Subsurface Agenda

1. Background
2. Geology
3. Drilling and Completions
4. Artificial Lift
5. Well Instrumentation
6. 4D Seismic
7. Scheme Performance
8. Future Plans
Background – Thermal Approval

- Approval No. 11377 for a thermal in-situ scheme consisting of a single well HCSS (horizontal cyclic steam stimulation) was received on November 10, 2009
- Approval No. 11377A was received on August 31, 2010 for a revised bottomhole location for the pilot well
- Approval No. 11377B was received on April 20, 2012 to extend the approval expiry to November 30, 2016
Background – Pilot Objectives

- A single HCSS well in the Bluesky Formation to evaluate thermal development in the area

- Inter-well spacing of 75m with respect to the thermal well and the offsetting primary wells, and a well length of 1,200m

- 80% quality steam injected at the heel of the well, not exceeding maximum bottomhole pressure of 10.5MPa
1. Background

2. **Geology**

3. Drilling and Completions

4. Artificial Lift

5. Well Instrumentation

6. 4D Seismic

7. Scheme Performance

8. Future Plans
Geology – Bluesky Formation Overview

- Series of north/south oriented, stacked distributary channels that have incised into the surrounding sand dominated tidal flat sediments
- Fine to medium grained litharenite
- Average depth is 650m TVD
- Thickness up to 24m
- Porosities from 24% to 33% (Avg 28%)
- Permeability from 50 to 5,500mD
- Oil Saturation from 40% to 85% (Avg 79%)
- API Gravities of 8.7 to 9.8 API at 15.6°C
- Viscosities from 8,300 – 26,000 cSt at 20°C
Geology – Thermal Pilot Location

- Pilot HCSS well
  - 105/16-05-082-15W5

- Three vertical observation wells
  - 103/13-05-082-15W5
  - 102/15-05-082-15W5
  - 106/16-05-082-15W5

- One deviated observation well
  - 107/16-05-082-15W5
Geology – Well Data

Cored Wells

CSS Thermal Well
Geology – Base Bluesky Structure
Geology – Net Pay Map

PennWest Exploration

Bluesky Net Pay (m)
(Phi >24%, Res >20ohmm)

Licensed to: Penn West Petroleum

By: JW  Date: 2011/11/02
Scale: 1:20000  Project: Seal Regional O
Geology – Core Photos

PENN WEST PETROLEUM LTD.
PENN WEST 103 SEAL 03/13-05-082-15 W5M/0
Core #1
Top 664.38 m
Bottom 668.79 m

PENN WEST ENERGY TRUST
PENN WEST 106 SEAL 06/16-05-082-15 W5M/0
Core #2
Top 659.59 m
Bottom 663.59 m
Penn West currently uses petrophysical cutoffs of 24% porosity and 50% water saturation to determine pay within the Bluesky in our thermal project areas at Seal Main and Harmon Valley South. These cutoffs closely conform to the 6 wt% bitumen cutoff that the AER prefers for oil sands projects. Penn West also uses an 8m pay thickness cutoff which we believe to be a generalized economic threshold for our CSS projects (as long as the above stated saturation and porosity cutoffs are met or exceeded).

Within the estimated drainage area of the pilot well in Seal Main, the entire Bluesky sand section meets or exceeds these three cutoffs, with the exception of the lean zone at the base of the reservoir, which falls below the minimum saturation cutoff of 50%. Average weight% bitumen within the lean zone is approximately 4%. For this reason, the lean zone is not included in our OBIP calculation.

The Net Pay map above shows that 20.3 ha was used for revised OBIP calculation. The 26.3 ha area shown originally on the average reservoir properties slide was for a longer thermal pilot horizontal well Penn West originally planned. Average reservoir properties slide has been revised to correct for this oversight.
<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net pay (m)</td>
<td>18.6</td>
</tr>
<tr>
<td>Area (ha)</td>
<td>20.3</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>27</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>21.6</td>
</tr>
<tr>
<td>Viscosity (cSt at 20°C)</td>
<td>16,950</td>
</tr>
<tr>
<td>Permeability (mD)</td>
<td>2,615</td>
</tr>
<tr>
<td>Formation Temperature (°C)</td>
<td>20</td>
</tr>
<tr>
<td>Original Formation Pressure (kPa)</td>
<td>4,670</td>
</tr>
<tr>
<td>Formation Volume Factor</td>
<td>1.02</td>
</tr>
<tr>
<td>OBIP (e^3m^3)*</td>
<td>782</td>
</tr>
</tbody>
</table>

*Based on the area immediately around the pilot well bounded by the adjacent primary wells*
Geology – 3D Seismic

- **3D Main**
  - Shot in February 2008
  - Processed in February 2008

- **3D GK-SLA**
  - Shot in January 1999
  - Reprocessed in July 2009
In 2009, a mini-frac test was conducted in 100/03-32-082-15W5

When Penn West re-evaluated the data in 2011, it deemed the test data as inconclusive

Penn West performed two new MDT mini-frac tests to determine the closure stress in the Wilrich and Bluesky Formations:
- At 05-29-082-15W5 crossing the fault in Section 29
- At 15-08-082-15W5 away from the fault

After processing the data, the following gradients are calculated:

<table>
<thead>
<tr>
<th>Stress Gradient Source</th>
<th>Stress Gradient kPa/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overburden stress (from density log)</td>
<td>21.3</td>
</tr>
<tr>
<td>Overburden stress (from minfrac) in Wilrich</td>
<td>21.4</td>
</tr>
<tr>
<td>Minimum horizontal stress in Wilrich</td>
<td>22.3</td>
</tr>
<tr>
<td>Minimum horizontal stress in Bluesky</td>
<td>18.6</td>
</tr>
</tbody>
</table>

The MOP granted by the AER for the pilot is 10.5MPa (16.5 kPa / m)
Subsurface Agenda

1. Background
2. Geology
3. Drilling and Completions
4. Artificial Lift
5. Well Instrumentation
6. 4D Seismic
7. Scheme Performance
8. Future Plans
Drilling and Completions – Wellbore Design

- 60.3mm guide string run to the toe of the well
- 44.5mm coil tubing fiber optic instrumentation line
- 114.3mm injection and production string landed at the heel of the well
Subsurface Agenda

1. Background
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Artificial Lift

- For the first two production cycles, a 3.25” insert rod pump was installed
  - A VFD was installed to control pump speed and efficiently maximize production rates
  - A 1280-365-240 pumpjack capable of moving 216 m³/d total fluids was installed

- For the third production cycle, a 220 MET 1000 PCP was installed
  - Rated for temperatures to 350°C
  - Good success to date, currently still running same pump in fourth production cycle
Subsurface Agenda

1. Background
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8. Future Plans
- Fiber optic DTS was installed in the pilot well to monitor temperature from wellhead to the toe of the well at 2,036m MD

- An automated dual bubble tube $\text{N}_2$ system was installed at the heel and toe for accurate pressure data measurement

- The system is designed with the ability to perform a $\text{N}_2$ purge from surface
Three observation wells were drilled at a lateral distance of 5.3m to 9.9m from the horizontal wellbore, at the heel, midpoint and toe.

Real-time pressure and temperature monitoring accomplished via fiber optics and single point pressure gauges spaced in the reservoir.

Deviated observation well at the toe of the horizontal wellbore equipped with casing conveyed pressure gauges.
1. Background

2. Geology

3. Drilling and Completions

4. Artificial Lift

5. Well Instrumentation

6. 4D Seismic

7. Scheme Performance

8. Future Plans
No current plans to conduct 4D seismic at Seal Main Pilot Project
Subsurface Agenda

1. Background
2. Geology
3. Drilling and Completions
4. Artificial Lift
5. Well Instrumentation
6. 4D Seismic
7. Scheme Performance
8. Future Plans
## Scheme Performance – Cumulative Volumes

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Steam (m³)</th>
<th>Oil (m³)</th>
<th>Water (m³)</th>
<th>Gas (e³m³)</th>
<th>CSOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>16,749</td>
<td>9,304</td>
<td>3,531</td>
<td>58</td>
<td>1.8</td>
</tr>
<tr>
<td>2nd</td>
<td>17,699</td>
<td>16,277</td>
<td>11,992</td>
<td>744</td>
<td>1.35</td>
</tr>
<tr>
<td>3rd</td>
<td>23,872</td>
<td>12,615</td>
<td>15,151</td>
<td>1,438</td>
<td>1.53</td>
</tr>
<tr>
<td>4th</td>
<td>28,616</td>
<td>7,142 **</td>
<td>15,546 **</td>
<td>898 **</td>
<td>1.92 **</td>
</tr>
</tbody>
</table>

**Construction of new OTSG and water treatment package**

**Production as of June 30th**
Scheme Performance – Steam Cycle 4

Steam Cycle #3

Steam Cycle #4
Scheme Performance – Production Rates

![Chart showing Scheme Performance and Production Rates](chart.png)
Scheme Performance – Monthly Injection and Water Production
Scheme Performance – Observation Wells 103/13-05-082-15W5

Graph showing pressure (kPa) over time from July 2011 to July 2016, with data points at 651 m, 666 m, and 673 m. The graph displays multiple cycles, with labels for End Prod Cycle 1, Start Steam Cycle 2, End Steam Cycle 2, End Prod Cycle 2, Start Steam Cycle 3, End Steam Cycle 3, and Mid Prod Cycle 3. A note indicates that data for the last cycle is unable to be retrieved.

The diagram also includes a linear scale for TVD (m) from 650 to 680, with depth markers at 15, 25, 35, 45, and 55. Additionally, there is a horizontal line indicating 103/13-05 with coordinates 9.9m, 102/15-05 with 5.3m, and 106/16-05 with 8.9m.
Scheme Performance – Observation Wells
102/15-05-082-15W5

Unable to retrieve data for last cycle
Scheme Performance – Observation Wells 106/16-05-082-15W5

Unable to retrieve data from last cycle

---

PennWest
Scheme Performance – Recovery Factor

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle 1 Production (m$^3$)</td>
<td>9,304</td>
</tr>
<tr>
<td>Cycle 2 Production (m$^3$)</td>
<td>16,277</td>
</tr>
<tr>
<td>Cycle 3 Production to Date (m$^3$)</td>
<td>12,615</td>
</tr>
<tr>
<td>Cycle 3 Production to Date (m$^3$)</td>
<td>4,232</td>
</tr>
<tr>
<td><strong>Total Production to Date (m$^3$)</strong></td>
<td><strong>46,220</strong>*</td>
</tr>
<tr>
<td>OBIP (m$^3$)</td>
<td>782,000</td>
</tr>
<tr>
<td>Current Recovery (%)</td>
<td>5.9%</td>
</tr>
<tr>
<td>Estimated Ultimate Recovery (%)</td>
<td>12%</td>
</tr>
</tbody>
</table>

* Only Thermal production included – as of June 30$^{th}$, 2016
Subsurface Agenda

1. Background
2. Geology
3. Drilling and Completions
4. Artificial Lift
5. Well Instrumentation
6. 4D Seismic
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Future Plans

- Currently progressing Seal Main Commercial Application

- Evaluated pilot project response and economics in light of current market conditions and decision made to discontinue the pilot program – suspension underway.
Surface Agenda

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3. Water Use
4. Water Treatment
5. Water and Waste Disposal
6. Sulphur Production
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8. Compliance
9. Non-Compliance
10. Future Plans
Facilities – Process Flow Diagram

<table>
<thead>
<tr>
<th>Facilities</th>
<th>Process Flow Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>SALINE SOURCE WATER FROM WELL</td>
<td>TO GAS TREATING LINE</td>
</tr>
<tr>
<td>RAW WATER</td>
<td>WATER TREATMENT PLANT</td>
</tr>
<tr>
<td>SORT WATER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>THERMAL WELL</td>
</tr>
<tr>
<td></td>
<td>HEAT EXCHANGER</td>
</tr>
<tr>
<td></td>
<td>GAS COOLER</td>
</tr>
<tr>
<td></td>
<td>COMpressor</td>
</tr>
<tr>
<td></td>
<td>GAS SEPARATOR</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SALES OIL</td>
</tr>
<tr>
<td></td>
<td>PRODUCTION EMULSION</td>
</tr>
<tr>
<td></td>
<td>PRODUCTION EMULSION</td>
</tr>
<tr>
<td></td>
<td>PRODUCTION EMULSION</td>
</tr>
<tr>
<td></td>
<td>FLARE KNOCK OUT</td>
</tr>
<tr>
<td></td>
<td>FLARE STACK</td>
</tr>
</tbody>
</table>

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Facilities – Water Treatment System
Facilities - Modifications

- No modifications made over last year
Facility Performance

- **Bitumen Treatment:**
  - Off-spec oil trucked to Tervita oil cleaning facility
  - Facility can produce sales spec oil

- **Steam Generation:**
  - OTSG capacity 7.33 MW and 80% steam quality
  - OTSG blower was oversized as the unit was built for operation in a warmer climate, Air-Fuel ratio adjusted accordingly
  - OTSG installed outside and exposure to low temperatures created a variety of operational issues. Currently steam in summer months to eliminate these operational issues.
Facility Performance

- Other Equipment:
  - Heat exchanger did not perform as designed due to corrosion, downtime required to clean and repair. No concerns since bundle replaced (original issue related to improper suspension of vessel)

- Many systems have no redundancy due to design as pilot facility

- Casing gas compressor in operation
Surface Agenda

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Measurement and Reporting

• Oil production volumes are estimated on lease by tank gauge and measured at the sales point by coriolis meter
• Gas production is measured on lease by orifice meters
• Steam injection volumes are measured by orifice meter
• Water flowing to injection facility from source water well is measured by turbine meter at the wellhead
• Fuel gas supply from 13-08-082-15W5 facility is measured by orifice meter
• As Seal Main is a single well pilot, no proration of injection or production is required
• Reporting as per Directive 017 requirements
Surface Agenda

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Water Use

- Continued to use source water from the well: 1F1/01-07-082-15W5
- A total of 29,070 m3 of source water was produced over the past year for one steam cycle.

<table>
<thead>
<tr>
<th>Month</th>
<th>Source Water (m3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 2015</td>
<td>0</td>
</tr>
<tr>
<td>Feb 2015</td>
<td>0</td>
</tr>
<tr>
<td>Mar 2015</td>
<td>0</td>
</tr>
<tr>
<td>Apr 2015</td>
<td>0</td>
</tr>
<tr>
<td>May 2015</td>
<td>4988</td>
</tr>
<tr>
<td>Jun 2015</td>
<td>7272</td>
</tr>
<tr>
<td>Jul 2015</td>
<td>5604</td>
</tr>
<tr>
<td>Aug 2015</td>
<td>7725</td>
</tr>
<tr>
<td>Sep 2015</td>
<td>3482</td>
</tr>
<tr>
<td>Oct 2015</td>
<td>0</td>
</tr>
<tr>
<td>Nov 2015</td>
<td>0</td>
</tr>
<tr>
<td>Dec 2015</td>
<td>0</td>
</tr>
<tr>
<td>Jan 2016</td>
<td>0</td>
</tr>
<tr>
<td>Feb 2016</td>
<td>0</td>
</tr>
<tr>
<td>Mar 2016</td>
<td>0</td>
</tr>
<tr>
<td>Apr 2016</td>
<td>0</td>
</tr>
<tr>
<td>May 2016</td>
<td>0</td>
</tr>
<tr>
<td>Jun 2016</td>
<td>0</td>
</tr>
</tbody>
</table>
Surface Agenda

1. Facilities
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3. Water Use
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5. Water and Waste Disposal
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7. Environmental
8. Compliance
9. Non-Compliance
10. Future Plans
Water Treatment

- Package designed to treat saline water and produce Boiler Feed Water (BFW) quality suitable for a 7.33 MW OTSG

- The system is based on conventional softening technology (Depth Filters, Strong Acid Cation (SAC) & Weak Acid Cation (WAC) Systems) and included dual trains for 100% redundancy
Surface Agenda

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10. Future Plans
Waste water from the pilot and 13-08-082-15W5 primary pad will continue to be injected into a Penn West disposal well located at 02-07-082-15W5 (Class II Disposal Well – Approval No. 10213 B)
Water Disposal Location
100/02-07-082-15W5

Thermal Pilot Location
105/16-05-082-15W5
Surface Agenda

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6. Sulphur Production
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9. Non-Compliance
10. Future Plans
Sulphur Production

- EPEA Approval for Seal Main Pilot facility does not require real-time Sulphur Dioxide (SO$_2$) emission monitoring
- Site is equipped with passive air monitoring for SO$_2$, nitrogen dioxide (NO$_2$) and hydrogen sulphide (H$_2$S) emissions
- Reports submitted monthly
- No exceedances on passive monitors for 2015.
## SO\textsubscript{2} Emissions Passive Monitoring

<table>
<thead>
<tr>
<th>2015</th>
<th>Average Reading (ppb)</th>
<th>Peak Reading (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>February</td>
<td>0.7</td>
<td>0.9</td>
</tr>
<tr>
<td>March</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>April</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>May</td>
<td>0.6</td>
<td>1.1</td>
</tr>
<tr>
<td>June</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>July</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>August</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>September</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>October</td>
<td>1.0</td>
<td>1.1</td>
</tr>
<tr>
<td>November</td>
<td>1.2</td>
<td>1.5</td>
</tr>
<tr>
<td>December</td>
<td>1.4</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Surface Agenda

1. Facilities
2. Measurement and Reporting
3. Water Use
4. Water Treatment
5. Water and Waste Disposal
6. Sulphur Production
7. **Environmental**
8. Compliance
9. Non-Compliance
10. Future Plans
Environmental

- EPEA Approval No. 308922-00-00 effective May 21, 2013

- Monitoring ongoing as per EPEA Approval conditions:
  - Air Emissions
  - Industrial Wastewater and Industrial Runoff
  - Groundwater
  - Soil Monitoring

- Participation in the Three Creeks Working
Surface Agenda

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7. Environmental
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10. Future Plans
Statement of Compliance

- To the best of our knowledge, Penn West is in compliance with all the requirements and conditions of Commercial Scheme Approval No. 11377B and all other approvals related to the Seal Main HCSS Pilot.
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1. Facilities
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No disclosures for 2015
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9. Non-Compliance
10. Future Plans
Future Plans

- No specific surface related plans
- Currently progressing Seal Main Commercial Application
- Evaluated pilot project response and economics in light of current market conditions and decision made to discontinue the pilot program – suspension underway.