2015 TD Securities
Calgary Energy Conference
Modelling Risk and Value in Unconventional Plays

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Understanding risk is more important than ever.
Was this a warning sign?

OIL DOMINATES US FIXED INVESTMENT

“Investments in oil and gas are now close to 20% of total US private fixed structure investment, the highest level ever.”

—Francisco Blanch, Head of Global Commodities Research at Bank of America Merrill Lynch Global Research
Low-cost producers continue to increase production...

Saudi and Iraq production increased 1 million bopd in March

This is approximately one ‘North Dakota Bakken’
...while everyone else strives to become a low-cost producer

EOG Eagle Ford Productivity Improvements

Source: RBN Energy, EOG
Is $65 the new $80?

- Efficiency
- Technology
- Cost deflation

Some plays are demonstrating better ROR in 2015 at $60 oil than in 2012 at $90 oil
How can we answer these questions?

1. What is the chance of realizing a 10%-discounted NPV greater than zero for an 8-well horizontal drilling program spread across the Kerrobert area Viking?
   – What if all 8 wells are drilled in the same section?

2. How likely is a single Kerrobert Viking well to have an IRR greater than zero?

3. How many Kerrobert Viking wells would need to be drilled to be 90% confident of a 10%-discounted PI greater than 1.2?
   – What if all wells are drilled within two miles of each other?

4. What is the chance that the WTI price will average at least $65/bbl in 2016?

5. What average 2016 WTI price are we 90% confident will be exceeded?
With probabilistic analysis!

- Identify analogous wells
- Build production forecasts
- Generate parameter distributions
- Create a correlation matrix
- Run Monte Carlo simulation
- Confirm Monte Carlo results
- Use a stochastic price forecast?
  - Yes: Use Ornstein-Uhlenbeck process
  - No: Use deterministic price forecast
- 100,000 iterations
- Generate revenues
- Apply costs, royalties & other adjustments
- Calculate final cash flows
- Calculate performance metrics
- Inform your decision
Which factors are “known”?

Components of a Half-Cycle Economic Analysis

- Prices
- Production & EUR
- Capital Costs
- Operating Costs
- Royalties

Less Certain

- Market prices are hard to predict
- Normally predictable to ±70% with 95% confidence one year out
- Hedging can improve certainty

- Well performance
- Operational issues
- Economic factors can limit

- Usually predictable within 15%
- Uncertainty largely tied to success/failure and experimentation

- Transportation bottlenecks
- Line pressures
- Unexpected issues, maintenance
- Competition, partnerships

- Long term uncertainty in regulatory framework
- Short term is (usually) quite certain

GLJ Petroleum Consultants
Choosing a sample area

- Geologically similar
- >30 wells is best
- Representative of your area of interest
Production forecasts

- Two-stage Arps hyperbolic declines
- Bootstrap resampling
- Flow regime diagnostics
Most relationships in resource analysis are nonlinear

Spearman’s Rank Correlation vs. Pearson’s Correlation

Pearson’s Correlation
- Assumes constant variance
- Tests fit to straight line
- Is the ‘R’ in the familiar ‘R^2’

Spearman’s Rank Correlation
- Is the linear correlation of ranks
- Better for nonlinear relationships
- Less sensitive to extreme outliers

Pearson’s R = -0.48
Spearman’s R = -1.00
Decline parameters are not independent!

It is nearly always incorrect to move a type curve up or down proportionally to IP – the EUR to IP relationship is nonlinear

<table>
<thead>
<tr>
<th>Spearman's Correlation Coefficients</th>
<th>qi</th>
<th>Di</th>
<th>bt</th>
<th>q1 (adj)</th>
<th>t1</th>
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Sampling with dependence - Kerrobert Viking

- Initial Rate
- Initial Decline Rate
- Transient Exponent

100,000 times
Sampling with dependence - Kerrobert Viking

Could also analyze on a per-frac or per-length basis
Confirming production forecast results

- Real Data looks good – P10/P90 ratios are within 4%
- MC Sim Results
Calculating revenues with stochastic pricing

Each of the 100k production forecasts run with a stochastic price forecast anchored by TD forecasts ($75 WTI and $3.50 Henry Hub)
A modified random walk with a mean reversion tendency

Has four parameters:
- $X_0$: initial price
- $\mu$: equilibrium price
- $\sigma$: volatility
- $\theta$: rate of shock dissipation

$\text{d}X_t = \theta(\mu - X_t)\text{d}t + \sigma\text{d}W_t$

Choosing suitable parameters for the O-U process

Initial price: $60

Volatility

Equilibrium Price: $75

Rate of shock dissipation: 5 years
(based on historical data, detailed in SPE-162629 paper)
WTI – 68% confidence that price will be between $40/bbl and $84/bbl through 2016

Implied volatility can be calculated from the prices of options sold by banks

68% confidence
Henry Hub – 68% confidence that price will be between $2.05/MMBtu and $5.25/MMBtu through 2016
Possible Future WTI Price Realizations

**O-U equilibrium prices:**
- WTI: $75/bbl
- HH: $3.50/MMBtu

*Possible future price realizations*
From revenues to cash flows

- Capital Costs
- Operating Costs
- GLJ Database + Probabilistic Sampling
  - Price Adjustments
  - Byproduct Yields
  - Surface Loss
  - $750k-$1000k
Single-well net present value, 10% discounting

**Mean:** $474k  
**P90:** -$549k  
**P50:** $137k  
**P10:** $2036k
Single-well profitability index, 10% discounting

**Kerrobert Area Viking: Single-Well Profitability Index, 10% Discounting**

- **Mean:** 1.55
- **P90:** 0.38
- **P50:** 1.16
- **P10:** 3.34
Single-well modified internal rate of return

Kerrobert Area Viking: Single-Well MIRR (4% finance rate, 8% reinvestment rate)

- **Mean:** 4.4%
- **P90:** -16.4%
- **P50:** 9.5%
- **P10:** 15.9%
**Single-well time to payout**

**Kerrobert Area Viking: Months to Payout**

- **Mean:** 27 mo
- **P90:** 7 mo
- **P50:** 17 mo
- **P10:** 60 mo

**36% never pay out**
Expectations tighten with more wells

Here, every well drilled is geostatistically independent from every other well ("shotgun blast" scenario)

### Kerrobert Area Viking NPV10 Per Well

Probability Density Distributions

<table>
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<tr>
<th># Wells</th>
<th>P50</th>
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<tr>
<td>1</td>
<td>$137k</td>
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<tr>
<td>2</td>
<td>$280k</td>
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<td>50</td>
<td>$525k</td>
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### NPV10 per well (CAD, thousands)

**Chart Notes**
- **1 Well**
- **2 Wells**
- **5 Wells**
- **10 Wells**
- **20 Wells**
- **50 Wells**
What if all wells are drilled in one small area?

Medicine Hat/Milk River Shallow Gas Example

Wells drilled nearer to each other are likely to perform more similarly than wells drilled further apart.
Expectations don’t tighten as much if wells are all drilled in one small area.

If 8 wells are all drilled in the same section, then some of the “law of averages” effect is lost.
1. What is the chance of realizing a 10%-discounted NPV greater than zero for an 8-well horizontal Viking drilling program spread across the Kerrobert area? 90%
   – What if all 8 wells are drilled in the same section? 84%
2. How likely is a single Kerrobert Viking well to have an IRR greater than zero? 57%
3. How many Kerrobert Viking wells would need to be drilled to be 90% confident of a 10%-discounted PI greater than 1.2? 21
   – What if all wells are drilled within two miles of each other? 23
4. What is the chance that the WTI price will average at least $65/bbl in 2016? 27%
5. What average 2016 WTI price are we 90% confident will be exceeded? $44/bbl

Based on June 9, 2015 market data
Applications

- Hedge evaluation
- Backstopping reserves work on major fields
- Robust A&D scoping work
- Comparing drilling programs
- Portfolio and efficient frontier analysis
- Asset valuation with intelligent sensitivities
- Generating informed distributions to apply to emerging plays
- BI and peer group analysis
Thank You

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