OPTIMIZING DEVELOPMENT STRATEGIES TO INCREASE RESERVES IN UNCONVENTIONAL GAS RESERVOIRS

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Agenda

- Project Objective and Goals
- Timing, Project Participants, Major Milestones
- Value of the Research – Project Impact
- Technical Overview – Status of Current Technology
- Project Deliverables
- Progress to Date
- Technical Issues/Problems Encountered
- Summary
Project Objective and Goals

Overarching Goal
Determine optimal development strategies for unconventional gas reservoirs, taking into account uncertainty and learning.

Specific Objectives
• Develop integrated reservoir and decision model to help operators determine optimal well spacing and completion strategies in highly uncertain and risky unconventional gas reservoirs as quickly as possible

• Determine optimal well spacing and completion methods in the Barnett Shale, Parker County, Texas, and the Gething tight gas formation in Alberta, Canada
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Partners

Pioneer Natural Resources
Irving, Texas
Area of interest: Gas shale
Level of field development: existing/emerging
Resource/play: Barnett shale, Parker Co., Texas

Unconventional Gas Resources
College Station, Texas and Calgary, Alberta
Area of interest: tight sands
Level of field development: existing/emerging
Resource/play: Gething formation, Deep Basin tight gas sands, western Canada
# Project Timeline and Milestones

## Project Schedule

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- **Completed**
- **In progress**
- **Not started**

## Major Milestones

1. Complete development and testing of reservoir and decision models.

2. Integrate and test reservoir and decision models and characterize test reservoirs prior to determining optimal well spacings in these reservoirs.
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Value of the Research

Problem Significance

1. Unconventional gas is poised to play a significant role in the Nation’s energy future.
2. Unconventional plays possess significant uncertainty
3. Optimization of spacing and completion practices is difficult
4. Previous unconventional developments have often taken decades to optimize development. This can reduce value by up to 50% (McKinney et al., 2002)
5. However, rapid development can result in overdrilling, which also reduces profitability and impacts environment
6. The NPC recently recommended a major increase in research funding to optimize drilling and completion methods

Expected Impacts

1. Short-term: help optimize development in the Barnett Shale and Gething gas sands
2. Long-term: integrating the technology by other operators should increase reserves, accelerate production, reduce environmental impacts (fewer wells), and reduce capital requirements
3. Modest improvement could have significant impact on recovery, e.g., in the Barnett Shale, which averages just 7% of gas in place (NPC, 2007)
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Most Accurate Method for Optimizing Development of Unconventional Gas Reservoirs

Detailed reservoir study

- build geological model
- estimate reservoir properties
- construct and calibrate a reservoir simulation model
- predict future performance

Prohibitively time-consuming and expensive, particularly for marginal reservoirs

Incorporating uncertainty increases time and costs considerably

Impractical for independents with limited staff
Moving Window Statistical Method

• BY = f(VBY, Gp/A, A)

• Method correlates EUR to readily available production indicators (Voneiff and Cipolla, 1996)
Simulation-Based Regression Method

Gao and McVay (2004) proposed a simulation-based approach

- Does not require a detailed reservoir characterization study
- Uses only well locations, production data and approximate reservoir description
- Combines reservoir simulation with automatic history matching

Combines greater accuracy of simulation-based methods with short analysis times and low costs of moving window methods
Advantage – Estimates Reservoir Properties

True permeability field

Inversed permeability field

Unit: md

True $\phi h$ field

Inversed $\phi h$ field

Unit: ft
Proposed Reservoir Model

Neither approach quantifies the large uncertainty in result, precluding use in decision models.

We will develop a fast, approximate, probabilistic reservoir model for predicting performance of unconventional gas reservoirs.

The model will be intermediate between statistical moving window approaches and simulation-based approaches.

- It will be capable of determining values of the input parameters (or proxies for these parameters) from readily available data such as production data.
- It will be capable of incorporating additional data, such as well log data or pressure transient test data, when available.

A major extension over previous methods will be including quantification of uncertainty.
Current Status of Decision Analysis in Oil and Gas Industry

• Decision analysis (DA) was introduced to the oil and gas industry in by Grayson (1960).

• Yet, many oil and gas companies still primarily rely on deterministic estimates (Bickel and Bratvold 2008).

• DA has been applied extensively in conventional reservoirs, but not in unconventional reservoirs, which pose special challenges (Haskett and Brown 2005).

• A key feature of DA is its ability to value information gathering opportunities. Value of information (VOI) has been applied to value new seismic technologies (Bickel et al. 2006) and to determine the optimal sequencing of exploration and appraisal wells (Bickel and Smith 2008).
We will construct a Bayesian decision model that will allow an operator to choose the optimal primary and secondary (or more) development plans.

The model is Bayesian in that our uncertainty quantification of the reservoir at any point will depend upon all preceding production results.
Decision Model Continued

We intended to evaluate different pilot programs.

The value of the primary production program is the immediate economic value it provides plus the value of information it provides to develop the optimal down spacing program.

We intended to use dynamic programming to model and evaluate the development programs. We will also include a budget constraint.
Example

Stage 1

Primary Spacing

Spacing 640

Spacing 320

Spacing 160

Production

High

Medium

Low

Secondary Spacing

Spacing 640

Spacing 320

Spacing 160

Stage 2

Production
Integration of Reservoir and Decision Models

We believe that significant value can be achieved by helping operators make better decisions in the face of uncertainty.

To achieve this we plan to develop an integrated decision support tool.
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Project Deliverables

1. A decision support system, consisting of integrated reservoir and decision models, for determination of optimal well spacing and completion method in unconventional gas reservoirs

2. Recommendations for optimal well spacing and completion method in the Barnett Shale in Parker County, Texas

3. Recommendations for optimal well spacing and completion method in the Gething formation in the Berland River area of Alberta
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Reservoir Model – Initial Implementation

The initial implementation is a single-well reservoir simulation model combined with Monte Carlo simulation.

Random variables are
- Porosity
- Permeability
- Net pay
- Pressure (depth)

Two stages of production
- Two years of production at 640, 320 or 160 ac
- Two years of production at 640, 320 or 160 ac
Reservoir Model - Parameters

Illustrative example results from the Gething formation, Berland River area, Alberta. This analysis is based on meetings with UGR and data that they have provided.

1) Depth to top (m) : Normal(2780,91,RiskTruncate(2600,3100))
2) Initial pore pressure gradient: 0.28 psi/ft
3) Net pay (m): Lognorm(6.5,4.45,RiskShift(0.6),RiskTruncate(0.4,15))
4) Water saturation: 30%
5) Hydraulic fracture, lengths vary from 150 ft to 250 ft, with Fcd around 1.3 (Fcd = wKf/LfK)
6) Total porosity, fraction: Normal(0.102,0.014,RiskTruncate(0.06,0.14))
7) Porosity-permeability “cloud” model:
   1.92*EXP(RiskNormal(47.517*C33*(1-Sw)+LN(0.0071),0.55))
Permeability-Porosity Cloud Model

![Permeability-Porosity Cloud Model Graph](image-url)
Reservoir Model – Stage Production Distributions
Decision Model

Reservoir Simulation

Histogram
Stage 1

Histogram
Stage 2 given Stage 1

Distribution Fitting

Histogram
Stage 1

Histogram
Stage 2 given Stage 1

Data Discretization

High 0.3
Level at 0.9
- Medium 0.4
- Low 0.3
- High 0.3
- L 0.9
- L 0.5
- L 0.1
- L 0.9
- L 0.5
- L 0.1

Medium 0.4
Level at 0.5
- Medium 0.4
- Low 0.3
- High 0.3
- L 0.5
- L 0.1
- L 0.9
- L 0.5
- L 0.1

Low 0.3
Level at 0.1
- Medium 0.4
- Low 0.3
- L 0.5
- L 0.1
**Decision Model**

**Stage 1/320**

Spacing

- **High**
  - Spacing 640
  - **E[NPV]** $3,465,776.15
- **Medium**
  - Spacing 320
  - **Production MMscf**
    - 3605
    - S1 Cash Flow + S2 NPV at year 2 = Total Revenue at year 2
    - $5,649,895
    - $5,696,620
    - **=** $11,346,515
    - **NPV** $10,025,781
- **Low**
  - Spacing 180
  - **550**
  - S1 Cash Flow + S2 NPV at year 2 = Total Revenue at year 2
    - $(2,709,671)$
    - $1,295,806$
    - **=** $(1,413,865)$
    - **NPV** $(1,249,291)$
In this example, the model suggests to use 320 spacing in stage one, and if the production is high downspace to 160. If the production is medium or low then we stay at 320.

We consider a cost of drilling and completing a well is $2,500,000. We assume a stage one gas price of $4/MCF and a stage two price of $5/MCF.
Next Steps

• Modify our subsurface and decision models to address the issues faced by Pioneer in the Barnett Shale.

• Identify a realistic development scenario for each partner.

• Improve the reservoir model by calibrating it to partner field data and adding uncertainty in drainage area.

• Expand the decision model to account for piloting.
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Technical Issues/Problems Encountered

- UGR and Pioneer decisions may require different types of subsurface models.
- It may be challenging to build reservoir models that fully represent the reservoir uncertainty, but are also fast to recalculate.
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Project Summary

Objective: Develop new technologies for determining optimal development strategies and testing programs in gas shale and tight sand reservoirs.

Core technology: Integrated reservoir and decision model that fully incorporates uncertainty in reservoir properties.

Application: University and industry partners to determine optimal well spacing and completion methods in the Barnett Shale, Parker County, Texas, and the Gething tight gas formation in Alberta, Canada.

Impact: Technology incorporation into operators’ development processes will enable reaching optimal spacing as quickly as possible, accelerating production and increasing reserves.

- Production, spacing, and completion history.
- Current spacing and completion alternatives.

Initial production, spacing, and completion history → Reservoir Model ← Forecasted production. → Decision Model → Optimal spacing and completion
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