Oil Sands Industry
SAGD – A Blow-by-Blow Account

Summary

Steam Assisted Gravity Drainage or SAGD is a process used to extract oil sands in situ. Given that the vast majority of the oil sands are too deep to mine coupled with the geology of the Wabiskaw-McMurray formation, SAGD is the process of choice for almost every new project in the Athabasca oil sands area (it is also starting to be used in other geological formations as well). As a result there is considerable discussion regarding the expectations of new SAGD projects in terms of ramp-up profiles, peak rates and steam oil ratios. For investors who would like additional information on SAGD, our report ‘Oil Sands Royale’ from Dec-20-06 provides some detailed information on the process.

In this report, we’ve analyzed the 10 existing SAGD projects in the McMurray to generate SAGD benchmarks. The analysis represents countless hours of painstaking work to convert raw SAGD data into the charts and graphs presented in the Appendices. Our goal was to provide a unique way to compare and contrast the various projects against one another.

All of the details are summarized in the following sections, but our key conclusions are:

- There are 4 newer SAGD projects, Devon’s (DVN-NYSE, not covered) Jackfish, ConocoPhillips’s (COP-NYSE, not covered) Surmont, Connacher’s (CLL-TSX, STRONG BUY, $7.25 target price) Great Divide and Nexen/OPTI’s (OPC-TSX, MARKET PERFORM, $23.00 target price) Long Lake projects. Of the four projects, the Nexen/OPTI Long Lake project is exhibiting the weakest performance in terms of average production rates per well, iSOR, cSOR and ramp profile – when the projects are compared to one another on a normalized basis. Granted Long Lake has experienced well documented surface related issues with steam generation and power reliability – but so have others. As far as we’re concerned, we still need to see Long Lake perform much better before being convinced that the project is ‘working’.

- Based on our analysis, we believe that Connacher’s Great Divide project is meeting expectations with ramp-up to 10,000 bbl/d expected later this year. We reiterate our STRONG BUY rating and $7.25 target price.

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In addition, there are a few other notable observations we can make:

- All of our conclusions and observations are derived from our analysis of government and publically available data for the existing SAGD projects. We’ve included numerous charts and figures to support our analysis.
- There are numerous parameters that drive production rates for SAGD wells, but well length and reservoir thickness/height are two readily understood parameters that have the largest impact, however the most important factor is the cleanliness of the reservoir – which is very difficult to quantify. Theoretical SAGD production rates are proportional to length and are related to the square root of reservoir thickness or net pay;
- Based on our theoretical analysis, we would expect Suncor’s (SU-TSX/NYSE, OUTPERFORM, $85 target price) Firebag wells to be the best producing wells, which in fact they are;
- Based on our theoretical analysis, we would expect the Nexen/OPTI (OPC-TSX, MARKET PERFORM, $23.00 target price) Long Lake project to be the second best SAGD project when in fact it is the second worst thus far;
- All projects experience downtime – which can be seen if you compare calendar day and producing day bitumen rates. The most common sources of downtime come from the water treatment and steam generation facilities;
- The range of production for wells after 18 months is 175 bbl/d to 2,700 bbl/d – so there are clearly very good SAGD wells and very poor SAGD wells;
- Generally speaking, a good SAGD well was always a good SAGD well – starting from its first month on production. In other words, a good SAGD well outperforms the group regardless of whether we look at the production data after the first, third, sixth (or other) months;
- The average SAGD well produces 825 bbl/d after 18 months of being on stream – with an SOR below 3.0. Interestingly the average well ramps up to 75% of the month 18 rate within the first 6 months;
- On average the iSOR converges to the 2.5 to 3.5 range for all projects. Encana’s (ECA-TSX/NYSE, UNDER REVIEW) Christina Lake Project has a cSOR of 2.2 and Petro-Canada’s (PCA-TSX/PCZ-NYSE, OUTPERFORM, $75.00 target price) MacKay River Project with a cSOR of 2.5 are the two best performing projects in terms of cumulative steam oil ratio;
- In the 10 SAGD projects we’ve analyzed, there are currently 260 SAGD well pairs in operation;
- The iSOR of an average SAGD project reaches its steady state within 6 months of first production.
Report Overview

There is understandably a lot of discussion in the investment community about the SAGD process for recovering oil sands. Of particular interest are the expectations of a SAGD project in terms of production ramp-up profiles, peak rates and steam oil ratios. In many ways, SAGD is still in its infancy – even though the process has been in development for 25+ years – operators are still learning how to apply the process effectively under different reservoir and operating conditions.

Needless to say, SAGD is a work in progress and significant strides should be made over the next several years across the SAGD process (drilling, completion, reservoir modeling and surface facilities). Our expectation, of course, is that newer projects should be able to leverage the learnings from older projects to deliver relatively better results.

That being said, we felt that an analysis of existing projects was warranted to provide some benchmarks against which existing SAGD projects could be compared and contrasted. Embarking on this type of analysis is a very time-consuming process and furthermore, it is fraught with potential pitfalls that can limit its validity. Issues like presence of top/bottom water, top gas, lean zones, length of the horizontal section, operating conditions, completion design, reservoir characteristics, the presence of barriers, homogeneity of the reservoir and operational know-how can all impact SAGD performance. A detailed analysis incorporating all of the above factors is well beyond the scope of this report. However, we firmly believe that comparing existing projects using production and steam oil ratios as a basis makes sense – at least in terms of a benchmark when trying to determine if a particular project is tracking the ‘norm’.

Our analysis for SAGD projects focuses on what we believe are the ‘important’ things like ramp-up profiles, peak rates and steam oil ratios and our methodology is outlined in the following pages. We’ve also included a brief section on theoretical SAGD well performance to better illustrate why people care about things like pay thickness, permeability and porosity when they talk about SAGD projects. Our goal here is to demystify the SAGD process, quantify why these factors are important and to demonstrate the impact that each variable has on production rates. We begin by providing a summary chart for each of the existing 10 SAGD projects that highlights the key project characteristics. In the appendices, there are a plethora of charts for each of the projects which show normalized production, steam oil ratios and project performance – all of which can be used when comparing the relative performance of the various projects.
Summary of Key Parameters for SAGD Projects

When companies discuss their SAGD projects, they often refer to thickness, permeability, porosity and average depth – some of the key factors that drive production rates, production ramp profiles and steam-oil ratios. In this section, we provide a summary of each of the existing 10 SAGD projects in terms of the key project parameters.

**Exhibit 1: Connacher Great Divide Key Project Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Bitumen Saturation (%)</td>
<td>80%</td>
</tr>
<tr>
<td>Average Permeability (Darcy)</td>
<td>3-9 D</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>33%</td>
</tr>
<tr>
<td>Average Net Pay Thickness (m)</td>
<td>18 m</td>
</tr>
<tr>
<td>Native Reservoir Pressure (kPa)</td>
<td>3,500 kPa</td>
</tr>
<tr>
<td>Depth to Top of Reservoir (m)</td>
<td>460 m</td>
</tr>
<tr>
<td>Average Horizontal Well Length (m)</td>
<td>900 m</td>
</tr>
</tbody>
</table>

Source: Company Disclosures, GeoScout, Raymond James Ltd.

**Exhibit 2: ConocoPhillips Surmont Key Project Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Bitumen Saturation (%)</td>
<td>75%</td>
</tr>
<tr>
<td>Average Permeability (Darcy)</td>
<td>3-10 D</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>36%</td>
</tr>
<tr>
<td>Average Net Pay Thickness (m)</td>
<td>30 m</td>
</tr>
<tr>
<td>Native Reservoir Pressure (kPa)</td>
<td>2,050 kPa</td>
</tr>
<tr>
<td>Depth to Top of Reservoir (m)</td>
<td>400 m</td>
</tr>
<tr>
<td>Average Horizontal Well Length (m)</td>
<td>1,100 m</td>
</tr>
</tbody>
</table>

Source: Company Disclosures, GeoScout, Raymond James Ltd.

**Exhibit 3: Devon Jackfish Project Key Project Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Bitumen Saturation (%)</td>
<td>80%</td>
</tr>
<tr>
<td>Permeability (Darcy)</td>
<td>2-10 D</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>33%</td>
</tr>
<tr>
<td>Average Net Pay Thickness (m)</td>
<td>25 m</td>
</tr>
<tr>
<td>Native Reservoir Pressure (kPa)</td>
<td>2,700 kPa</td>
</tr>
<tr>
<td>Depth to Top of Reservoir (m)</td>
<td>385 m</td>
</tr>
<tr>
<td>Average Horizontal Well Length (m)</td>
<td>750 m</td>
</tr>
</tbody>
</table>

Source: Company Disclosures, GeoScout, Raymond James Ltd.
### Exhibit 4: Encana Christina Lake Key Project Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Bitumen Saturation (%)</td>
<td>80%</td>
</tr>
<tr>
<td>Average Permeability (Darcy)</td>
<td>3-10 D</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>33%</td>
</tr>
<tr>
<td>Average Net Pay Thickness (m)</td>
<td>25 m</td>
</tr>
<tr>
<td>Native Reservoir Pressure (kPa)</td>
<td>2,000 kPa</td>
</tr>
<tr>
<td>Depth to Top of Reservoir (m)</td>
<td>400 m</td>
</tr>
<tr>
<td>Average Horizontal Well Length (m)</td>
<td>900 m</td>
</tr>
</tbody>
</table>

Source: Company Disclosures, GeoScout, Raymond James Ltd.

### Exhibit 5: Encana Foster Creek Key Project Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Bitumen Saturation (%)</td>
<td>80%</td>
</tr>
<tr>
<td>Average Permeability (Darcy)</td>
<td>6 D</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>34%</td>
</tr>
<tr>
<td>Average Net Pay Thickness (m)</td>
<td>10-30 m</td>
</tr>
<tr>
<td>Native Reservoir Pressure (kPa)</td>
<td>2,700 kPa</td>
</tr>
<tr>
<td>Depth to Top of Reservoir (m)</td>
<td>180-225 m</td>
</tr>
<tr>
<td>Average Horizontal Well Length (m)</td>
<td>950 m</td>
</tr>
</tbody>
</table>

Source: Company Disclosures, GeoScout, Raymond James Ltd.

### Exhibit 6: JACOS Hangingstone Key Project Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Bitumen Saturation (%)</td>
<td>85%</td>
</tr>
<tr>
<td>Average Permeability (Darcy)</td>
<td>2-4 D</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>30%</td>
</tr>
<tr>
<td>Average Net Pay Thickness (m)</td>
<td>15-26 m</td>
</tr>
<tr>
<td>Native Reservoir Pressure (kPa)</td>
<td>4,650 kPa</td>
</tr>
<tr>
<td>Depth to Top of Reservoir (m)</td>
<td>275 m</td>
</tr>
<tr>
<td>Average Horizontal Well Length (m)</td>
<td>900 m</td>
</tr>
</tbody>
</table>

Source: Company Disclosures, GeoScout, Raymond James Ltd.

### Exhibit 7: Nexen-OPTI Long Lake Key Project Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Bitumen Saturation (%)</td>
<td>75%</td>
</tr>
<tr>
<td>Average Permeability (Darcy)</td>
<td>7 D</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>35%</td>
</tr>
<tr>
<td>Average Net Pay Thickness (m)</td>
<td>40 m</td>
</tr>
<tr>
<td>Native Reservoir Pressure (kPa)</td>
<td>1,200 kPa</td>
</tr>
<tr>
<td>Depth to Top of Reservoir (m)</td>
<td>250 m</td>
</tr>
<tr>
<td>Average Horizontal Well Length (m)</td>
<td>1,050 m</td>
</tr>
</tbody>
</table>

Source: Company Disclosures, GeoScout, Raymond James Ltd.
### Exhibit 8: Petro-Canada MacKay River Key Project Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Bitumen Saturation (%)</td>
<td>74%</td>
</tr>
<tr>
<td>Average Permeability (Darcy)</td>
<td>3-10 D</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>35%</td>
</tr>
<tr>
<td>Average Net Pay Thickness (m)</td>
<td>15-35 m</td>
</tr>
<tr>
<td>Native Reservoir Pressure (kPa)</td>
<td>500 kPa</td>
</tr>
<tr>
<td>Depth to Top of Reservoir (m)</td>
<td>80-135 m</td>
</tr>
<tr>
<td>Average Horizontal Well Length (m)</td>
<td>950 m</td>
</tr>
</tbody>
</table>

Source: Company Disclosures, GeoScout, Raymond James Ltd.

### Exhibit 9: Suncor Firebag Key Project Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Bitumen Saturation (%)</td>
<td>79%</td>
</tr>
<tr>
<td>Average Permeability (Darcy)</td>
<td>6-10 D</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>35%</td>
</tr>
<tr>
<td>Average Net Pay Thickness (m)</td>
<td>37 m</td>
</tr>
<tr>
<td>Native Reservoir Pressure (kPa)</td>
<td>800 kPa</td>
</tr>
<tr>
<td>Depth to Top of Reservoir (m)</td>
<td>320 m</td>
</tr>
<tr>
<td>Average Horizontal Well Length (m)</td>
<td>1,300 m</td>
</tr>
</tbody>
</table>

Source: Company Disclosures, GeoScout, Raymond James Ltd.

### Exhibit 10: Total Joslyn Key Project Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Bitumen Saturation (%)</td>
<td>76%</td>
</tr>
<tr>
<td>Average Permeability (Darcy)</td>
<td>5 D</td>
</tr>
<tr>
<td>Average Porosity (%)</td>
<td>35%</td>
</tr>
<tr>
<td>Average Net Pay Thickness (m)</td>
<td>20-40 m</td>
</tr>
<tr>
<td>Native Reservoir Pressure (kPa)</td>
<td>900-1800 kPa</td>
</tr>
<tr>
<td>Depth to Top of Reservoir (m)</td>
<td>90-105 m</td>
</tr>
<tr>
<td>Average Horizontal Well Length (m)</td>
<td>800 m</td>
</tr>
</tbody>
</table>

Source: Company Disclosures, GeoScout, Raymond James Ltd.

Based on the data:
- Average bitumen saturation ranges between 74% and 85%
- Average permeability ranges between 2 and 10 Darcies
- Average porosity ranges from 30% to 36%
- Average net pay thickness ranges from 10m to 40m
- Native reservoir pressure ranges from 800 kPa to 4,650 kPa
- Average horizontal well length ranges from 750m to 1,300m

These parameters are summarized for all projects in a radar chart, shown in Exhibit 11.
As we will outline in the following sections, each of these key parameters is important when trying to predict SAGD well performance.
**Theoretical SAGD Equation**

With any SAGD well pair, the ultimate goal is to obtain high production rates with low steam oil ratios. The problem, of course, is that our expectations for what the wells are capable of delivering need to be based on some sort of theoretical/empirical equation. All we can really do is measure and estimate some of the physical parameters and use the governing SAGD equation as a starting point.

Every investor has likely heard the terms permeability, porosity, viscosity and reservoir thickness tossed about in an effort to compare and contrast one project versus another. But how actually do these variables affect a SAGD operation and which variables are most important? We present the governing SAGD equation (developed by Roger Butler) below for the theoretical peak flow rate from a SAGD well in an ideal reservoir. One important point is that over the years, this formula has been modified and tweaked by empirical results (those modifications are not relevant for the purposes of our discussion), but suffice it to say that the equation below allows us to understand how the physical parameters (permeability, porosity, reservoir thickness, oil saturation, temperature, length and viscosity) affect SAGD production rates. The equation for production rate from a SAGD well is:

\[
q = 2 \sqrt{\frac{2\phi \Delta S_0 \Delta g \alpha \phi h}{m \nu_s}} \cdot L
\]

Where:

- \( \phi \) = Porosity
- \( \Delta S_0 \) = Initial oil saturation – Residual oil saturation
- \( k \) = Permeability
- \( g \) = Local acceleration due to Gravity
- \( \alpha \) = Thermal diffusivity
- \( h \) = Height of reservoir
- \( m \) = Kinematic viscosity of the oil at the steam temperature
- \( L \) = Length of horizontal section of well

\[
m = v_s \int_{T_R}^{T_s} \frac{1}{v_s} \frac{1}{V_R} \frac{dT}{T - T_R} \quad \text{(Parameter)}
\]
There are a few important items to note from the formula. First is that the production rate is proportional to the well’s horizontal length. Also, the production rate is related to the square root of factors like permeability, reservoir height and bitumen saturation. So referring once again to the equation, if the average reservoir thickness at Suncor is 37m and the average reservoir thickness at Connacher is 18m – we would theoretically expect the production from the Suncor wells to be 1.434 times higher than Connacher’s wells (all else being equal). The factors that have the largest potential impact on the production rate are the reservoir thickness, the permeability and the length of the horizontal section (because all of these factors can be double, triple or even higher from project to project – in contrast, bitumen saturation varies from 74% to 85% representing only a 15% swing).

We again need to highlight that the above equation is the theoretical governing formula for SAGD production. In practice, there are a multitude of issues that cause the actual results to deviate from theory – reservoir heterogeneity, top water, bottom water, top gas and operational nuances – but we still think the theoretical equation is a useful starting point.

That takes care of predicting the bitumen production rate. But what about the steam injection rate? It should come as no surprise that predicting steam injection rates and SOR is also very complex – particularly when non-ideal reservoirs are modeled (non-homogeneity, top/bottom water and top gas to name a few). The steam injection rates are a function of many of the same variables as for SAGD production rate – like reservoir height, porosity, bitumen saturation, permeability with the addition of factors related to the heat capacity and density of bitumen, reservoir and overburden.

In general, steam is required to:

1. Raise the steam chamber temperature from initial reservoir temperature to steam temperature
2. Raise the bitumen temperature to the production temperature
3. Account for heat losses to the overburden above the steam chamber
4. Account for heat losses in the reservoir beyond the advancing front

In any event, we hope that we’ve somewhat de-mystified the SAGD equation and provided a cursory overview of how the various reservoir and well parameters can impact the production rates of SAGD wells.
Analysis

Armed with the theoretical SAGD equation and a summary by project of each of the ‘important’ parameters that govern the SAGD process, we can calculate which projects should outperform based on the horizontal length, reservoir thickness, permeability, porosity and saturation. Although we would like to include other factors in our analysis, we are limited to the five parameters because they are readily available.

Given the parameters, we can apply a ‘weighting’ factor to each. For example, if the average well length for project A is twice as long as it is for project B, we would expect a production rate 2 times greater for project A. (In practice there is a physical limitation to the well length. Past a certain point an increase in the horizontal well length will yield no incremental production). Additionally, since we have the ranges for each of the 5 variables for all 10 projects and we have the theoretical impact of each parameter on the SAGD production rate, we can scale the variables for each project. By summing the five weighted and scaled factors, we arrive at a relative ranking for each project. The project with the highest ranking should in theory have the best performing wells – accounting for the 5 factors mentioned\(^1\). Our analysis is shown below in Exhibit 12.

### Exhibit 12: Relative Rankings by Project Parameters

<table>
<thead>
<tr>
<th></th>
<th>Saturation</th>
<th>Permeability</th>
<th>Porosity</th>
<th>Well Length</th>
<th>Pay Thickness</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Suncor Firebag</td>
<td>3.3%</td>
<td>26.5%</td>
<td>3.0%</td>
<td>73.3%</td>
<td>42.4%</td>
</tr>
<tr>
<td>2.</td>
<td>Nexen/OPTI Long Lake</td>
<td>0.7%</td>
<td>17.7%</td>
<td>3.0%</td>
<td>40.0%</td>
<td>49.1%</td>
</tr>
<tr>
<td>3.</td>
<td>ConocoPhillips Surmont</td>
<td>0.7%</td>
<td>13.2%</td>
<td>4.4%</td>
<td>46.7%</td>
<td>26.8%</td>
</tr>
<tr>
<td>4.</td>
<td>Petro-Canada MacKay</td>
<td>0.0%</td>
<td>13.2%</td>
<td>3.0%</td>
<td>26.7%</td>
<td>15.6%</td>
</tr>
<tr>
<td>5.</td>
<td>Encana Christina Lake</td>
<td>3.9%</td>
<td>13.2%</td>
<td>0.0%</td>
<td>20.0%</td>
<td>15.6%</td>
</tr>
<tr>
<td>6.</td>
<td>JACOS Hangingstone</td>
<td>7.2%</td>
<td>8.8%</td>
<td>0.0%</td>
<td>20.0%</td>
<td>15.6%</td>
</tr>
<tr>
<td>7.</td>
<td>Encana Foster Creek</td>
<td>3.9%</td>
<td>8.8%</td>
<td>1.5%</td>
<td>26.7%</td>
<td>4.5%</td>
</tr>
<tr>
<td>8.</td>
<td>Total Joslyn</td>
<td>1.3%</td>
<td>0.0%</td>
<td>3.0%</td>
<td>6.7%</td>
<td>26.8%</td>
</tr>
<tr>
<td>9.</td>
<td>Connacher Great Divide</td>
<td>3.9%</td>
<td>8.8%</td>
<td>0.0%</td>
<td>20.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>10.</td>
<td>Devon Jackfish</td>
<td>3.9%</td>
<td>8.8%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>15.6%</td>
</tr>
</tbody>
</table>

Source: Raymond James Ltd., Company Disclosures

What Exhibit 12 shows is that based on the 5 variables we have used, we would expect Suncor’s Firebag project to be the best producing project and Devon’s Jackfish project to be the worst.

\(^1\) In practice there are a multitude of factors over and above the 5 factors that can impact SAGD performance. The most important factor in determining peak production rates in steam oil ratios is the cleanliness of the reservoir (i.e. presence of barriers and shale breaks).
If we then look at the charts we’ve created for normalized production for each of the projects, we can rank them by production rate using month 5 (which is the lowest common denominator across all the projects). The ranking by project is shown in Exhibit 13.

### Exhibit 13: Relative Rankings by Month 5 Production Rate

<table>
<thead>
<tr>
<th>Rank</th>
<th>Project</th>
<th>Month 5 Normalized Production Using a 50 bbl/d Cutoff (bbl/d/well)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Suncor Firebag</td>
<td>1,069</td>
</tr>
<tr>
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<td>8.</td>
<td>Petro-Canada MacKay</td>
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<td>9.</td>
<td>NXY/OPC Long Lake Pilot</td>
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<td>10.</td>
<td>Connacher Great Divide</td>
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<td>11.</td>
<td>NXY/OPC Long Lake Commercial*</td>
<td>254</td>
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<tr>
<td>12.</td>
<td>Total Joslyn</td>
<td>160</td>
</tr>
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</table>

*Uses month 4 production data

Source: Raymond James Ltd., Company Disclosures

If we compare Exhibits 12 and 13 together, we can draw a number of interesting conclusions from a production rate standpoint:

- Firstly, based on the theory, we would expect that Suncor’s Firebag wells should be the best performing project in terms of production – which is in fact the case.
- Secondly, we would expect that Devon’s Jackfish project to be the worst performing project – when in fact it is in the middle of the pack.
- Finally, we would expect the Nexen/OPTI Long Lake wells to be the second best performing, when in fact they are actually the second worst (just ahead of Total’s Joslyn project).
- Given the limitations of the theoretical equation, all other projects are generally in line with where we would expect them to be producing.
- The difference between the theoretical rates and the actual results can be attributed to ‘other’ factors such as top/bottom water, top gas, lean zones, operating conditions, completion design, the presence of barriers, heterogeneity in the reservoir and operational know-how – but likely the most important factor is the cleanliness of the reservoir.
Before rushing to judgment, we do have to acknowledge that the Long Lake project has experienced numerous surface related issues. Furthermore, we are using month 5 data (because that is the lowest common denominator across all 10 projects) which is early in the SAGD process – but at this point it is the best data we have. Given the results to date, we are watching closely to see if the Long Lake project will turn the corner and begin to improve markedly in the coming months. In the meantime, we are sitting on the sidelines and waiting to see what happens.

One final point – which is worth noting again – regarding this analysis is that the theoretical rates and actual rates are impacted by numerous factors that we simply have not even considered in our analysis. So the bottom line here is that our analysis is cursory at best – non-ideal reservoirs, top water, bottom water, top gas and differences in operating parameters were not accounted for. Nevertheless, we still believe that our analysis is useful in highlighting which projects are on track and which are not.
Methodology

In our quest to put together a report for contrasting and comparing SAGD projects, we quickly realized that significant processing of the raw data would be required to extract meaningful information. In a nutshell, we’ve built an application that takes the raw production and injection data, processes it and then creates a series of charts – with a number of assumptions and adjustments along the way. In this section, we detail our methodology from the raw data to the charts included in this report.

- The raw production and injection data used to generate our reports came from GeoScout™ – as of the report date, the most recent data is for June 2008;
- Each SAGD production well was matched with its corresponding injection well using GeoScout™ data;
- The raw data was pulled for each SAGD well pair and then aggregated by project by our application;
- In generating the reports, it became necessary to implement the concept of a cutoff – a value below which the data was ignored. There were a number of instances where the production from a well was in the 10 to 20 bbl/d range – for several months before the ‘real’ SAGD ramp-up began. These lower rates are indicative of wells that are not in SAGD production mode but rather in a steaming or pre-SAGD phase. In an effort to normalize the data between the various well pairs, the data we present in this report uses cutoffs. With the cutoff enabled, we ignore all production data until production reaches our specified cutoff value and then set that particular month as the ‘First Month of Production’;
- In generating the statistical grouping charts, we ignore wells with zero production;
- In our report, we present the data using a 25 bbl/d cutoff and a 50 bbl/d cutoff but have the ability to run the charts with any user specified cutoff;
- We’ve attempted to ignore wells that are deemed in-fill wells (i.e. wells that are scavenging heat from previous steam injection);
As we’ve noted, there are a number of parameters that influence the rates from SAGD wells – most notably – the pay thickness and well length (in reality there are several others as well such as permeability, porosity, steam temperature, viscosity, oil saturation and reservoir homogeneity). In theory, SAGD well pair production rates are proportional to horizontal well length and reservoir thickness (as discussed previously). With respect to well length, a well that is twice as long should have twice the flow rate, but there is a practical limit after which this relationship breaks down. For reservoir thickness, a well with double the reservoir thickness should have $1.414 (\sqrt{2})$ times the flow rate. We have not made any adjustments to the raw data to account for differing lengths or thicknesses – we have simply used the raw data disclosed by the company;

- In calculating instantaneous and cumulative steam-oil-ratios, we have used steam injection from both the production and the injection wells.

There are 3 main charts that we’ve created in our application:

1. Normalized SAGD well performance by statistical grouping (Exhibit 17 to Exhibit 28)
2. Normalized SAGD well performance by project (Exhibit 29 to Exhibit 52)
3. SAGD project performance (Exhibit 53 to Exhibit 63)

Each of the charts is described below to provide readers with an understanding of the data being presented. We have included a section in Appendix A for specific terms and definitions.
Exhibit 14: Normalized SAGD well performance by statistical grouping

This set of charts looks at all SAGD wells across all projects and normalizes the data based on time. The data is then sorted by production and production month and statistical groupings are created to show how a top, mid or bottom tier SAGD well performs from its first month on production to production month 18. The same analysis is performed for instantaneous SOR. The data in this chart is subject to an RJ defined cutoff parameter.

1: We present the data using calendar day and producing day. This accounts for different production levels attributable to downtime.

2: These numbers represent the number of wells included in analysis for the month. For example, in the top chart 132 wells were used to create the tiers in month 14.

3: We can create rankings based on any month of production (Month 1 to Month 12). We can also create statistical groupings by tier, quartile and decile. Since rankings are based on production rates, what the reader will notice is that the ISOR for the sort month is exaggerated for the first tier/quartile/decile.

Source: Raymond James Ltd., GeoScout
Exhibit 15: Normalized SAGD well performance by project

This chart shows normalized production data by project. Once again this data is subject to the cutoff parameter that we’ve defined. This chart is useful in understanding the ramp profile of the wells for the various projects – and since time is normalized – the chart corrects for the staggered start-up of SAGD wells.

Source: Raymond James Ltd., GeoScout

Exhibit 16: Historical SAGD project performance

This chart shows the raw data by project without adjusting for a cutoff parameter. It shows production volumes, instantaneous steam oil ratios and cumulative steam oil ratios by month (accounting for steam injected from both wells).

Source: Raymond James Ltd., GeoScout
Appendix A: Definitions

Absolute Viscosity
Also called dynamic viscosity, it is a fluid’s resistance to flow (shear stress) at a given temperature.

Calendar Day
The total number of days in a month for which production is averaged over irrespective of whether the well was producing or not (i.e. 30 days for April).

Cumulative SOR (cSOR)
Total steam injected divided by the total bitumen produced since inception.

Decile
Any of the values in a series that divides the distribution of individuals in that series into ten groups of equal frequency.

Local Acceleration due to Gravity
This is the normal acceleration due to gravity. By definition it is equal to 9.80665 m/s².

Instantaneous SOR (iSOR)
The steam oil ratio in a given month (i.e. total steam injected in a particular month divided by total bitumen produced for that same month).

Kinematic Viscosity
The ratio of the absolute viscosity of a liquid to its specific gravity at the temperature at which the viscosity is measured.

Oil Saturation
The percentage of a rock’s porosity that is occupied by oil.

Permeability
The ability, or measurement of a rock's ability, to transmit fluids, typically measured in darcies or millidarcies. Absolute permeability is the measurement of the permeability conducted when a single fluid, or phase, is present in the rock. Effective permeability is the ability to preferentially flow or transmit a particular fluid through a rock when other immiscible fluids are present in the reservoir (for example, effective permeability of gas in a gas-water reservoir).
Porosity
The percentage of pore volume or void space, or that volume within rock that can contain fluids. Porosity can be a relic of deposition (primary porosity, such as space between grains that were not compacted together completely) or can develop through alteration of the rock (secondary porosity, such as when feldspar grains or fossils are preferentially dissolved from sandstones).

Producing Day
Production is averaged over the timeframe when the well was actually producing (i.e. it ignores downtime in the calculation). Production by producing day is always equal to or higher than production by calendar day because production by producing day does not include days where the well was not producing.

Quartile
The division an ordered distribution into four parts, each containing a quarter of the population.

Thermal Conductivity
A property of a material that indicates its ability to conduct heat.

Thermal Diffusivity
The ratio of thermal conductivity to volumetric heat capacity. Substances with high thermal diffusivity rapidly adjust their temperature to that of their surroundings, because they conduct heat quickly in comparison to their thermal 'bulk'.

Tiers
The division an ordered distribution into three parts, each containing one third of the population.
Appendix B: Statistical Grouping of SAGD Well Pair Production and SOR (25 bbl/d Cutoff)

Exhibit 17: All SAGD Well Pairs by Tiers Ranked by Month 3 Production

Normalized SAGD Bitumen Producing Day Rate Versus Time

Normalized SAGD Bitumen Calendar Day Rate Versus Time

Normalized Instantaneous Steam Oil Ratio Versus Time

Source: GeoScout, Raymond James Ltd.
Exhibit 18: All SAGD Well Pairs by Tiers Ranked by Month 6 Production

Normalized SAGD Bitumen Producing Day Rate Versus Time

Normalized SAGD Bitumen Calendar Day Rate Versus Time

Normalized Instantaneous Steam Oil Ratio Versus Time

Source: GeoScout, Raymond James Ltd.
Exhibit 19: All SAGD Well Pairs by Quartiles Ranked by Month 3 Production

Normalized SAGD Bitumen Producing Day Rate Versus Time

Normalized SAGD Bitumen Calendar Day Rate Versus Time

Normalized Instantaneous Steam Oil Ratio Versus Time

Source: GeoScout, Raymond James Ltd.
Exhibit 20: All SAGD Well Pairs by Quartiles Ranked by Month 6 Production

Normalized SAGD Bitumen Producing Day Rate Versus Time

Normalized SAGD Bitumen Calendar Day Rate Versus Time

Normalized Instantaneous Steam Oil Ratio Versus Time

Source: GeoScout, Raymond James Ltd.
Exhibit 21: All SAGD Well Pairs by Deciles Ranked by Month 3 Production

Normalized SAGD Bitumen Producing Day Rate Versus Time

Normalized SAGD Bitumen Calendar Day Rate Versus Time

Normalized Instantaneous Steam Oil Ratio Versus Time

Source: GeoScout, Raymond James Ltd.
Exhibit 22: All SAGD Well Pairs by Deciles Ranked by Month 6 Production

**Normalized SAGD Bitumen Producing Day Rate Versus Time**

**Normalized SAGD Bitumen Calendar Day Rate Versus Time**

**Normalized Instantaneous Steam Oil Ratio Versus Time**

Source: GeoScout, Raymond James Ltd.
Appendix C: Statistical Grouping of SAGD Well Pair Production and SOR (50 bbl/d Cutoff)

Exhibit 23: All SAGD Well Pairs by Tiers Ranked by Month 3 Production

Normalized SAGD Bitumen Producing Day Rate Versus Time

Normalized SAGD Bitumen Calendar Day Rate Versus Time

Normalized Instantaneous Steam Oil Ratio Versus Time

Source: GeoScout, Raymond James Ltd.
Exhibit 24: All SAGD Well Pairs by Tiers Ranked by Month 6 Production

Normalized SAGD Bitumen Producing Day Rate Versus Time

Normalized SAGD Bitumen Calendar Day Rate Versus Time

Normalized Instantaneous Steam Oil Ratio Versus Time

Source: GeoScout, Raymond James Ltd.
Exhibit 25: All SAGD Well Pairs by Quartiles Ranked by Month 3 Production

Normalized SAGD Bitumen Producing Day Rate Versus Time

Normalized SAGD Bitumen Calendar Day Rate Versus Time

Normalized Instantaneous Steam Oil Ratio Versus Time

Source: GeoScout, Raymond James Ltd.
Exhibit 26: All SAGD Well Pairs by Quartiles Ranked by Month 6 Production

Normalized SAGD Bitumen Producing Day Rate Versus Time

Normalized SAGD Bitumen Calendar Day Rate Versus Time

Normalized Instantaneous Steam Oil Ratio Versus Time

Source: GeoScout, Raymond James Ltd.
Exhibit 27: All SAGD Well Pairs by Deciles Ranked by Month 3 Production

Normalized SAGD Bitumen Producing Day Rate Versus Time

Normalized SAGD Bitumen Calendar Day Rate Versus Time

Normalized Instantaneous Steam Oil Ratio Versus Time

Source: GeoScout, Raymond James Ltd.
Exhibit 28: All SAGD Well Pairs by Deciles Ranked by Month 6 Production

Normalized SAGD Bitumen Producing Day Rate Versus Time

Normalized SAGD Bitumen Calendar Day Rate Versus Time

Normalized Instantaneous Steam Oil Ratio Versus Time

Source: GeoScout, Raymond James Ltd.
Appendix D: Normalized Production and SOR by Project (25 bbl/d Cut-off)

Exhibit 29: All SAGD Wells Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.

Exhibit 30: Connacher Great Divide Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.
Exhibit 31: ConocoPhillips Surmont Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.

Exhibit 32: Devon Jackfish Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.
Exhibit 33: Encana Christina Lake Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.

Exhibit 34: Encana Foster Creek Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.
Exhibit 35: JACOS Hangingstone Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.

Exhibit 36: Nexen/OPTI Long Lake Pilot Production and iSOR

Source: GeoScout, Raymond James Ltd.
Exhibit 37: Nexen/OPTI Long Lake Commercial Production and iSOR

Source: GeoScout, Raymond James Ltd.

Exhibit 38: Petro-Canada MacKay River Production and iSOR

Source: GeoScout, Raymond James Ltd.
Exhibit 39: Suncor Firebag Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.

Exhibit 40: Total Joslyn Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.
Appendix E: Normalized Production and SOR by Project (50 bbl/d Cut-off)

Exhibit 41: All SAGD Wells Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.

Exhibit 42: Connacher Great Divide Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.
Exhibit 43: ConocoPhillips Surmont Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.

Exhibit 44: Devon Jackfish Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.
Exhibit 45: Encana Christina Lake Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.

Exhibit 46: Encana Foster Creek Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.
Exhibit 47: JACOS Hangingstone Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.

Exhibit 48: Nexen/OPTI Long Lake Pilot Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.
Exhibit 49: Nexen/OPTI Long Lake Commercial Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.

Exhibit 50: Petro-Canada MacKay River Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.
Exhibit 51: Suncor Firebag Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.

Exhibit 52: Total Joslyn Normalized Production and iSOR

Source: GeoScout, Raymond James Ltd.
Appendix F: Historical SAGD Production and SOR by Project

Exhibit 53: Connacher Great Divide Production and SOR

* The company reported 7,000 bbl/d average production for July and 7,400 bbl/d for August

Source: GeoScout, Raymond James Ltd.

Exhibit 54: ConocoPhilips Surmont Production and SOR

Source: GeoScout, Raymond James Ltd.
Exhibit 55: Devon Jackfish Production and SOR

Source: GeoScout, Raymond James Ltd.

Exhibit 56: Encana Christina Lake Production and SOR

Source: GeoScout, Raymond James Ltd.
Exhibit 57: Encana Foster Creek Production and SOR

Source: GeoScout, Raymond James Ltd.

Exhibit 58: JACOS Hangingstone Production and SOR

Source: GeoScout, Raymond James Ltd.
Exhibit 59: Nexen/OPTI Long Lake Pilot Production and SOR

Source: GeoScout, Raymond James Ltd.

Exhibit 60: Nexen/OPTI Long Lake Commercial Production and SOR

* The company reported production of 7,200 bbl/d in June, 8,400 bbl/d in July and 11,600 bbl/d in August.

Source: GeoScout, Raymond James Ltd.
Exhibit 61: Petro-Canada MacKay River Production and SOR

Source: GeoScout, Raymond James Ltd.

Exhibit 62: Suncor Firebag Production and SOR

Source: GeoScout, Raymond James Ltd.
Exhibit 63: Total Joslyn Production and SOR

Source: GeoScout, Raymond James Ltd.
### Appendix G: Oil Sands Comp Tables

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</tbody>
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*Note: Data for UTS recoverable bitumen due from Conoco-As are included in our NAV summary.

**UTS (Lease 311 only) recoverable bitumen assume 80% recovery factor.

***Recoverable figure is SCO barrels, SU and COS.UN do not make a recoverable bitumen figure available.

****Rating System: 1- STRONG BUY; 2- OUTPERFORM; 3- MARKET PERFORM; 4- UNDERPERFORM

*****Na is abbreviated for not applicable

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Source: Raymond James Ltd.
Risks

Some of the specific risk factors that pertain to these companies over the next 6 to 12 months include: 1) Operational risks, including asset reliability risks at oil sands projects in Northern Alberta and reservoir performance risks for in-situ projects; 2) Project execution risks, especially related to large-scale oil sands projects, including the availability and cost of materials, equipment and qualified personnel; 3) The impact of general economic, business and market conditions on the company’s ability to finance its expansions; 4) Infrastructure and labour availability in the Fort McMurray area where many large scale projects are being undertaken; impact of labour productivity on project costs and deadlines; 5) Increased dependence on capital-intensive oil sands business may require companies to forego investment opportunities in other segments of its operations; 6) Marketing risks, including disruptions in supply and market accessibility; commodity price volatility and credit risk; and volatility of downstream margins; 7) Environmental risks, including costs of new equipment and associated construction costs for maintaining environmental integrity; 8) Regulatory risks with regard to expansions of the oil sands operations; 9) Interest rate risk for levered companies and 12) Exchange rate risk.
Analyst Certification

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