PennWest

Harmon Valley South HCSS Pilot Subsurface Review
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 – Primary Development

- Primary scheme development began in 2004 under Approval No. 11060.

- The Harmon Valley South (HVS) Primary field has 50 primary wells operating on 14 pad sites. There is an ongoing drilling program in the area with 18 primary wells to be drilled over the next 6 months.
Background – Pilot Objectives

- A three well HCSS project in the Bluesky Formation
- 80% quality steam injected at the heel of the well
- Inject steam at a target rate of 500 m$^3$/d
- Original intent was to evaluate technology in various reservoir conditions:
  - Well 100/07-36: Tighter, more viscous conditions
  - Well 102/15-06: Higher water saturation
  - Well 103/14-06: High permeability
- Actual - drilled wells resulted in fairly similar conditions
<table>
<thead>
<tr>
<th>Approval</th>
<th>Date</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Approval 11895</td>
<td>21-Sep-12</td>
<td>Original Pilot Approval</td>
</tr>
<tr>
<td>Approval 11895A</td>
<td>28-Nov-12</td>
<td>Revised bottomhole location for pilot wells</td>
</tr>
<tr>
<td>AUC Approval for Pilot Power Plant</td>
<td>3-Oct-12</td>
<td>AUC Approval received</td>
</tr>
<tr>
<td>Approval 11895B</td>
<td>3-Mar-14</td>
<td>Increase maximum bottomhole operating pressure from 14,500 kPag to 21,500 kPag and light hydrocarbon circulation prior to steam injection</td>
</tr>
<tr>
<td>Approval 11895C</td>
<td>11-Aug-14</td>
<td>Increase steam injection volume above 14,500 kPag from 2,500 m³ to 12,500 m³ and reduction in maximum bottomhole injection pressure from 21,500 kPag to 20,000 kPag</td>
</tr>
</tbody>
</table>
Subsurface Agenda

1. Background
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Geology – Bluesky Formation Overview

- Series of north/south oriented, stacked tidal distributary channels
- Fine to medium grained litharenite
- Average depth is 675m TVD
- Thickness up to 26m
- Porosities from 24% to 30% (Avg 25%)
- Permeability from 450 to 4,200 mD
- Oil Saturation from 55% to 85% (Avg 76%)
- API Gravities of 8.7 to 9.8 API at 15.6°C
- Viscosities from 11,000 to 300,000 cSt at 20°C
Geology – Thermal Pilot Location

- **Pilot HCSS Wells**
  - 100/07-36-082-18W5
  - 102/15-06-083-17W5
  - 103/14-06-083-17W5

- **Observation Wells**
  - 100/10-06-083-17W5
  - 100/15-06-083-17W5
  - 102/14-06-083-17W5
  - 100/15-36-082-18W5
  - 100/02-06-083-17W5
  - 100/11-06-083-17W5
Geology – 3D Seismic

- **3D-HVS09**
  - Shot in January 2009
  - Processed in January 2009

- **3D-HVS**
  - Shot in March 2008
  - Processed in March 2008
Geology – Bluesky Top Structure Map
Geology – Net Pay Map

PennWest Exploration

Bluesky Net Pay (m)
(Phi>24%, Res>20 ohmm)
Geology – Structural Cross-Section
102/15-06-083-17W5

Wilrich Mkr
Bluesky Pay Top
Getting
Geology – Structural Cross-Section
103/14-06-083-17W5

<table>
<thead>
<tr>
<th>102/14-06-083-17W5/00</th>
<th>100/11-06-083-17W5/00</th>
<th>100/06-06-083-17W5/00</th>
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<tbody>
<tr>
<td>Wilrich Mkr</td>
<td>Wilrich Mkr</td>
<td>Wilrich Mkr</td>
</tr>
<tr>
<td>Bluesky</td>
<td>Bluesky</td>
<td>Bluesky</td>
</tr>
<tr>
<td>Pay Top</td>
<td>Pay Top</td>
<td>Pay Top</td>
</tr>
<tr>
<td>Getting</td>
<td>Getting</td>
<td>Getting</td>
</tr>
</tbody>
</table>

PennWest
Geology - Cored Wells

- Cored Wells
- CSS Thermal Well
Geology – Core Photos

PENN WEST ENERGY INC.
PENN WEST WALRUS 00/10-06-083-17 W5M/0
Core #1
Top 684.09 m
Bottom 688.59 m

52139-11-5270 F02
52140-11-1146
March 14, 2011

PENN WEST ENERGY INC.
PENN WEST WALRUS 00/15-06-083-17 W5M/0
Core #2
Top 685.96 m
Bottom 689.59 m

52139-11-5305 F03
52140-11-1177
March 20, 2011
<table>
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<tr>
<th>Property</th>
<th>Value</th>
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<tr>
<td>Net pay (m)</td>
<td>14.7</td>
</tr>
<tr>
<td>Area (ha)</td>
<td>184</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>27</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>24</td>
</tr>
<tr>
<td>Viscosity (cSt at 20°C)</td>
<td>30,000</td>
</tr>
<tr>
<td>Average Hz Permeability (mD)</td>
<td>1,500</td>
</tr>
<tr>
<td>Formation Temperature (°C)</td>
<td>22</td>
</tr>
<tr>
<td>Original Formation Pressure (kPa)</td>
<td>4,800</td>
</tr>
<tr>
<td>Formation Volume Factor</td>
<td>1.02</td>
</tr>
<tr>
<td>OBIP (e³m³)*</td>
<td>5,441</td>
</tr>
</tbody>
</table>

*Based on the pilot project area
In 2011, a mini-frac test was conducted in 100/03-06-083-17W5

Penn West performed two new MDT mini-frac tests to determine the closure stress in the Wilrich and Bluesky Formations:

- Wilrich Fm depth of 672m MD
- Bluesky Fm depth of 698m MD

After processing the data, the following gradients are calculated:

<table>
<thead>
<tr>
<th>Zone</th>
<th>Depth (m)</th>
<th>Min Stress (kPa)</th>
<th>Gradient (kPa/m)</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wilrich</td>
<td>672</td>
<td>16,000</td>
<td>23.8</td>
<td>horizontal</td>
</tr>
<tr>
<td>Bluesky</td>
<td>698</td>
<td>12,600</td>
<td>18.1</td>
<td>vertical</td>
</tr>
</tbody>
</table>

The MOP granted by the AER for the pilot is 20MPa (29.8 kPa / m)
Subsurface Agenda

1. Background
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8. Future Plans
Drilling and Completions – Wellbore Design

- 60.3mm guide string to the toe
- 38.1mm coil tubing thermocouple instrumentation line inside the guide string
- 114.3mm injection and production string landed at the heel
- Bubble tube strapped to the guide string
Subsurface Agenda

1. Background
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3. Drilling and Completions
4. **Artificial Lift**
5. Well Instrumentation
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8. Future Plans
3.25” insert rod pumps were initially run on all three wells

- 15-06 able to produce consistently through rod pump
- 7-36 has seen shorter run-life’s due to pump plugging
- 14-06 required a PCP to move fluid. A Weatherford 56-1500 Insert PCP run in May 2014 to enable continued production. Had ~ 5 month run-life before failure (down since)
Subsurface Agenda

1. Background
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Well Instrumentation – HCSS Wells

- Multiple thermocouples to monitor temperature from wellhead to the toe of the well (1,600 – 1,800m MD)
- Heel pressure measurement via bubble tube strapped to the 60.3mm guide string
- Toe pressure measurement via bubble tube in instrumentation coil
- Ability to perform $N_2$ purge from surface
Well Instrumentation – Observation Wells

- Five observation wells to measure reservoir response at various locations along the horizontal lengths of the wells
- Real-time pressure and temperature monitoring via thermocouples and single point pressure gauges spaced in the reservoir
- Permanent passive micro-seismic monitoring from 2 observation wells to monitor casing and cap rock integrity
Subsurface Agenda

1. Background
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No current plans to conduct 4D Seismic at HVS
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Cycle #1

Operational issues – Down until next cycle

Cycle #2

Operational issues – Down until next cycle

Cycle #3

Operational issues – Down until next cycle

- Produced Oil
- Produced Water
- Steam Injection
- cSOR
Scheme Performance – 100/07-36-082-18W5

Steam Cycle #1

- Steam Quality (%)
- Steam Rate (m3/day)
- Steam Temperature (oC)
- Steam Pressure (kPa)

Jun 01, 2014 to Jun 15, 2014

Steam Cycle #2

- Steam Quality (%)
- Steam Rate (m3/day)
- Steam Temperature (oC)
- Steam Pressure (kPa)

Apr 01, 2015 to Apr 29, 2015

* Data not reading on current steam cycle #3 – looking into
* Sensor data doesn’t change after July 2015
Stim conducted to try and get more injection away
Scheme Performance – 102/15-06-083-17W5

Steam Cycle #2

Steam Cycle #3

Steam Cycle #4

* Missing data from Steam Cycle #1
Scheme Performance – 102/15-06-083-17W5

100/10-06-083-17W5

100/15-06-083-17W5

- Start Steam Cycle 1
- End Steam Cycle 1
- End Prod Cycle 1
- Start Steam Cycle 2
- End Steam Cycle 2
- End Prod Cycle 2
- Start Steam Cycle 3
- End Steam Cycle 3
- Current Prod Cycle 3

TVD (m)

Temperature (°C)
Producer failed – not repaired. New thermocouple string required.
Scheme Performance –103/14-06-083-17W5

Steam Cycle #1

Steam Rate (m³/day)
Steam Temperature (°C)
Steam Quality (%)

Nov 01, 2013 to May 01, 2014

Steam Cycle #2

Steam Rate (m³/day)
Steam Temperature (°C)
Steam Quality (%)

Dec 01, 2014 to Apr 01, 2015

Steam Quality
Rate (m³/day)
Steam Temperature (°C)
Steam Pressure (kPa)
Scheme Performance – 103/14-06-083-17W5

100/11-06-083-17W5

- Start Steam Cycle 1
- End Steam Cycle 1
- End Prod Cycle 1
- Start Steam Cycle 2
- End Steam Cycle 2
- Current

102/14-06-083-17W5

- Start Steam Cycle 1
- End Steam Cycle 1
- End Prod Cycle 1
- Start Steam Cycle 2
- End Steam Cycle 2
- Current

TVD (m)

Temperature (°C)
Offsetting wells within 1,000 m are thermally compatible (as per map)
No signs of communication between primary and thermal wells
Scheme Performance – Recovery Factor

<table>
<thead>
<tr>
<th>Total Production to Date (m³)</th>
<th>12,451</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBIP, m³</td>
<td>5,441,000</td>
</tr>
<tr>
<td>Current Recovery, %</td>
<td>0.23%</td>
</tr>
<tr>
<td>Estimated Ultimate Recovery, %</td>
<td>3%</td>
</tr>
</tbody>
</table>

- EUR is low due to large defined project area
- Typical recovery would be ~ 5%
Subsurface Agenda

1. Background
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Future Plans

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

1. Facilities
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5. Water and Waste Disposal
6. Sulphur Production
7. Environmental
8. Compliance
9. Non-Compliance
10. Future Plans
Surface Agenda

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10. Future Plans
• Pilot plant facility construction completed in Q4 2013 with the following major equipment:
  • 14.65 MW OTSG
  • Water Treatment Package
  • Water Tank Farm
  • Produced Fluids Tank Farm
  • MCC / Instrument Air Building
  • Diesel and Natural Gas Generators
  • Glycol System
  • HP/LP Flare
  • Three HCSS wells with electrically powered pump jacks
Facilities - Modifications

- Drilled one horizontal source water well (14-25-082-18W5) and one vertical source water well (16-36-082-18W5) and connected to the facility via pipeline in Q3 2013

- Constructed 8” 23.4km fuel gas pipeline from TransCanada 05-09-085-17W5 to pilot facility

- Constructed telecommunications infrastructure in Q3 2013 including tower, microwave and radio equipment and UPS
Facility Performance

- **Bitumen Treatment:**
  - Successfully produced sales spec oil with existing facility
  - Each production well is tied into common header/production system

- **Steam Generation:**
  - OTSG capacity 14.65MW and 80% steam quality
  - Design to steam one well at a time
  - Have not run the OTSG consistently at full capacity and steam quality due to injectivity constraints caused by the reservoir conditions
Surface Agenda

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• Updated MARP submitted in August 2014 - Revision 6

• Oil production volumes are estimated on lease by tank gauge and measured at the sales point by coriolis meter

• Gas produced with emulsion and casing gas flows directly to HP Flare and is measured by annubar meter. Solution gas from the produced fluid tanks is directed to LP Flare and measured by ultrasonic meter. Both meters to be updated on new MARP revision.

• Steam injection volumes are measured by differential pressure meter across the flow nozzle

• Water to injection facility from source water wells is measured at each well by turbine meters

• Fuel gas supply from TransCanada Pipeline is measured at facility by vortex meters
Measurement and Reporting

- Test separator equipped with watercut analyzer used to prorate oil volumes to each well
- Wells put into test on rotation
- Reporting as per Directive 017 requirements
1. Facilities
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Water Use

- **Water source wells:** 1F1/16-36-082-18W5 and 100/14-25-082-18W5

- **A Water Act Application was not required** as water is sourced from the Paddy-Cadotte Aquifer of the Peace River Formation, which is approximately 4,700 ppm TDS in this area

<table>
<thead>
<tr>
<th>Month</th>
<th>100/14-25-082-18W5/0 (m3)</th>
<th>1F1/16-36-082-18W5/0 (m3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 2015</td>
<td>1885</td>
<td>21</td>
</tr>
<tr>
<td>Feb 2015</td>
<td>20</td>
<td>4192</td>
</tr>
<tr>
<td>Mar 2015</td>
<td>1241</td>
<td>4400</td>
</tr>
<tr>
<td>Apr 2015</td>
<td>2944</td>
<td>2237</td>
</tr>
<tr>
<td>May 2015</td>
<td>0</td>
<td>401</td>
</tr>
<tr>
<td>Jun 2015</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Jul 2015</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Aug 2015</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sep 2015</td>
<td>485</td>
<td>114</td>
</tr>
<tr>
<td>Oct 2015</td>
<td>1824</td>
<td>4566</td>
</tr>
<tr>
<td>Nov 2015</td>
<td>187</td>
<td>5567</td>
</tr>
<tr>
<td>Dec 2015</td>
<td>302</td>
<td>5505</td>
</tr>
<tr>
<td>Jan 2016</td>
<td>153</td>
<td>2997</td>
</tr>
<tr>
<td>Feb 2016</td>
<td>0</td>
<td>1876</td>
</tr>
<tr>
<td>Mar 2016</td>
<td>190</td>
<td>2117</td>
</tr>
<tr>
<td>Apr 2016</td>
<td>1148</td>
<td>677</td>
</tr>
<tr>
<td>May 2016</td>
<td>1040</td>
<td>183</td>
</tr>
<tr>
<td>Jun 2016</td>
<td>297</td>
<td>41</td>
</tr>
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</table>
Surface Agenda

1. Facilities
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Water Treatment

- Water Treatment Package designed to treat saline water and produce BFW quality suitable for OTSG.
- The source water is treated by a softening system consisting of multimedia filter, primary and secondary WAC softeners, neutralization, regen and dosing systems.
- Water Treatment Package designed with condensed equipment and piping spacing, resulting in limited maintenance access.
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Water and Waste Disposal

- Produced water from the facility is sent for disposal to the Class II Disposal facility at 14-18-082-17W5
- Class II Disposal Scheme Approval No. 11913 for disposal in the Leduc Formation
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Sulphur Production

- EPEA Approval for Harmon Valley South Pilot facility does not require real-time Sulphur Dioxide (SO₂) emission monitoring
- Site is equipped with passive air monitoring for SO₂, nitrogen dioxide (NO₂) and hydrogen sulphide (H₂S) emissions
- Reports submitted monthly
## SO$_2$ Emissions Passive Monitoring

<table>
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<tr>
<th>2015</th>
<th>Average Reading (ppb)</th>
<th>Peak Reading (ppb)</th>
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<tbody>
<tr>
<td>January</td>
<td>0.33</td>
<td>0.4</td>
</tr>
<tr>
<td>February</td>
<td>0.6</td>
<td>0.9</td>
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<tr>
<td>March</td>
<td>0.25</td>
<td>0.3</td>
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<tr>
<td>April</td>
<td>0.15</td>
<td>0.2</td>
</tr>
<tr>
<td>May</td>
<td>0.13</td>
<td>0.2</td>
</tr>
<tr>
<td>June</td>
<td>0.0</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>July</td>
<td>0.4</td>
<td>1.10</td>
</tr>
<tr>
<td>August</td>
<td>0.03</td>
<td>0.1</td>
</tr>
<tr>
<td>September</td>
<td>0.03</td>
<td>0.1</td>
</tr>
<tr>
<td>October</td>
<td>0.18</td>
<td>0.2</td>
</tr>
<tr>
<td>November</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>December</td>
<td>0.28</td>
<td>0.3</td>
</tr>
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Surface Agenda

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Penn West received EPEA Approval No. 303255-00-00 on October 23, 2012

- Additional burners on new emulsion tanks added Q2 2014 operating under Director’s Authorization

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

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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. 11895C and all other approvals related to the Harmon Valley South HCSS Pilot.
Surface Agenda

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Non-Compliance

- Reported one contravention for a damaged NO$_2$ filter resulting in a failed sample.
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Future Plans

- No specific surface related plans
- Evaluated pilot project response and economics in light of current market conditions and decision made to discontinue the pilot program – suspension underway.
Stock Exchange
Toronto:  PWT
New York:  PWE

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