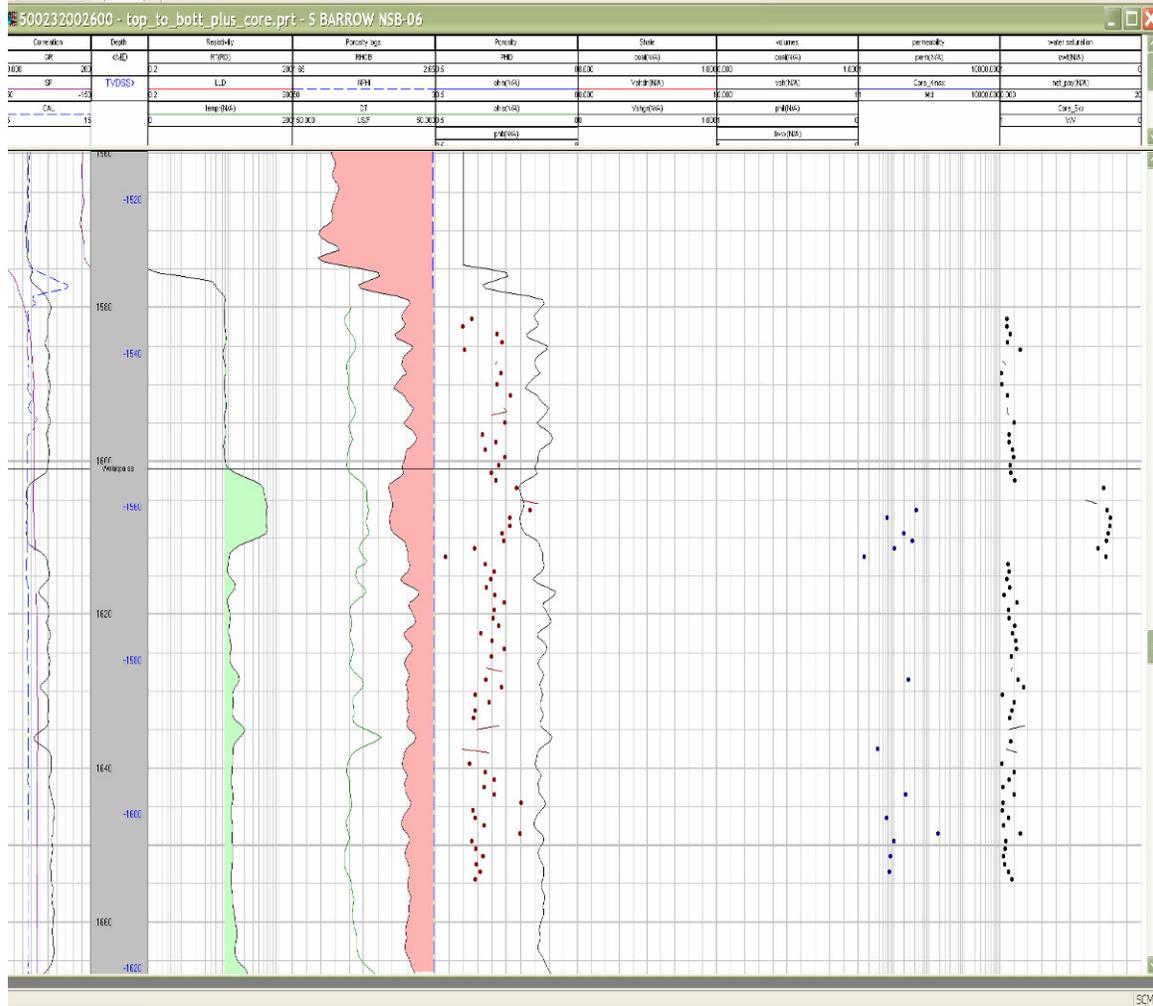
During this fifth quarter of the project, additional 1970's vintage seismic data was identified and acquired from the USGS for integration into the reservoir characterization. Some of the USGS data was not available digitally, and hardcopies of the stacked lines had to be scanned and migrated. The additional seismic data provided more structural detail, particularly in the East Barrow area.

One-dimensional and two-dimensional seismic modeling is still ongoing, with the objective of quantifying the effects of reservoir pore-fluid saturations (free gas vs. hydrate) on the seismic response, and wedge modeling to assess the impact of thinning reservoir section. This modeling was temporarily put on hold to allow for completion of the seismic interpretation and mapping.

Core analysis and well log interpretation were completed, and maps of reservoir thickness, net-to-gross, porosity, water saturation, and permeability were generated to QC the interpretation. The results of this work will be incorporated in an integrated 3D reservoir model in the next project quarter.

The Walakpa was encountered in several updip wells, where mud logs and wireline logs showed evidence of gas saturated reservoir, although the interval flowed little or no hydrocarbon when tested. In the NSB #6 well, nine feet of Walakpa Sand was cored at a depth of 1603 ft., with an average porosity of 21%. The Walakpa in this well is ten miles updip and 420 ft. shallower than Walakpa #1. The Walakpa sand is a transgressive sand overlying the Lower Cretaceous Unconformity (LCU), and is known to be regionally extensive. The presence of this reservoir interval in the Brontosaurus well fifteen miles southeast of the Walakpa Field, and in East and South Barrow Field wells some fifteen miles updip of Walakpa leads to the postulation that this pool is comprised of a large aquifer, in equilibrium with a several hundred foot high hydrocarbon column, capped by an extensive hydrate interval. Needless to say, the potential significance of this system could be tremendous.

## NSB #6 Well Logs Showing Walakpa Sand Interval



### TASK 5c: EB #14 Water Sample Analysis

Comparative analysis of the recent E.B. #14 well produced water sample against earlier East Barrow well samples was completed, and samples will continue to be collected periodically from E.B. #14 to track any compositional changes over time.

As there is very little water produced with the gas in the Barrow Gas Fields, and there is currently no means of separating any produced water at the wellhead, a bailing tool was acquired and utilized to “dip” formation water from the wellbore for analysis.

The recent sample analysis reflects an increase in total dissolved solids in the formation water from past samples, which was contrary to our expectations.

Well East Barrow #14 water sample analysis:

	TDS	Sodium	Calcium	Sulfate	Chloride	NaCl	Comment
SB 14 1977	111662	5108	35600	790	67000	107809	Contaminated

SB 15 DST4 1980	24475	8907	550	1	14400	24300	
SB15 DST4 1980	24120	7804	1465	2	14000	23778	
SB 17 Prod test 1978	21569	7666	620	Tr	13000	21555	
SB 20 Prod test 1980	62931	860	21622	110	40000	61934	
2007 Analytika	34500	3830	6890	ND	20400		

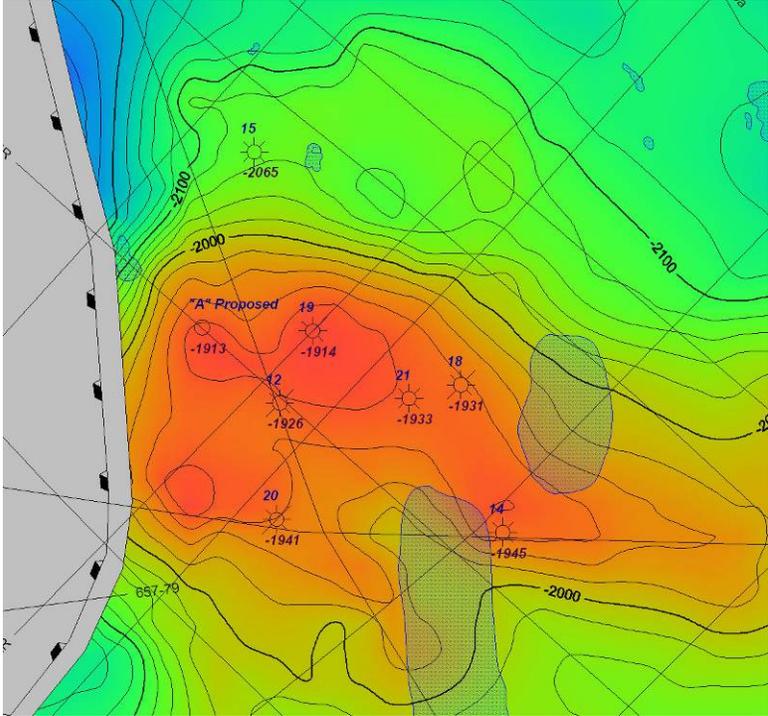
### **TASK 6: Reservoir Characterization and Selection of Optimum Test Well Location**

An intermediate modeling step was added to the project scope to determine if we could explain the production history performance results for the East Barrow Field with either volumetric gas expansion, volumetric gas expansion coupled with aquifer support, or hydrate dissociation, gas expansion and aquifer support. The "tank" modeling results indicated that volumetric expansion and aquifer support combined could not explain the pressure response of the reservoir, and that hydrate dissociation must be a factor. This was a valuable step that supports the full dynamic reservoir modeling effort.

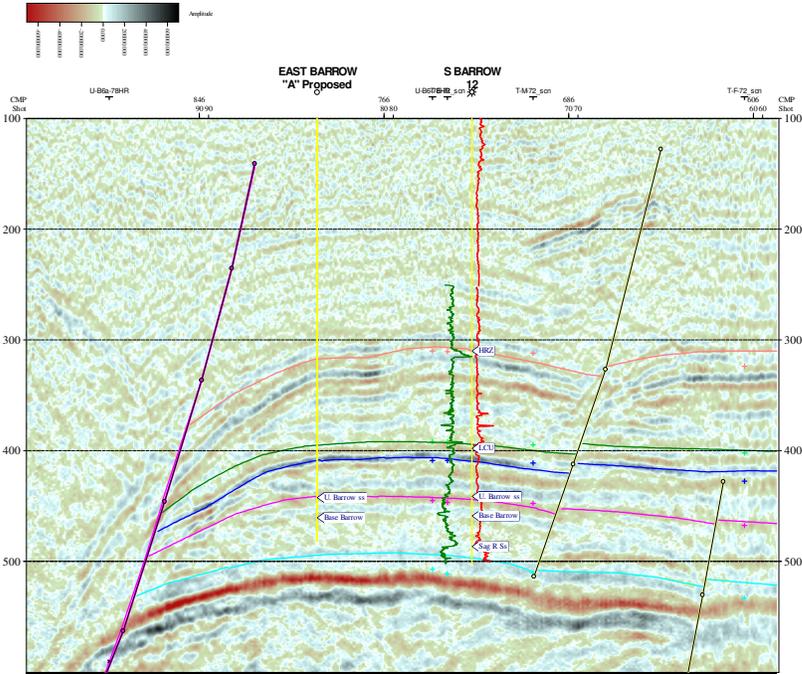
The material balance study confirmed the existence of a thick hydrate layer overlying the free gas zone within East Barrow reservoir. The analysis also shows an association of a weak aquifer providing partial pressure support to the gas reservoir. Results obtained for the hydrate-capped free gas reservoir with weak aquifer support closely matched the production data with a maximum percentage error of 10%.

The full results of this work will be described in a topical report.

Two potential locations were selected as optimal hydrate test well sites, based on geoscience, reservoir and logistical considerations. The wells are situated near the modeled base of hydrate stability zone, ideally intersecting the hydrate/free-gas interface, and they are both located on seismic lines. The primary candidate is in the updip extent of the East Barrow Gas Field, and is favored due to proximity to road access. The second location is updip of the main Walakpa Gas Field, and while more difficult logistically, it benefits from better seismic and well coverage, and therefore more accurate reservoir characterization.



Map of East Barrow Gas Field with Proposed Hydrate Test Well Location



Seismic Line through Proposed East Barrow Hydrate Test Well Location



## **Phase 1 Barrow Gas Field Modeling Results**

Work recently completed as part of Phase 1 of the Barrow Gas Field Hydrate Study (Characterization And Quantification Of The Methane Hydrate Resource Potential Associated With The Barrow Gas Fields, DOE project # DE-FC26-06NT42962) is of great significance to the longer-term study of gas hydrates in Barrow and on the North Slope, but will also hopefully prove to be of broader significance to the global hydrate research effort.

The objectives of Phase 1 were:

- To determine whether or not methane hydrates are likely to exist in association with the Barrow Gas Fields through modeling of the methane hydrate stability zone in the Barrow Gas Field area.
- Characterization of the reservoir properties through integrated geological, geophysical, petrophysical, and production information.
- Reservoir modeling to determine the potential size of a methane hydrate resource, the possible depletion mechanisms associated with historic and future production, and optimal production parameters for the fields.

The objectives of the study were met by carrying out three basic phases of investigation:

- Hydrate stability modeling
- Reservoir characterization
- Reservoir simulation modeling

The methane hydrate stability modeling effort involved: gathering of legacy subsurface temperature and pressure data, and gas and formation water composition analysis; collection of new temperature, pressure and fluid composition data; and integration of all of this data in the Colorado School of Mines CSM-Hyd modeling application to predict hydrate stability envelopes for the three Barrow Gas Fields. Results of this modeling indicated that the base of the hydrate stability zone would intersect the free gas reservoir in the East Barrow Gas Field, and the Walakpa Gas Field, but not the South Barrow Gas Field. The positive results for the two fields triggered commencement to the next phase of the study.

The reservoir characterization phase of the study involved: collection of all available seismic, well log, core, and reservoir fluid property information; interpretation and mapping of all of the data; and creation of an integrated 3D reservoir model for the fields. The completion of the detailed reservoir characterization allowed for calculation of volumetrics for the free gas pool, the hydrate accumulations, and the aquifers associated with the fields.

The final phase of the study involved material balance modeling of the reservoirs to screen the postulated depletion mechanisms associated with free gas production; and full-field reservoir simulation to model historical production, and to predict future production from the fields.

### **HYDRATE STABILITY MODELING**

The methane hydrate stability models for the three BGF are based on the analysis of gas composition, formation water composition, and local pressure and temperature gradient of the individual fields. These parameters, along with the known phase behavior of methane gas hydrate, determine the existence and extent of the hydrate stability zone, postulated by previous researchers.

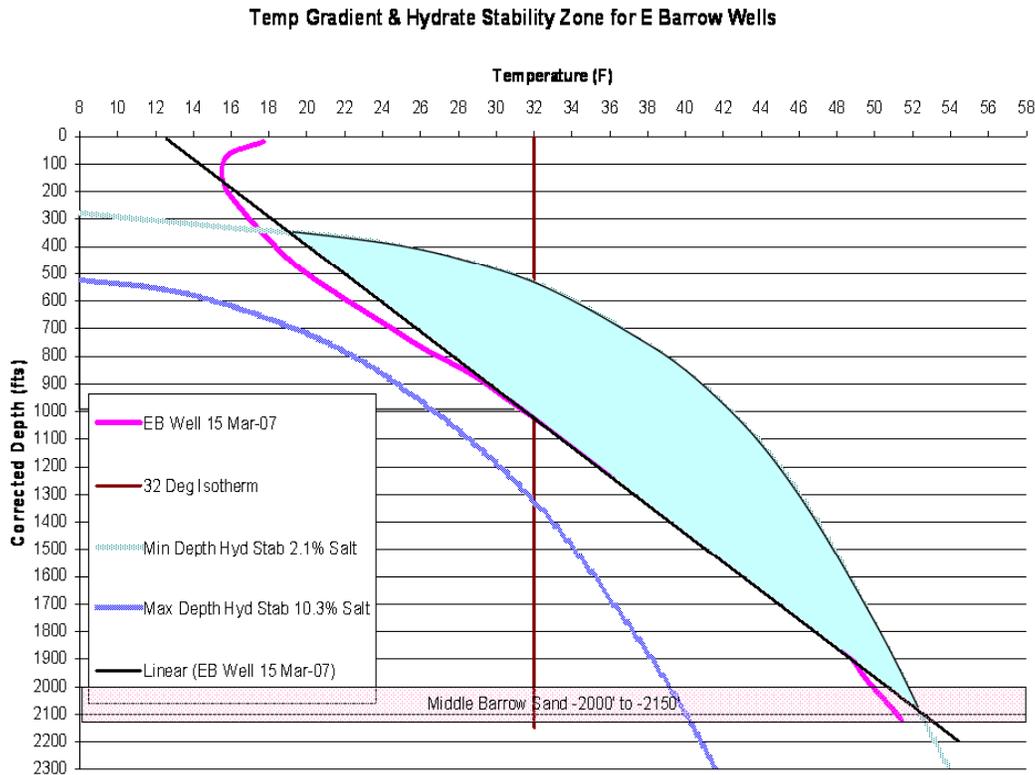
Historical temperature gradient surveys were collected from well files and field records. These were summarized to use for definition of the methane hydrate stability zone (HSZ).

#### East Barrow Field HSZ Results

Static temperature gradient surveys were made in wells E Barrow #15 and #21, which had been shut-in for 7+ months and the temperature data from these wells represents the best static reservoir temperature information available.

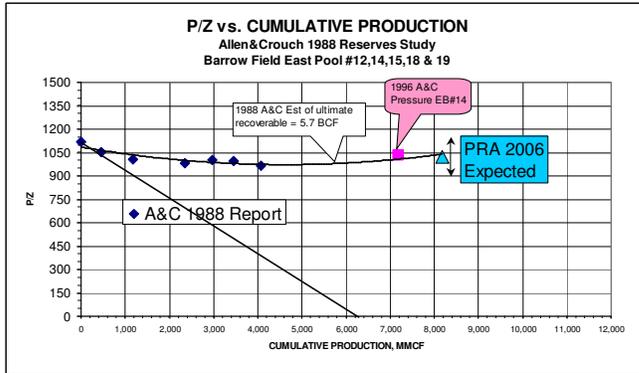
Gas and water compositions and temperature and pressure gradients were modeled in the Colorado School of Mines methane hydrate stability modeling application (CSMHYD). The modeling results are sensitive to formation water salinity, and the best information available for the East pool indicates salinities in the range of 2.1-2.4% NaCl, based on analysis of samples from the Barrow Sand interval in the SB #15 and SB #17 wells.

Model results indicate that the East Barrow Field is in communication with a methane hydrate zone, as the base of the hydrate stability zone intersects the shallowest known free gas reservoir (Figure 4).



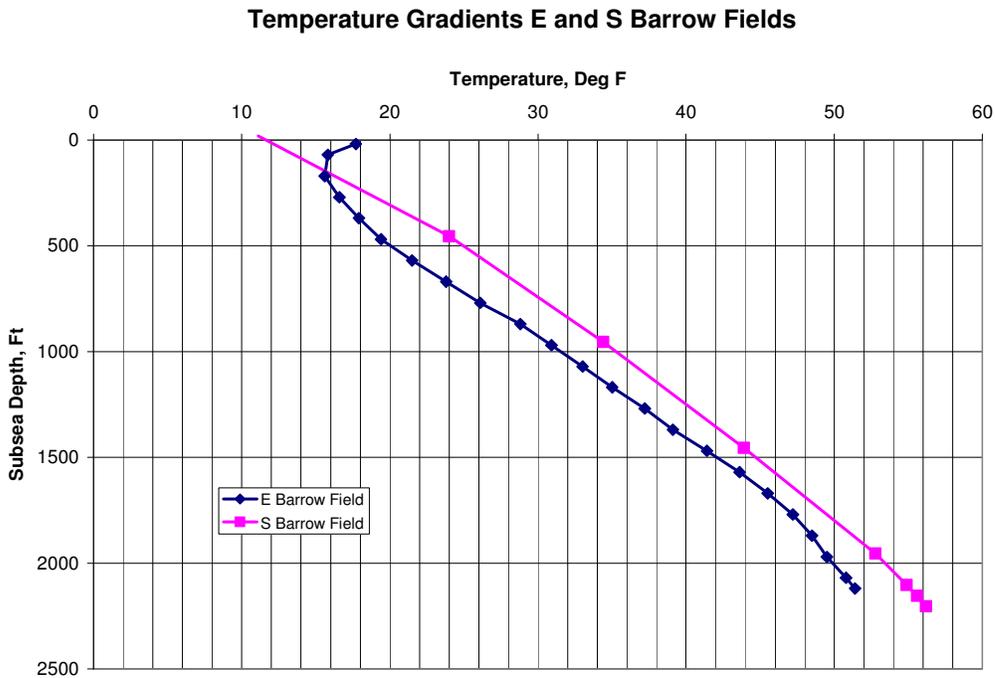
**Figure 4. Hydrate Stability Envelope for E. Barrow Field**

These model results aid in explaining the apparent pressure support in the reservoir, with no appreciable water production or watering out of wells, as would be expected if a water drive was providing support to the reservoir. The East Barrow Field was suspected to be a reservoir with strong aquifer support from initial material balance work, based on P/Z response (Figure 5) and the field was expected to water-out by now, having produced over 8 BSCF of gas from an original reserve estimate of 6 BSCF.



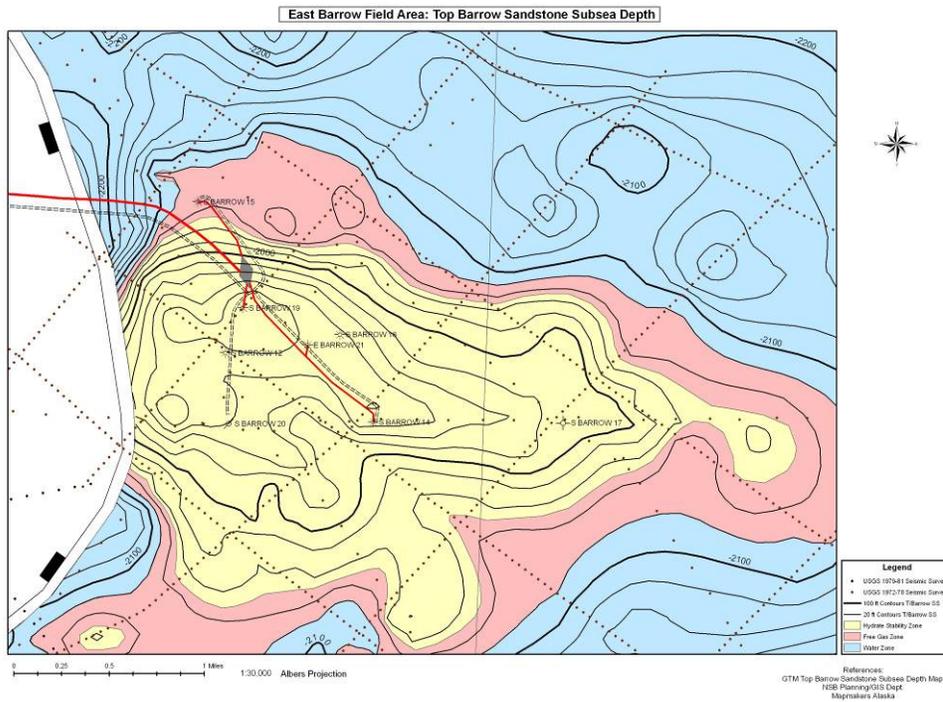
**Figure 5. P/Z vs. Cumulative Production for E. Barrow Gas Field**

Pressure support from hydrate dissociation could possibly explain the pressure response and production characteristics of this field. The other indicator that may support hydrate dissociation occurring in the East Barrow Field is the cooler temperature gradient at equivalent depths compared to the South Barrow Field. Figure 6 shows the temperature gradients for East Barrow and South Barrow Fields at equivalent subsea depths. The cooler temperatures in the East Barrow Field may be due to the endothermic cooling from the dissociation of methane hydrates, having the effect of “robbing” the heat geothermal heat flux from the interval above the hydrate zone. In any case, the lower geothermal gradient at East Barrow promotes a deeper base to the methane hydrate stability zone than that in the South Barrow pool.



**Figure 6. Temperature Gradients for East and South Barrow Gas Fields**

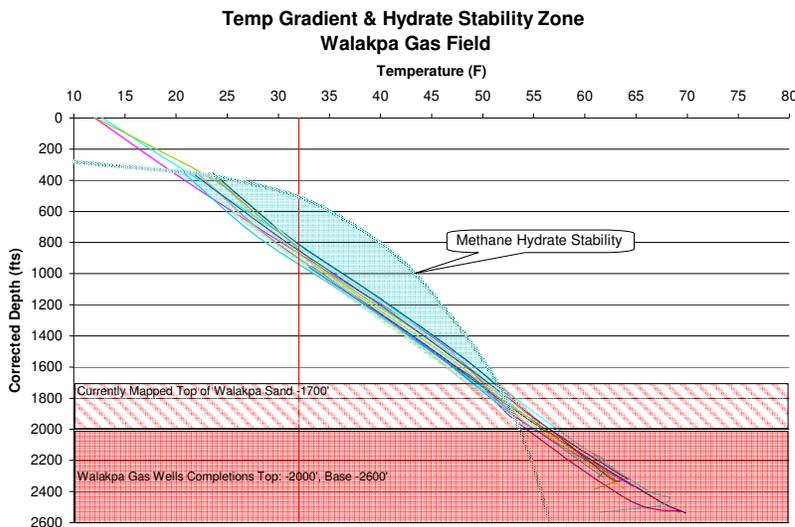
The modeled hydrate stability zone for the East Barrow Gas Field is shown in map view, overlying the Top Upper Barrow Sandstone Depth Structure Map (Figure 7), and all of the producing wells in the East Barrow Field lie within the outline of the modeled BHSZ. However, most of the production from the East Barrow Gas Field is coming from the Lower Barrow Sandstone, which is generally higher quality reservoir, and the potential recharge of produced gas from dissociated hydrates would be contributed largely from the Upper Barrow Sandstone, based on geometry and reservoir dynamic modeling results.



**Figure 7. Modeled Hydrate Stability Zone for East Barrow Gas Field**

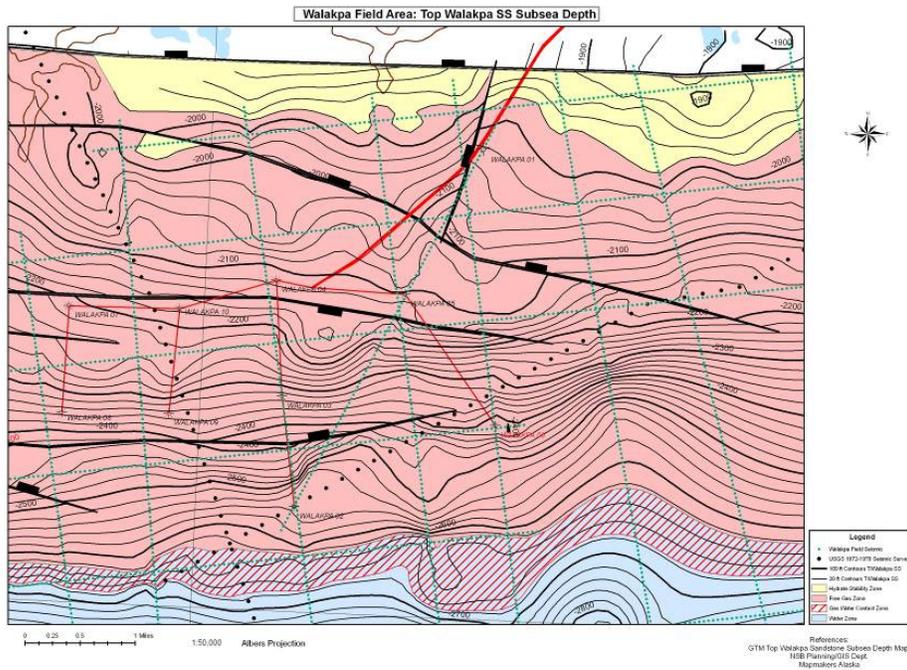
Walakpa Field HSZ Results

Analysis of the pressure, temperature, gas and fluid data for the Walakpa Field similarly support the presence of a hydrate stability zone which is potentially in communication with the free gas reservoir in this field. The base of the modeled hydrate stability zone at Walakpa (Figure 8) coincides with the shallowest well penetration of the free-gas sand.



**Figure 8. Walakpa Field Modeled Hydrate Stability Envelope**

The Walakpa Gas Field is believed to represent an extensive reservoir, with a significant downdip aquifer to the south and west of the free gas pool, and an extensive hydrate accumulation updip to the north and east of the free gas pool (Figure 9).



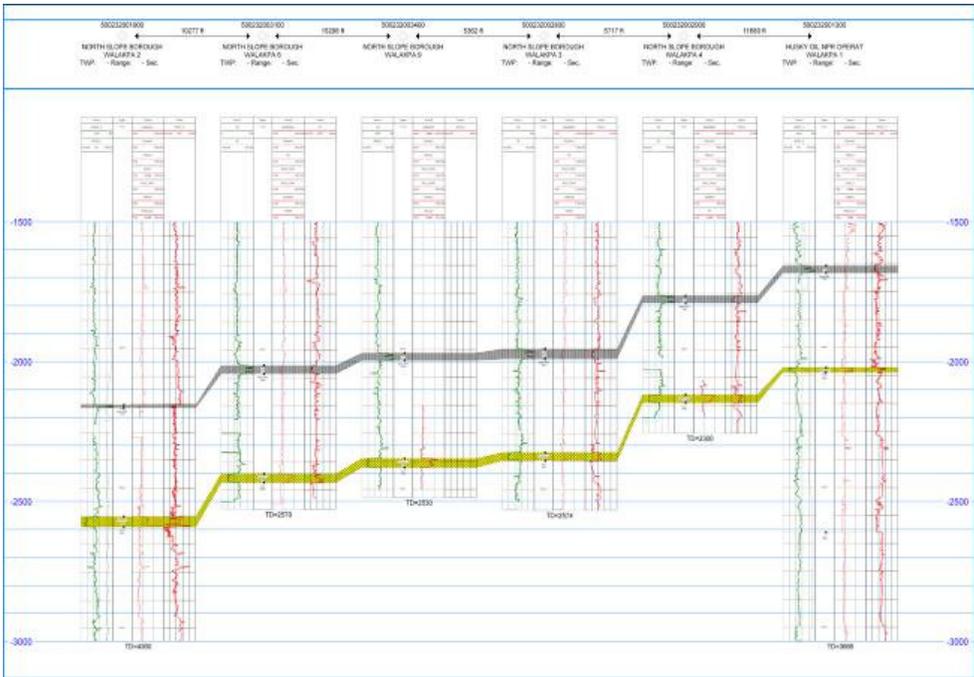
**Figure 9. Modeled Hydrate Stability Zone in Walakpa Field**

## RESERVOIR CHARACTERIZATION

Updated seismic mapping work was undertaken across the Barrow High area, including 1) the Barrow Gas Fields, in which the Jurassic Barrow sandstone is the primary reservoir unit, and 2) the Walakpa Gas Field, which produces from a Neocomian sandstone that was deposited on the Lower Cretaceous Unconformity (LCU) surface. A depth structure map on the LCU was produced for the entire region, and a sub-regional depth structure map on the top of the Barrow sandstone was produced covering the East Barrow, South Barrow, and Sikulik field areas. In addition, individual field maps were produced for all four fields.

All available well data files and reports were reviewed and incorporated into the interpretation, and an updated well pick data set was created from log correlation work. The well picks were used as control for the depth conversion of corresponding seismic horizons and for the generation of isochore maps. Structure and thickness grids, together with the well picks that resulted from this study, were used to build the framework for subsequent gas and methane hydrate reservoir modeling work within and near the field areas.

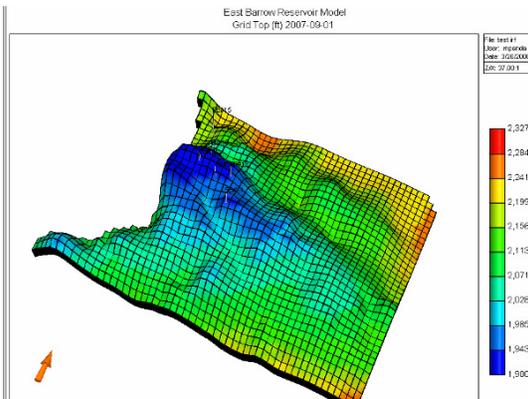
Careful tying of the seismic data with existing well control, incorporation of all available seismic lines, and phase and time matching of seismic data sets has resulted in improved structural maps for the region. Detailed stratigraphic interpretation of the key reservoir intervals through seismic modeling and attribute work has not been undertaken to date, due to the limited and inconsistent quality of available seismic data. Seismic isochore mapping of the HRZ to LCU interval was undertaken and may provide some insight into the distribution of Walakpa sandstone to the north and east of the existing Walakpa Field area.



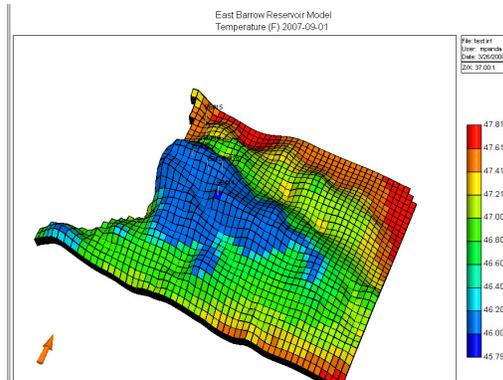
**Figure 10. Structural Well Cross-Section, SW-NE Through Walakpa Gas Field**

Extensive well log interpretation and correlation was integrated with the seismic interpretation to create depth and thickness maps for the Walakpa and Barrow Sandstone reservoirs. Figure 10 shows a SW-NE well cross-section through the Walakpa Gas Field, from the Walakpa #2 well to the updip Walakpa #1 well. Correlation of the Walakpa reservoir updip of the Walakpa #1 well indicates that the Walakpa reservoir extends tens of miles to the northeast, and well into the hydrate stability zone.

Geostatistical reservoir models were created in Roxar's RMS integrated modeling application for both E Barrow and Walakpa Fields, incorporating all interpreted well, seismic and reservoir information. These models allowed for interactive Q.C. of the interpretation results, and visualization of all reservoir parameters before loading to the CMG-Stars reservoir modeling application for dynamic simulation. Reservoir depth-structure maps, isochores, N/G, porosity, permeability, and Sw calculated curves were all loaded to Roxar RMS to build the two geostatistical models of the East Barrow and Walakpa Fields. Selected realizations of the geostatistical models were then used for reservoir simulation modeling.



**Figure 11 Depth grid on Top Upper Barrow Sandstone, E Barrow Field**



**Figure 12 Reservoir Temperature for E Barrow Field**

## MATERIAL BALANCE “TANK” MODELING

Material balance modeling was carried out as a screening-level study to compare relative impacts of volumetric expansion, aquifer support, and hydrate dissociation as potential drive mechanisms for gas production in the East Barrow Gas Field. This simple “tank” modeling was undertaken prior to building a full-field reservoir simulation model to indicate whether or not there was enough evidence in the production history to support further investigation of the hydrate dissociation drive mechanism.

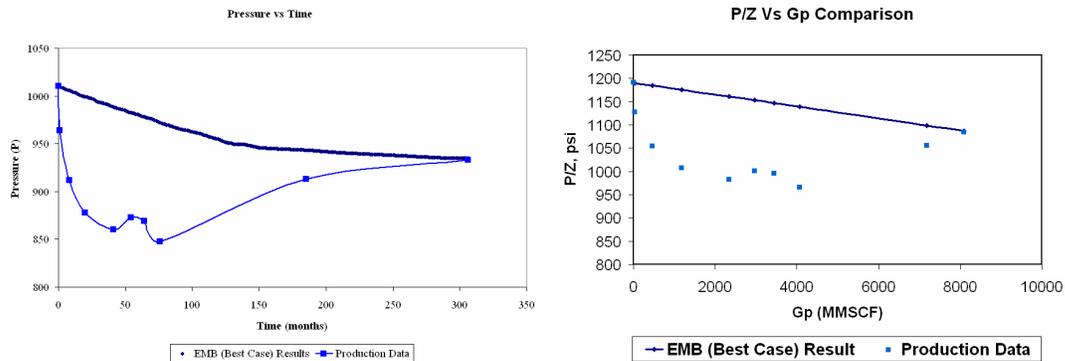
Reservoir performance history matching using material balance models was done progressively as follows:

- a volumetric reservoir with an iterative technique that was developed for tight shallow gas reservoirs by West and Cochrane, 1994 called Extended Material Balance (EMB).
- a volumetric reservoir with aquifer support with an analysis technique developed by Pletcher, 2002 and Ahmed & McKinney, 2005.
- a volumetric reservoir with methane hydrate dissociation model used was developed by Gerami & Darvish, 2006.

### Volumetric Reservoir Analysis

The EMB methodology was applied to East Barrow gas reservoir. Several iterations were carried out to obtain a constant deliverability coefficient ( $C$ ).  $Z$ -factor and gas viscosity calculations were also undertaken to provide accurate gas property. The best case (constant  $C$ ) was obtained by assuming an initial gas in place,  $G$  of 90 std bcf. The initial reserve obtained using this model is exceptionally high compared to volumetric estimates of 15 std bcf (Gruy 1978).

$P/Z$  vs.  $G_p$  relationship obtained for the best case and the actual production data is compared in Figure 13. As it is clearly evident from the plot, the profile obtained from EMB model follows a typical volumetric reservoir profile. The model incorporates the deliverability equation in the material balance equation by considering the fact that for a shallow gas reservoir, like East Barrow, the pressure decline is primarily under the influence of pseudo steady state condition.



**Figure 13. EMB Model – Pressure ( $P$ ) vs. Time plot and  $P/Z$  vs.  $G_p$  plot for East Barrow gas reservoir**

$P/Z$  vs.  $G_p$  relationship obtained for the base case is used to obtain reservoir pressure  $P$  vs. monthly Time ( $t$ ) (refer Figure-13). The plot is compared with the production profile. Extremely low production rates keeps the bottom hole pressure essentially equal to the reservoir pressure and hence the EMB model matches the production history data in later times, but cannot simulate early pressure draw down.

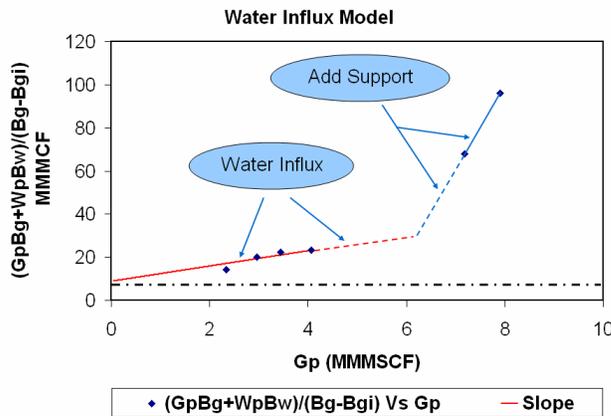
A maximum error of 20% was observed between the EMB model results and production data. Figure 13 clearly shows that the production history data taken from East Barrow gas reservoir never followed the EMB results. This marked deviation confirms that the East Barrow gas reservoir is not volumetric.

The actual reservoir performance for E Barrow pool was not even close to the prediction for a volumetric reservoir drive. This can be seen in Figure 13. The flattening of the P/Z vs. Cum curve is the classic sign of water influx or other replacement of voidage as gas is produced.

Water Influx Analysis

East Barrow production data is utilized to develop material balance model considering a waterdrive mechanism. Figure 14 shows a plot between  $(GpBg + WpBw)/(Bg - Bgi)$  and cumulative gas production Gp. A slope is constructed passing through points lying in early production times. Following are the observations and inferences drawn from the plot.

1. The data points clearly show a positive buildup of slope thereby confirming the hypothesis that the reservoir is not volumetric.
2. The steep slope observed in early production time confirms the fact that the reservoir was dominated by gas expansion accompanied with considerable water influx.



**Figure 14. Water in Influx Model -  $(GpBg + WpBw) / (Bg - Bgi)$  vs. Gp plot**

3. However during later stages of production, the data points shows a vertical jump. Such behavior cannot be explained with water influx model.
4. Hence, due to the limitation with water influx model, the study is now limited to early time periods only. The slope developed through the data points results into an OGIP estimate of 9 Std BCF. Based on this information cumulative water influx,  $W_e$  calculations are also performed. At the end of 76 month about 6.83 MMBBLS of water influx has taken place.
5. Interestingly, while estimating aquifer size, it was observed that the aquifer size tends to increase with time and never remained constant as expected. This observation confirms that the size of associated aquifer may not be large enough to support observed reservoir pressures. Nevertheless, after 76<sup>th</sup> month of production, the size of the aquifer was estimated in the range of 6 MMBBLS. In other words one will require 6 MMBBLS of aquifer size to supply water to the gas reservoir in order to achieve the observed reservoir pressure after 76 months of gas production.

To summarize, water influx study confirmed the existence of an aquifer in contact with the gas reservoir. During early production time, the reservoir was producing under moderate to active water drive. However, the model failed to explain the observed shift/jump in the slope (Figure 14) in later time periods.

Methane Hydrate Material Balance Analysis

The Darvish hydrate model and modified version constructed during this study provides a powerful tool to compare the performance of the East Barrow reservoir in presence of hydrate zone.

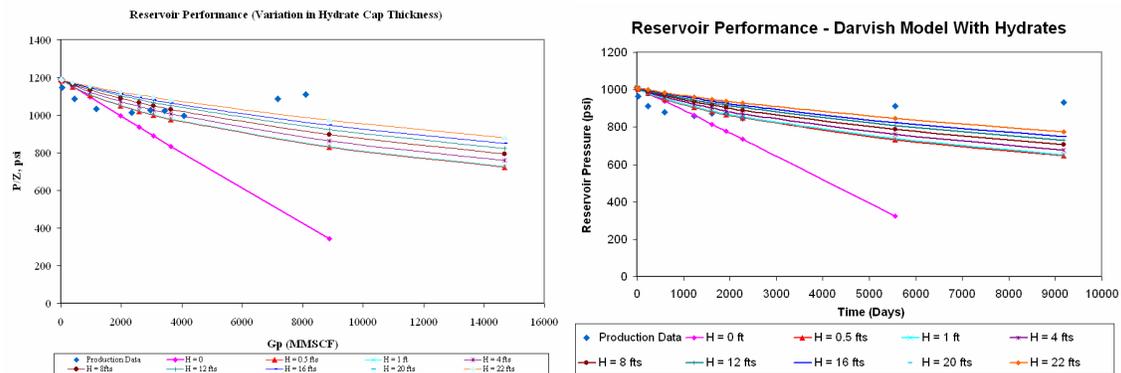
1. Modifications to Darvish model were made to handle gas reservoir (with no associated hydrates). The result obtained from modified Darvish model was validated by comparing the performance of a volumetric reservoir (no hydrates). The P/Z vs. Gp and P vs. Time plots were constructed and responses were compared. The results show a close agreement between the results obtained using

two different models. The exercise validates the effectiveness of modified Darvish model in representing no hydrate condition in a gas reservoir.

2. The modified Darvish model is now applied to East Barrow type reservoir. The reservoir is produced at a constant production rate of 1600 MSCF/Day. The reservoir is considered to be of volumetric type (no associated hydrates). Actual production data is compared with the performance of modified Darvish model.

As expected the production data and modified Darvish results never matched during the entire production life of the reservoir. Thus, we conclude that the reservoir is under constant pressure support from either water influx and/or associated hydrates.

3. To study the impact of hydrate layer on reservoir performance, original Darvish model is used and performance of East Barrow type reservoir model is evaluated. The reservoir performance is then compared for several hydrate thicknesses as shown in Figure 15. The plot shows that as the thickness of hydrate zone is increased, the reservoir pressure stabilizes.
4. The Darvish model is proposed for a volumetric gas reservoir system with a layer of hydrates. It has no provision to include the effect of water influx into the overall material balance and therefore the two external pressure support mechanisms (water influx and hydrate supports) cannot be modeled together with simple material balance method.



**Figure 15. Hydrate Model: P/Z vs. Gp and Pressure vs. Time comparison for Darvish model**

#### Material Balance Modeling Conclusions

The reservoir performance is not volumetric and therefore has external pressure support either from an aquifer, methane hydrate dissociation or a combination of both.

The water influx model did not match the reservoir performance, as matching the pressure history required an increasing size of aquifer.

The hydrate model came close to matching the reservoir performance with thicknesses of 22' of hydrates, but it still did not fully explain the pressure history.

Based on the material balance investigation with the volumetric model, the water influx model and the methane hydrate model, it is apparent that the pressure history can be explained by a combination of water influx and methane hydrate dissociation. The material balance modeling justifies the next step in modeling this reservoir using a three dimensional reservoir and thermodynamic model. This will also allow varying the strength of the aquifer and the thickness of the hydrate zone to better match the reservoir performance.

Based on the results of the material balance modeling, a full-field reservoir simulation model was run using CMG-STARs to extend the history match work and to facilitate planning for potential drilling and production of the methane hydrate reservoir.

## FULL-FIELD HISTORY MATCH AND FORECAST MODELING

Porosity and permeability grids were imported from the geostatistical characterizations generated in Roxar RMS for the East Barrow and Walakpa gas reservoirs, along with all other interpreted and modeled reservoir parameters. CMG data decks were generated. Individual well gas and water historical production data were used for all wells as input to the history matching process. An interpreted gas-water contact was derived from the well log interpretation (E Barrow #17 well) for E Barrow Field, and a range of GWC was used for the Walakpa Field, as no GWC has been encountered in a well in that field. Base of the hydrate stability zone was derived from the regional temperature and pressure regimes, as described above. Average reservoir pressure of the fields and the cumulative water production were used as the history matching parameters.

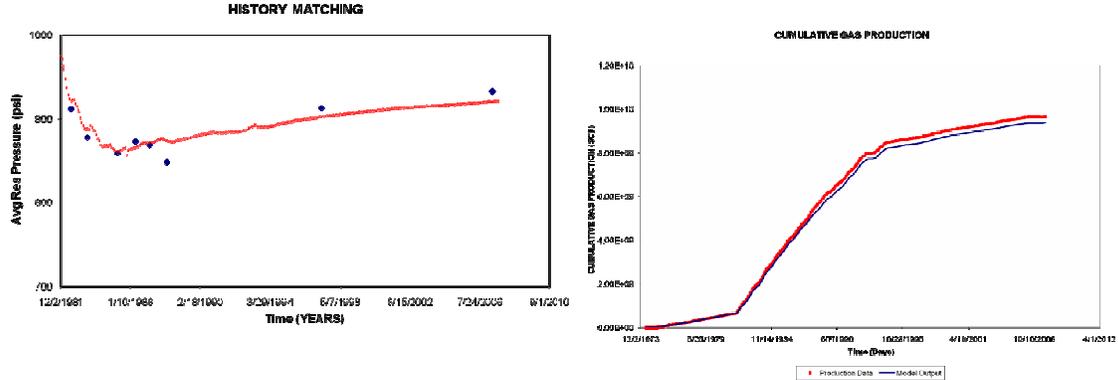


Figure 16 E Barrow Field Average Reservoir Pressure and Cumulative Production History Match

Several sensitivity runs were also made to test the variation in the gas-water-contact and the hydrate stability zone: 1. free gas only, 2. free gas and aquifer only. A number of variations of case 2 are also studied. The sensitivity analysis shows that the free gas volumetric expansion case cannot match the dip in pressure at the outset of production, but does a fair job of matching pressure at later stages of field life, with low production rates. The free gas expansion with aquifer support does a better job matching the dip in pressure in the early stages of production, but shows only minor correction to pressure response at later stage of production, indicating that the aquifer response cannot account for the pressure recovery measured at E Barrow Gas Field. Finally, the combination of volumetric gas expansion, aquifer support and hydrate dissociation represent a very good match to historic pressure response with gas offtake. A fairly exhaustive set of realizations were run for each of the three depletion mechanisms described, and the best matches for each are shown in Figure 16.

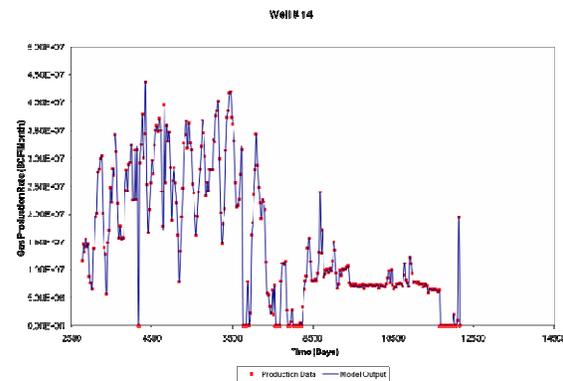


Figure 17 Individual well history match EB 14 History Match

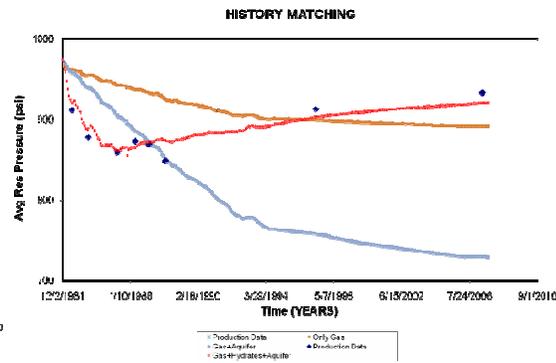
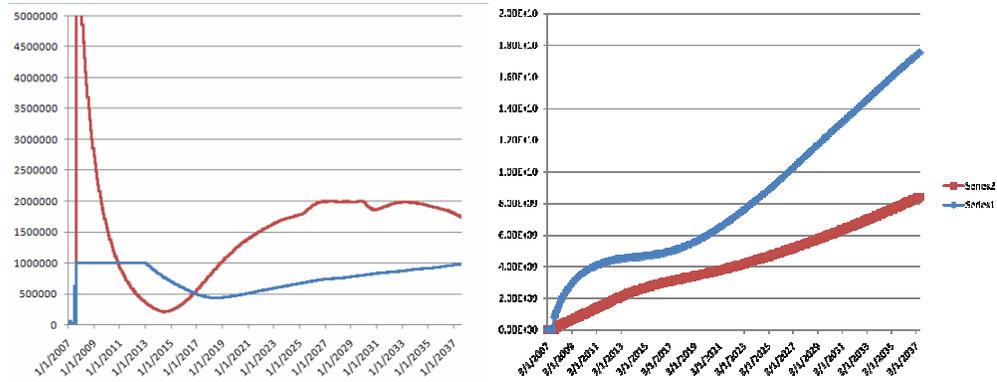


Figure 18 Fieldwide Aver. Pressure History Match

Based on the history match two forecast runs were made using EB#14 well as the producer. In the first forecast run EB#14 was used as a vertical producer and in the 2<sup>nd</sup> run it is used as a horizontal producer. The forecast runs show that the horizontal well is more prolific as a gas producer, both in terms of rate and cumulative gas production (Figure 19).



**Figure 19 Horizontal vs. Vertical Producer, Rate and Cumulative Gas Production, East Barrow (EB #14 Well)**

The results of the modeling are the subject of a forthcoming topical report which will cover this material in much greater detail, and the material will also be included in the Final Phase 1 Technical Report.

## TECHNOLOGY TRANSFER

- An abstract and full manuscript have now been submitted to present project findings at the 2008 International Conference on Gas Hydrates, and acceptance of the abstract has been confirmed.

## CONCLUSION

Significant progress was made this quarter in modeling reservoir production history, and forecasting production from vertical and horizontal wells. Detailed results of findings will be described in a topical report, covering the full-field history-matched reservoir simulation, and well production forecasting. A final comprehensive technical report for all of Phase 1 is underway for submission in June, 2008.

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