### Outline – Subsurface

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Background
Location of Kirby Project
• Recovery Process: Steam Assisted Gravity Drainage (SAGD)
DIRECTIVE 54 SECTION 3.1.1
SUBSURFACE ISSUES RELATED TO
RESOURCE EVALUATION AND RECOVERY
Geology
Project Area SAGD Pay Isopach
Geology
Project Area Volumetrics

<table>
<thead>
<tr>
<th></th>
<th>Average Pay Thickness (m)</th>
<th>Average Oil Saturation (%)</th>
<th>Average Porosity (%)</th>
<th>OBIP (e³m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kirby Approved Project Area</td>
<td>14.6</td>
<td>78.6</td>
<td>32.8</td>
<td>275,515</td>
</tr>
</tbody>
</table>

OBIP = Original Bitumen In Place
Volumetric calculation = Area within 10m contour \( \times \) SAGD thickness \( \times \) avg. oil saturation \( \times \) avg. porosity
Geology
Stratigraphic Schematic
Geology
Kirby South Type Log
Geology
Kirby South Structural Cross-Section
Geology
Kirby South Development Area

- Recovery Process: Steam Assisted Gravity Drainage (SAGD)
Geology
Kirby South SAGD Pay Isopach
### Geology

**Kirby South Development Area Volumetrics**

<table>
<thead>
<tr>
<th></th>
<th>Average Pay Thickness (m)</th>
<th>Average Oil Saturation (%)</th>
<th>Average Porosity (%)</th>
<th>OBIP (e³m³)</th>
</tr>
</thead>
<tbody>
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<td>76.6</td>
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</tbody>
</table>

**OBIP = Original Bitumen In Place**

**Volumetric calculation** = Area within 10m contour x SAGD thickness x avg. oil saturation x avg. porosity
### Geology

**Kirby South Drainage Area Volumetrics**

<table>
<thead>
<tr>
<th>Drainage Area</th>
<th>Area (m²)</th>
<th>Oil Saturation (%)</th>
<th>Porosity (%)</th>
<th>Pay Thickness (m)</th>
<th>DBIP (e³m³)</th>
</tr>
</thead>
<tbody>
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<td>A</td>
<td>600,017</td>
<td>67.9</td>
<td>33.3</td>
<td>28.9</td>
<td>3,920</td>
</tr>
<tr>
<td>B</td>
<td>669,345</td>
<td>75.4</td>
<td>32.8</td>
<td>23.4</td>
<td>3,880</td>
</tr>
<tr>
<td>C</td>
<td>629,989</td>
<td>78.3</td>
<td>33.4</td>
<td>25.4</td>
<td>4,180</td>
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<td>D</td>
<td>809,000</td>
<td>79.5</td>
<td>33.3</td>
<td>26.3</td>
<td>5,610</td>
</tr>
<tr>
<td>E</td>
<td>502,828</td>
<td>75.5</td>
<td>34.2</td>
<td>23.1</td>
<td>3,000</td>
</tr>
<tr>
<td>F</td>
<td>462,018</td>
<td>77.6</td>
<td>33.3</td>
<td>21.0</td>
<td>2,510</td>
</tr>
<tr>
<td>G</td>
<td>790,445</td>
<td>82.9</td>
<td>33.2</td>
<td>23.9</td>
<td>5,200</td>
</tr>
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</table>

**DBIP = Developable Bitumen In Place**

Volumetric calculation = Area within drainage box boundary and 10m contour × SAGD thickness × avg. oil saturation × avg. porosity
## Geology
### Average Reservoir Properties

<table>
<thead>
<tr>
<th></th>
<th>Initial Reservoir Pressure (kPa)</th>
<th>Initial Bottom Water Pressure (kPa)</th>
<th>Initial Reservoir Temperature (°C)</th>
<th>Average Depth of Reservoir, McMR SAGD Pay Top (mTVD)</th>
<th>Average Pay Thickness (m)</th>
<th>Average Porosity, $\Phi$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kirby South Operating Area</strong></td>
<td>~2600</td>
<td>~2550</td>
<td>13</td>
<td>530</td>
<td>21.9</td>
<td>33.2</td>
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<tr>
<td><strong>Kirby Approved Project Area</strong></td>
<td>~2600</td>
<td>~2550</td>
<td>13</td>
<td>490</td>
<td>14.8</td>
<td>32.7</td>
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<table>
<thead>
<tr>
<th></th>
<th>Average Oil Saturation (%)</th>
<th>Average Water Saturation (%)</th>
<th>Average Horizontal Permeability from OB plugs, $Kh$ (mD)</th>
<th>Average Vertical Permeability from OB plugs, $Kv$ (mD)</th>
<th>$Kv/Kh$ Ratio</th>
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<tr>
<td><strong>Kirby South Operating Area</strong></td>
<td></td>
<td></td>
<td>6410</td>
<td>5260</td>
<td>0.82</td>
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<tr>
<td><strong>Kirby Approved Project Area</strong></td>
<td>78.4</td>
<td>21.6</td>
<td>6560</td>
<td>5510</td>
<td>0.84</td>
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Geology
Kirby South 2017 Special Core Analysis

• No special core analysis performed on Kirby South cores in 2017
Geology
Kirby South SAGD Pay Top Structure
Geology
Kirby South Net Water Sand Isopach
Geology
Kirby North Type Log
Geology
Kirby North Structural Cross Section

A

Cleanwater A Shale
Wabiskaw Wabiskaw B
Wabiskaw D McMurray
Paleozoic Unconformity

A'

Cap Rock Interval
McMurray SAGD Pay
McMurray Basal Water Sand
Geology
Kirby North SAGD Pay Isopach
Geology
Kirby North 2017 Special Core Analysis

• No special core analysis performed on Kirby North cores in 2017
### Geology

**Kirby North Development Area Volumetrics**

<table>
<thead>
<tr>
<th></th>
<th>Average Pay Thickness (m)</th>
<th>Average Oil Saturation (%)</th>
<th>Average Porosity (%)</th>
<th>OBIP (e³m³)</th>
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<tbody>
<tr>
<td>Wabiskaw D Reservoir</td>
<td>15.6</td>
<td>77.5</td>
<td>32.8</td>
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<tr>
<td>McMurray Reservoir</td>
<td>17.8</td>
<td>80.5</td>
<td>32.7</td>
<td>78,887</td>
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<tr>
<td>Kirby North Approved Development Area</td>
<td></td>
<td></td>
<td></td>
<td>122,578</td>
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</table>

OBIP = Original Bitumen In Place

Volumetric calculation = Area within 10m contour x SAGD thickness x avg. oil saturation x avg. porosity
**Geology**  
**Kirby North Drainage Area Volumetrics**

<table>
<thead>
<tr>
<th>Drainage Area</th>
<th>Area (m²)</th>
<th>Oil Saturation (%)</th>
<th>Porosity (%)</th>
<th>Pay Thickness (m)</th>
<th>DBIP (e³m³)</th>
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</thead>
<tbody>
<tr>
<td>KN01</td>
<td>763,120</td>
<td>80.3</td>
<td>32.6</td>
<td>22</td>
<td>4,391</td>
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<td>KN02</td>
<td>757,079</td>
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<td>32.4</td>
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<td>KN03</td>
<td>763,033</td>
<td>84.3</td>
<td>33.1</td>
<td>23.4</td>
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<td>KN04</td>
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<tr>
<td>KN05a</td>
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</table>

DBIP = Developable Bitumen In Place  
Volumetric calculation = Area within drainage box boundary and 10m contour × SAGD thickness × avg. oil saturation × avg. porosity
Geology
Kirby North Wabiskaw D SAGD Pay Top Structure
Geology
Kirby North Wabiskaw D SAGD Pay Base Structure
Geology
Kirby North McMurray SAGD Pay Top Structure
Geology
Kirby North McMurray SAGD Pay Base Structure
Geology
Kirby North McMurray Net Bottom Water Isopach
**Geology**

**3D Seismic Coverage**

Note: 4D seismic was acquired over the Kirby South Pads A-F operational area in 2015
Geology
Cap Rock Interval Isopach Map
Kirby South Formation and Well Placement Overview
Some OCDs and ICDs are shiftable tools in the closed position.

### Completion Summary

- **Production:** majority of wells are equipped with ESPs.
- **Injection:** majority of wells are completed with a heel and toe string
- **Completions** are continually optimized as required by well behavior
  - Outflow control devices are installed to improve steam distribution in the injector
  - Scab liners are installed to enhance toe production in the producer and reduce heel hot spots
  - Inflow control devices are installed to limit single point breakthrough and/or to control to wellbore hydraulics

<table>
<thead>
<tr>
<th>AL Type</th>
<th>Well Count</th>
<th>Lift Capacity (m³/d)</th>
<th>Operating Temperature (DegC)</th>
</tr>
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<tbody>
<tr>
<td>ESP</td>
<td>47</td>
<td>150-1000</td>
<td>&lt;250</td>
</tr>
<tr>
<td>Rod Pump</td>
<td>1</td>
<td>0-300</td>
<td>&lt;250</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Completion Tool</th>
<th>OCD</th>
<th>Scab Liner</th>
<th>ICD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well Count</td>
<td>11</td>
<td>20</td>
<td>11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ICDs</th>
<th>OCDs</th>
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</thead>
<tbody>
<tr>
<td>A5P</td>
<td>C2</td>
</tr>
<tr>
<td>B2</td>
<td>C3</td>
</tr>
<tr>
<td>B3</td>
<td>C4</td>
</tr>
<tr>
<td>B6</td>
<td>D1</td>
</tr>
<tr>
<td>C6</td>
<td>D4</td>
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<td>C7</td>
<td>E2</td>
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<td>D6</td>
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<td>D7</td>
<td>E6</td>
</tr>
<tr>
<td>F4</td>
<td>F1</td>
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<tr>
<td>F5</td>
<td>F2</td>
</tr>
<tr>
<td>F6</td>
<td>F4</td>
</tr>
</tbody>
</table>
Instrumentation Summary

• Blanket gas pressure is used to monitor bottom hole pressures for SAGD injection wells.

• SAGD producers are equipped with fiber optic temperature monitoring (DTS) along the lateral and bubble tubes with surface measurement for heel or toe pressure.

• Observation wells gather multiple temperatures and pressures at various elevations.
Well Schematics
Injection Well (Dual String)

- 339.7 mm (13 3/8") Surface Casing set @ ~ 200.0 mKB
- 244.5 mm (9 5/8") Casing set @ ~ 750.0 mKB
- 88.9 mm (3 1/2") short tubing (Heel) @ ~ 750.0 mKB
- 88.9 mm (3 1/2") Long Tubing (Toe) @ ~ 1700.0 mKB
- Liner Hanger ~20 m behind ICP
- Slotted Liner 177.8 mm (7")
- 600-1000 m Hz sections
Well Schematics
Injection Well (Single String)

339.7 mm (13 3/8") Surface Casing set @ ~ 200.0 mKB

244.5 mm (9 5/8") Casing set @ ~ 750.0 mKB

114.3 mm (4 1/2") Long Tubing @ ~ 1700.0 mKB

Liner Hanger ~20 m behind ICP

2 - 114.3 (4 1/2") Steam Splitters

Slotted Liner 177.8 mm (7")

600-1000 m Hz sections
Well Schematics
Production Well

339.7 mm (13 3/8”) Surface Casing set @ ~ 200.0 mKB

244.5 mm (9 5/8”) Casing set @ ~ 750.0 mKB

88.9 mm (3 ½”) tubing to Pump landed ~50 m behind Liner Hanger

48 mm (1.9”) guide string with DTS fibre instrumentation

600-1000 m Hz sections

177.8 mm (7”) Slotted Liner

Liner Hanger ~20 m behind ICP

Pump
Well Schematics
Production Well (Scab Liner)

339.7 mm (13 3/8") Surface Casing set @ ~ 200.0 mKB

244.5 mm (9 5/8") Casing set @ ~ 750.0 mKB

88.9 mm (3 ½") tubing to Pump landed ~50 m behind Liner Hanger

Liner Hanger ~20 m behind ICP

600-1000 m Hz sections

Pump
Production Port if Required
Slotted Liner 177.8 mm (7’’)

Scab Liner 127 mm (5’’)

48 mm (1.9”) guide string with DTS fibre instrumentation
Well Schematics
Production Well (Tubing Deployed ICDs)

- 48 mm (1.9") guide string with DTS fiber instrumentation
- 88.9 mm (3 ½") tubing to Pump landed ~50 m behind Liner Hanger
- 244.5 mm (9 5/8") Casing set @ ~ 750.0 mKB
- 339.7 mm (13 3/8") Surface Casing set @ ~ 200.0 mKB
- Slotted Liner 177.8 mm (7")
- 600-1000 m Hz sections
- Retrievable Hanger (unless run as patch)
- Pump
- Swellable Packer
- Blank Pipe
- Closed Toe
Well Schematics
Production Well (Liner Deployed ICDs)

- 339.7 mm (13 3/8”) Surface Casing set @ ~ 200.0 mKB
- 244.5 mm (9 5/8”) Casing set @ ~ 750.0 mKB
- 88.9mm (3 ½”) tubing to Pump landed ~50 m behind Liner Hanger
- 48 mm (1.9”) guide string with DTS fiber instrumentation
- Slotted Liner 168.3 mm (6-5/8 “)
- Pump
- ICDs
- Liner Hanger ~20 m behind ICP
- 600-1000 m Hz sections
- Closed Toe
Completion Optimization

• Steam splitter and scab liner installations/removals were selected based on specific opportunities for each well.
  – Steam splitters to target a specific stream distribution in the injector
  – Scab liner installs to encourage toe development and minimize heel temperature variations
  – Scab liner removals to promote heel development after toe fluids are mobile

• ICDs and swellable packers strings were used to limit single point breakthrough and/or to control to wellbore hydraulics
Well Schematics
Observation Well

8 to 20 Temperature measurement points (Basal McMurray to CLWT)

222mm Surface Casing

139.7mm Production Casing

Thermal cement to surface

CLWTR A shale

External casing pressure Transmitter
(Pressure and Temperature sensor)

Mid MCM

Note: Shows a plan for 2011-2013 drilled observation wells, as previous wells don’t have external casing transmitters
Well Schematics
Disposal Well

244.5 mm SURFACE CASING
SET BETWEEN 25 m & 150 m
CEMENTED FULL LENGTH

177.8 mm PRODUCTION CASING
THERMALLY CEMENTED TO SURFACE

88.9 mm TUBING

ANNULUS FILLED WITH
INHIBITED WATER

MCMURRAY TOP

INJECTION ISOLATION PACKER

PERFORATIONS OR SCREEN

MCMURRAY BASAL AQUIFER (~ 550 m)
**Well Schematics**
**13-20 Hz Water Disposal Well**

- **339.7 mm (13 3/8”) Surface Casing set @ ~ 182.0 mKB**
- **244.5 mm (9 5/8”) Casing set @ ~ 730.0 mKB**
- **114.3 mm (4 1/2”) Tubing @ ~ 692.0 mKB with isolation packer set at 690.0**
- **Liner Hanger 20 m behind ICP**
- **Slotted Liner 177.8 mm (7”) Slotted Liner w/perfs**
- **525m Hz section**
Operational Strategy
SAGD

- Injection Strategies
  - Steam down heel and toe string in dual string completion
  - Steam down single long string with steam splitters
- Pump fluid from producer using artificial lift
- Operate wells based on a target steam chamber pressure and target subcool
- Steam chamber pressure is measured by blanket gas pressure in the injector and is controlled by the steam injection rate
  - Target pressure chosen to balance bottom water where it exists, typically 2.5 MPa to 3.5 MPa
Operational Strategy
SAGD Continued

• Subcool is the difference between saturated temperature at producer pressure and the highest temperature along the producer lateral
  • Target chosen to maximize production and minimize live steam production

• To optimize pressure and subcool target, a combination of parameters are monitored including:
  • Water retention in reservoir
  • Chlorides concentration in produced water
  • Steam Oil Ratio (SOR)
  • Bottom hole pressures
Kirby South Drilling Activity Update

• Completed Drilling operations:
  – Re-Drills:
    ▪ B2P
      ▪ Reason for re-drill: loss of sand control
      ▪ Offset from original producer: vertical 0 m, horizontal 5 m North
    ▪ A1P&I
      ▪ Reason for re-drill: Well pair was underperforming and producer had loss of sand control; review of geology indicated re-drilling at higher elevation would improve performance
      ▪ Offsets from original producer and injector: vertical +13 m, horizontal 25 m North
    ▪ D7P
      ▪ Reason for re-drill: First re-drill lost sand control, remediated well with ICD (failed). Well was re-drilled a second time.
      ▪ Offset from original producer: vertical 0 m, horizontal 10 m North (5 m North from Re-drill)
  – New Drills:
    ▪ D9P&I, D10P&I, F8P&I, F9P&I
  – Infills:
    ▪ B3PI
Kirby South
SAGD Well Spacing

<table>
<thead>
<tr>
<th>Pad</th>
<th>Number of Well Pairs</th>
<th>Inter well Spacing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>100</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>100</td>
</tr>
<tr>
<td>D</td>
<td>10</td>
<td>80</td>
</tr>
<tr>
<td>E</td>
<td>6</td>
<td>80</td>
</tr>
<tr>
<td>F</td>
<td>9</td>
<td>50</td>
</tr>
<tr>
<td>G</td>
<td>8</td>
<td>80</td>
</tr>
</tbody>
</table>

- Original well spacing on Pads A, B, & C were 100 m.
- Well spacing was optimized from 100 m to 80 m to achieve improved CDOR, SOR and recovery factors for wells with less bottom water influence.
- F Pad spacing was decreased to 50 m where thicker bottom water exists to lessen the slumping of oil and therefore improve CDOR, SOR and recovery factor.
- Infills are typically drilled half way between wells.
Kirby South Performance Pad Recoveries

<table>
<thead>
<tr>
<th>Pad</th>
<th>DBIP (E3m³)</th>
<th>Ult. Recovery (E3m³)</th>
<th>Cum Oil (E3m³)</th>
<th>RF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3,920</td>
<td>2,352</td>
<td>589</td>
<td>15.0%</td>
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<tr>
<td>B</td>
<td>3,880</td>
<td>2,328</td>
<td>845</td>
<td>21.8%</td>
</tr>
<tr>
<td>C</td>
<td>4,180</td>
<td>2,508</td>
<td>1199</td>
<td>28.7%</td>
</tr>
<tr>
<td>D</td>
<td>5,610</td>
<td>3,306</td>
<td>922</td>
<td>16.4%</td>
</tr>
<tr>
<td>E</td>
<td>3,000</td>
<td>1,800</td>
<td>839</td>
<td>28.0%</td>
</tr>
<tr>
<td>F</td>
<td>2,510</td>
<td>1,506</td>
<td>528</td>
<td>21.0%</td>
</tr>
<tr>
<td>G</td>
<td>5,200</td>
<td>2,718</td>
<td>1015</td>
<td>19.5%</td>
</tr>
<tr>
<td>Total</td>
<td><strong>27,530</strong></td>
<td><strong>16,518</strong></td>
<td><strong>5937</strong></td>
<td><strong>21.5%</strong></td>
</tr>
</tbody>
</table>

Recovery as of August 13, 2017

DBIP = Developable Bitumen In Place
Volumetric calculation = Area within drainage box boundary and 10m contour x SAGD thickness x avg. oil saturation x avg. porosity
Kirby South Performance
Kirby Field Production

Kirby South Production

- Oil Production
- Water Production
- Steam Injection
- Plant Nameplate Oil
- iSOR
- cSOR

- Plant Issues
- Forest Fires
- First SAGD conversion
- Plant T/A
Kirby South Performance Summary

• Reservoir performance is similar to expectations, currently optimizing well-pair conformance.

• Plant turnarounds:
  – October 2015: Evap cleaning and Boiler 2 inspection
  – February 2016: Evap 3 cleaning and Boiler 5 inspection
  – August 2016: Evap 1 cleaning and Boiler 1 inspection
  – May 2017: Major vessels regulatory inspections and maintenance

• Record oil production to date ~7,120 m$^3$/d (44,790 bbl/d)

• 8 wells lost sand control, 8 wells remediated

<table>
<thead>
<tr>
<th>Well</th>
<th>Well</th>
<th>Remediation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A5</td>
<td>1</td>
<td>TD ICD</td>
</tr>
<tr>
<td>B3</td>
<td>2</td>
<td>TD ICD</td>
</tr>
<tr>
<td>C6</td>
<td>3</td>
<td>TD ICD</td>
</tr>
<tr>
<td>C7</td>
<td>4</td>
<td>TD ICD</td>
</tr>
<tr>
<td>D7</td>
<td>5</td>
<td>Re-Drill &amp; LD ICD</td>
</tr>
<tr>
<td>F4</td>
<td>6</td>
<td>TD ICD</td>
</tr>
<tr>
<td>F5</td>
<td>7</td>
<td>TD ICD</td>
</tr>
<tr>
<td>F6</td>
<td>8</td>
<td>TD ICD</td>
</tr>
</tbody>
</table>
Kirby South Performance – Low Recovery
Pad A

- SAGD well pair: 6
- First steam: Oct. 2013
- Inter-well pair spacing: 100 m
- Avg. net pay: 29 m
- Avg. So: 68%
- Avg. porosity: 33%
- Current RF: 15.0%
Kirby South Performance
Pad A Production

Re-drills successfully targeted better reservoir.
Kirby South Performance
High Recovery Pad A Well Pair

Kirby South A6 Production

- Oil Production
- Water Production
- Steam Injection
- ISOR
- cSOR

Best performer

Plant T/A
Kirby South Performance
Low Recovery Pad A Well Pair

Re-drill successful, ramping to targeted performance
Kirby South Performance
Pad A Obs Well – 26 metres from A4

Chamber has intersected the obs well.
Kirby South Performance
Pad A Obs Well Pressures

- BW pressure changes as pad pressures are increased / decreased
- McMurray pressure is being influenced by SAGD pressure (26m from A4)
- Clearwater gauge landed in impermeable shale
- Clearwater declining pressure result of gauge effects and does not indicate change in cap rock properties
Kirby South Performance
Pad A Key Learnings

- Pad A has performed at reservoir expectations through this year
- Redrill of A1 Q4-2016 has not performed to expectation
Kirby South Performance – Mid Recovery
Pad D

- SAGD well pair: 10
- First steam: Oct. 2013
- Inter-well pair spacing: 80 m
- Avg. net pay: 26 m
- Avg. So: 80%
- Avg. porosity: 33%
- Current RF: 16.7%
Kirby South Performance
Pad D Production

Circulating Re-Drills
Conversion of Re-Drills
D7 RR
D9/D10 on Circulation
D4 back online producing at high watercut
Kirby South Performance
High Recovery Pad D Well Pair

Kirby South D4 Production

- Oil Production
- Water Production
- Steam Injection
- ISOR
- cSOR

D4 Pump Replacement
 Kirby South Performance
Low Recovery Pad D Well Pair
Kirby South Performance
Horizontal Observation Well

CNRL HZ 11 1-29 Kirby 10-20-73-7 Trajectory

CNRL HZ 11 1-29 Kirby 10-20-73-7 Temperature Profiles

Includes 620 m behind ICP
Some wells may be shifted
Kirby South Performance
Pad D Obs Well Pressures

- Pad D Obs wells show good pressure sensitivities to changes in SAGD operations
Kirby South Performance
Pad D Obs Well – 5 m From D2

Investigating temperature response
Kirby South Performance
Pad D Obs Well – 5.5 m From D2
Kirby South Performance
Pad D Key Learnings

• Reservoir performance is meeting expectations
• Both step out pairs drilled and on circulation as of Q3 2017
• Known communication through old RAX SAGD pilot
  – To date no performance issues due to RAX pilot
  – Long term strategy to balance pressures between C & D pad
  – Continually monitor RAX pressure and temperatures
Kirby South Performance
Pad C – High Recovery Pad

- SAGD well pair: 7
- First steam: Sept. 2013
- Inter-well pair spacing: 100 m
- Avg. net pay: 25 m
- Avg. So: 78%
- Avg. porosity: 33%
- Current RF: 28.7%
Kirby South Performance
Pad C Production

Kirby South Pad C Production

- Oil Production
- Water Production
- Steam Injection
- iSOR
- cSOR

Canadian Natural
Kirby South Performance
High Recovery Pad C Well Pair

Kirby South C2 Production

- Oil Production
- Water Production
- Steam Injection
- iSOR
- cSOR

Rate (m³/d) vs. SOR (ms/m²)
Kirby South Performance
Pad C Obs Well – 36 m From C2
Kirby South Performance
Pad C Obs Well – 27 m From C2

Investigating temperature response
Kirby South Performance
Pad C Key Learnings

• Reservoir performance is meeting expectations
• Upside production is contributing to some of the wells performance
• Chamber communication is observed in a high level on C pad
• Known communication through old RAX SAGD pilot
  – No impact on production
Kirby South Performance
5 Year Outlook – Pad Abandonments

• No expected pad abandonments in the next 5 years
Kirby South Performance
Wellhead Steam Quality

• During steady operations, wellhead quality should be 95% or greater

• There is some evidence that certain pads and wells have experienced slightly lower quality during start-up
  – This is not expected to have an impact on recovery

• E-Pad Co-injection
  – 7 E3m3/d started in July 2017
  – No GOR or SOR effects seen yet
Kirby South Observation Well Results
100/10-28-073-07W4 – 4 m From G3

Colony gas well to evaluate the ability of non-thermal cement to maintain hydraulic isolation in a thermal environment

No thermal impacts
Kirby South Observation Well Results
Overall Performance

• 100/09-28-073-07W4/00
  – Appears to have fluid migrating into well from bottom. Data not required for pad monitoring, but potential to blow well dry and re-run fiber string this winter for pad optimization.

• 100/10-28-073-07W4/00
  – 1 TC showing erroneous data but not effecting monitoring purpose of well, therefore no action to be taken.

• Annual preventative maintenance program for all observation wells.
Kirby South Observation Well Results
Overall Performance

• 1AB/11-20-073-07W4/00 OB1C
  – Well is cased to 498.0 mKB and has an estimated cement top within the casing of 475.0 mKB. A 10 point thermocouple string is landed from 446.0 – 473.0 mKB across the Clearwater cap rock. There are no plans to enter this well.

• 100/06-21-073-07W4/00
  – In March 2014, the thermocouple string was pulled and the McMurray bottom water was perforated because the external pressure gauge was not providing accurate data. An internal pressure gauge was run and the thermocouple string was not re-run. There are no plans to enter this well.
Future Plans – Approved Drills

• Continue to optimize SAGD pairs

• Approved wells to be drilled in the next year:
  – Infills:
    ▪ 4 on B pad to be drilled in remainder September
    ▪ 7 on C pad to be drilled after B pad infills
  – Step Outs:
    ▪ D11 Approved
    ▪ G9 and G10 Approved
Future Plans – Evaluation Potential

• Pending favorable economic conditions, the following future plans are contemplated:
  – Infills:
    ▪ Pad A application to be submitted
    ▪ Pad D and G currently evaluating
  – Scheme Amendments:
    ▪ KS 10/11 pads D78 application submitted in July
    ▪ KSW pad application in progress
Future Plans - G Step Outs

- 2 step outs planned on G Pad (G9 & G10)
  - Wells to be drilled West of existing well pairs
    - G9 will be 75m from G1
    - D10 will be 65m from G9
  - 980m well lengths
  - 10-34m pay height
  - D78 approval received Sept. 5, 2017
  - Drilling planned for Q4 2017/Q1 2018
Future Plans - A Pad Infills

• 5 infills planned on A pad
  – Plan to drill 5 infill producers spaced 50m from existing producers
  – 10-40m pay height
  – Plan to drill at the same TVD as existing A Pad wells
  – D78 amendment submitted in Aug. 2017
Future Plans - KS10 & 11

- Adding two drainage boxes KS10 & KS11 to Kirby South Development Area
  - 5 well pairs planned in KS10 and 6 well pairs planned in KS11
- 600-900m in lateral length
- 50m spacing
- D78 application submitted in July 2017
Future Plans – KS20-26

- Request to add 9 drainage boxes in the KSW development (KS20 to KS26)
  - 60 well pairs planned
- Currently preparing D78 application to be submitted in Sept. 2017
DIRECTIVE 54 SECTION 3.1.2
SURFACE OPERATIONS, COMPLIANCE AND
ISSUES NOT RELATED TO RESOURCE
EVALUATION AND RECOVERY
Surface Facilities Overview
Plot Plans

• Detailed Site Plot Plans:
  – Kirby SAGD Production Pad Plot Plan
    ▪ Dwg No. KBF-G-210-0001
  – Kirby South Central Plant Plot Plan
    ▪ Dwg No. KBP-00-210-0002

• Simplified Schematic:
  – Kirby In-Situ Oil Sands Project Simplified Schematic
Surface Facilities Overview
Kirby South SAGD Production Pad Plot Plan
Surface Facilities Overview
Kirby South Central Plant Plot Plan
Surface Facilities Overview
Kirby South Modifications

• Summary of Modifications since August 2016
  – A compressor was added on Pad E for produced gas co-injection with steam to improve steam-oil-ratio while having minimal impact on oil rates.
  – Disposal filtering skid bypassed from disposal wellheads except during pigging operations.
  – Small facility modifications during the May turnaround (tank bypasses).
  – Meter upgrades: Added Butane meter and upgraded 1-FT-3290 & 2-FT-0051 flow meters.
  – Upsized inlet separator emulsion outlet control valve 1-LV-1000C.
  – Constructions completed on Pad D and F for step outs.
  – Permanent gas tie-in from West Kirby compressor stations sales line to Kirby supply line.
Kirby South Facility Performance
Oil Treating/Produced Water De-oiling Area

• Overall water quality and oil treating targets have been met
  – Oil treating is running very stable, short term upsets from well ramp ups after acid stimulation activities is still experienced, but are manageable
    ▪ Optimization work continues on the chemical program and pressure optimization trials.
  – PW de-oiling upsets leading to evaporator fouling and additional cleanings has been nearly eliminated
  – New production record reached on June 3rd, 44,790 BPD.
  – Treatment of slop generated on site has been improved through process and chemical program optimization
    ▪ Recycled most of the slop back to FWKO
Kirby South Facility Performance
Water Treatment Area

• Great performance in the evaporators – reached name plate capacity after the May plant turnaround

• Water upsets affecting evaporator performance has been nearly eliminated, increasing steam availability

• Disposal well injectivity is no longer limited with monthly disposal line pigging program

• Pre-heater fouling due to brackish water hardness is an ongoing issue.
Kirby South Facility Performance
Boilers

– No tubing failures since 2014. No casing failures since August 2016

– One casing failure on Boiler 4 in August 2016 due to high vibrations knocking refractory off the casing walls. Lots of tuning and shimming work was done on boiler 4 to remedy the vibration issue.

– All boilers’ refractory were inspected during the turnaround and all were in good shape. NDT and a more detailed inspection will be performed on the boilers in 2018 for regulatory inspections.

– All boilers have met nameplate capacity after the May turnaround.
Salt caverns continue to manage evaporator blowdown solids

Caverns are operating in series, Cavern 2 is receiving concentrate (brine) from Cavern 1

2017 Sonar Logging

– Cavern 1 last completed on October, 2016, another sonar logging scheduled September 2017

– Cavern 2 last completed on June, 2016, another sonar logging scheduled September 2017
Kirby South Facility Performance
Power Consumption

• Power Consumption on a monthly basis

<table>
<thead>
<tr>
<th>Month</th>
<th>Total Power Consumption (kWh)</th>
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</thead>
<tbody>
<tr>
<td>Sep -16</td>
<td>17,129,300</td>
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<tr>
<td>Oct -16</td>
<td>17,318,494</td>
</tr>
<tr>
<td>Nov -16</td>
<td>17,091,532</td>
</tr>
<tr>
<td>Dec -16</td>
<td>17,745,480</td>
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<tr>
<td>Jan -17</td>
<td>17,804,724</td>
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<tr>
<td>Feb -17</td>
<td>15,897,516</td>
</tr>
<tr>
<td>Mar -17</td>
<td>17,717,028</td>
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<tr>
<td>Apr -17</td>
<td>16,360,645</td>
</tr>
<tr>
<td>May -17</td>
<td>12,694,176</td>
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<tr>
<td>Jun -17</td>
<td>17,400,680</td>
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<tr>
<td>Jul -17</td>
<td>17,252,878</td>
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<tr>
<td>Aug -17</td>
<td>17,527,219</td>
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</table>
Gas Usage on a monthly basis

<table>
<thead>
<tr>
<th>Month</th>
<th>Total Purchased Gas e3m3</th>
<th>Total Gas Produced e3m3</th>
<th>Total Gas Vented e3m3</th>
<th>Total Solution Gas to Flare e3m3</th>
<th>Solution Gas Recovered %</th>
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<tbody>
<tr>
<td>Sep-16</td>
<td>28,137</td>
<td>848</td>
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<td>27,330</td>
<td>1,300</td>
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<td>11.4</td>
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<td>Nov-16</td>
<td>27,169</td>
<td>1,135</td>
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<td>Dec-16</td>
<td>28,466</td>
<td>1,002</td>
<td>-</td>
<td>5.1</td>
<td>99.5</td>
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<tr>
<td>Jan-17</td>
<td>27,965</td>
<td>1,288</td>
<td>-</td>
<td>6.1</td>
<td>99.5</td>
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<tr>
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<td>1,329</td>
<td>-</td>
<td>5.6</td>
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<td>Mar-17</td>
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<td>-</td>
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<td>99.3</td>
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<td>19,835</td>
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<td>Jun-17</td>
<td>28,506</td>
<td>1,209</td>
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<td>27,774</td>
<td>1,167</td>
<td>-</td>
<td>5.2</td>
<td>99.6</td>
</tr>
</tbody>
</table>

Recovering greater than 98% solution gas
Kirby South – Greenhouse Gas Emissions

- Kirby South Greenhouse Gas Emissions
  - 2016 emissions are actuals
  - 2017 emissions are estimates
    - Will be verified Q1 2018

<table>
<thead>
<tr>
<th>Month</th>
<th>2016/2017 (tCO2e)</th>
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</thead>
<tbody>
<tr>
<td>September</td>
<td>62,360</td>
</tr>
<tr>
<td>October</td>
<td>59,520</td>
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<tr>
<td>November</td>
<td>58,840</td>
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<td>61,240</td>
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<td>January</td>
<td>61,750</td>
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<td>February</td>
<td>55,110</td>
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<td>March</td>
<td>60,430</td>
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<tr>
<td>April</td>
<td>56,340</td>
</tr>
<tr>
<td>May</td>
<td>48,490</td>
</tr>
<tr>
<td>June</td>
<td>63,870</td>
</tr>
<tr>
<td>July</td>
<td>59,140</td>
</tr>
<tr>
<td>August</td>
<td>61,980</td>
</tr>
</tbody>
</table>
Kirby South Facility Performance Emissions

• Kirby Sulphur Emissions
  – No exceedance of the EPEA daily SO2 emissions limit (2.0 t/d before Feb 10th, 3.0 t/d after Feb 10th)
  – No exceedance of the AER D56 calendar quarterly sulphur limit of 0.99 t/d
  – No plans for sulphur recovery installation at this time
  – Contingency plan is to reduce production if the sulphur emission rate approaches the EPEA or D56 limit
Kirby South Facility Performance
Sulphur Emissions
Kirby South Facility Performance
Ambient Air Quality Results

• Air Quality monitoring trailers is scheduled to be deployed and in service from Sept – Dec 2017 and Jan – Mar 2018. No continuous monitoring data from August 2016 to August 2017

• There were no SO2, H2S, or NO2 monthly readings above the Alberta Ambient Air Quality Objective from August 2016 to August 2017
Measurement and Reporting
Summary

- MARP approved in October 2011 and last updated in February 2017
  - Disposal well 100/09-19-073-08W4 was added to the document, the disposal well flow meter is 1019FQI2000.
  - Kirby South Gas Injection was added to the document for E pad produced gas co-injection.
  - Solution gas flare calculation modified as per discussion with AER, MARP document updated.

- Methods for estimating well production and injection volumes:
  - Produced emulsion from the scheme is commingled at the battery. Bitumen and water production from the battery will be prorated to each well using monthly proration test data and proration factors
    - Total Battery Oil (Water) / Total Test Oil (Water) at Wells = Oil (Water) Proration Factor
    - Oil (Water) Proration Factor * Each Well Test Oil (Water) Volume = Oil (Water) Allocated to Each Well
  - Gas is allocated to each well using a Field GOR
    - Total Solution Gas Produced + Total Co-injected Produced Gas / Total Battery Oil = Gas Oil Ratio
    - Gas Oil Ratio * Oil Allocated to Each Well = Gas Allocated to Each Well
  - Injected steam volumes will be continuously measured at the wellhead and prorated to the total steam leaving the injection facility

- Test Durations
  - Based on operating experience to date, well test duration has been optimized at 1 hour and each well is tested 3 to 4 times per day.
Measurement and Reporting
Proration Factors

- 100% compliance with D17 (3-month avg. range 0.85-1.15)
- The spike in May 2017 is due to ramp up after full plant turnaround
Future Plans – Surface
Kirby South Planned 2017 – 2018 Activities

• Central Plant
  – Evap outages for maintenance and boiler outages for regulatory inspections
  – Disposal filter optimization trial with permanent filter skids by the well heads
  – Internal inspections on Skim tanks, slop oil tanks, sales oil tanks and butane bullets

• Pads
  – Piping modifications on step outs, infills and re-drills
    ▪ 7 infill wells on Pad C, 4 infill wells on Pad B
    ▪ Potential wells on Pad D and Pad G
Kirby North Site Activities Summary

• Central Plant
  – Civil work for equipment/building foundations completed
  – Piping module assembly contracts awarded and kicked off
  – Plant mechanical and electrical contracts awarded and kicked off
  – Module setting resumed for main rack, oil treating and water treating areas
  – Tank painting, insulating and internal coating completed
  – IGF orders completed and ready to ship to site
• Pads & Pipelines
  – Detailed engineering of pad design completed
  – Pipeline engineering and surveying completed and materials ordered
• Steam-in planned for late, 2019
Water Treatment Technology Summary

• Mechanical Vapor Compression (MVC) evaporators selected for BFW treatment
  – Treatment of both recycled produced water and makeup water
  – Evaporator blow down solids disposal to on-site salt cavern
  – Silica Sorption process selected vs. high pH process from application
Mechanical Vapor Compression Evaporator:
Kirby South Produced and Make-up Water Usage

Water Sources

• Saline
  – McMurray Fm
    ▪ TDS 14,500 ppm
    ▪ Pressure balance and make-up
  – Grand Rapids
    ▪ TDS 4,500 ppm
    ▪ Make-up

• Non-Saline
  – Grand Rapids
    ▪ TDS 2,450 ppm
    ▪ Make-up
  – Empress Fm
    ▪ TDS 550 ppm
    ▪ Utility and Make-up
Kirby South Produced and Make-up Water Usage

<table>
<thead>
<tr>
<th>Month</th>
<th>Non-saline Volume</th>
<th>Saline Volume</th>
<th>Non Saline Make-Up Percentage</th>
<th>Injection</th>
<th>Produced</th>
<th>PWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sep-16</td>
<td>10,500</td>
<td>25,814</td>
<td>29</td>
<td>14,027</td>
<td>491,741</td>
<td>97</td>
</tr>
<tr>
<td>Oct-16</td>
<td>8,772</td>
<td>11,363</td>
<td>44</td>
<td>27,632</td>
<td>490,012</td>
<td>94</td>
</tr>
<tr>
<td>Nov-16</td>
<td>8,235</td>
<td>43,374</td>
<td>16</td>
<td>28,761</td>
<td>483,560</td>
<td>94</td>
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<tr>
<td>Dec-16</td>
<td>5,817</td>
<td>41,760</td>
<td>12</td>
<td>39,614</td>
<td>498,614</td>
<td>92</td>
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<tr>
<td>Jan-17</td>
<td>6,254</td>
<td>42,383</td>
<td>13</td>
<td>43,616</td>
<td>500,453</td>
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<td>Feb-17</td>
<td>4,612</td>
<td>47,772</td>
<td>9</td>
<td>33,233</td>
<td>449,048</td>
<td>92</td>
</tr>
<tr>
<td>Mar-17</td>
<td>8,543</td>
<td>61,136</td>
<td>12</td>
<td>32,077</td>
<td>495,809</td>
<td>93</td>
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<td>Apr-17</td>
<td>8,891</td>
<td>21,627</td>
<td>29</td>
<td>21,127</td>
<td>456,806</td>
<td>95</td>
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<tr>
<td>May-17</td>
<td>10,329</td>
<td>25,016</td>
<td>29</td>
<td>33,336</td>
<td>345,488</td>
<td>90</td>
</tr>
<tr>
<td>Jun-17</td>
<td>27,113</td>
<td>39,743</td>
<td>41</td>
<td>25,131</td>
<td>518,556</td>
<td>95</td>
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<tr>
<td>Jul-17</td>
<td>11,253</td>
<td>29,546</td>
<td>28</td>
<td>25,963</td>
<td>488,422</td>
<td>95</td>
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<tr>
<td>Aug-17</td>
<td>8,115</td>
<td>27,919</td>
<td>23</td>
<td>30,566</td>
<td>510,249</td>
<td>94</td>
</tr>
<tr>
<td>2016-17 Totals</td>
<td>118,434</td>
<td>417,453</td>
<td>22</td>
<td>355,083</td>
<td>5,728,758</td>
<td>94</td>
</tr>
</tbody>
</table>

- Directive 81 Disposal Limit = 12%, Actual Disposal = 6% for 2016-2017
- Potable Water
  - A total of 16,242 m3 of water was used to supply KS camps and office complex
  - Water Act Diversion licenses received for KN Camp and CPF office (effective May 26, 2017).
    - With the recommencement of Kirby North project construction, a total of 2,570 m3 has been used for since May
Kirby South Source and Disposal Well Map
## Kirby South Source Wells - Saline

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Use</th>
<th>Unique Well Identifier</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>McMurray Source Wells</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNRL WSW01 Kirby 14-30-73-7</td>
<td>Make-up Source (not used)</td>
<td>1F1/14-30-73-7W4M</td>
</tr>
<tr>
<td>CNRL WSW MC01 Kirby 10-33-73-8</td>
<td>Make-up Source</td>
<td>1F1/10-33-73-8 W4M</td>
</tr>
<tr>
<td>CNRL WSW MC02 Kirby 10-33-73-8</td>
<td>Make-up Source</td>
<td>1F2/10-33-73-8 W4M</td>
</tr>
<tr>
<td><strong>Grand Rapids Source Well</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNRL WSW GR01 Kirby 13-21-73-7</td>
<td>Make-up Source</td>
<td>1F3/13-21-073-07W4M</td>
</tr>
</tbody>
</table>
# Kirby South Source Wells – Non-Saline

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Use</th>
<th>Unique Well Identifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRAND RAPIDS Formation</td>
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<tr>
<td>Grand Rapids Source Wells</td>
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<tr>
<td>CNRL WSW02 Kirby 14-30-73-7</td>
<td>Make-up Source</td>
<td>1F2/14-30-73-8W4M</td>
</tr>
<tr>
<td>EMPRESS Formation Source Wells</td>
<td></td>
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<tr>
<td>CNRL WSW Kirby 13-21-73-7</td>
<td>Utility Source</td>
<td>1F2/13-21-73-07W4M</td>
</tr>
<tr>
<td>CNRL WSW EMP03 12-21-73-7</td>
<td>Utility Source</td>
<td>1F1/12-21-73-07W4M</td>
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<tr>
<td>MURIEL LAKE Formation - Source Wells</td>
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<tr>
<td>CNRL WSW ML03 Kirby 13-21-73-7</td>
<td>Domestic Source</td>
<td>1F4/13-21-73-7W4M</td>
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<tr>
<td>ETHEL LAKE Formation - Source and Standby Wells</td>
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<tr>
<td>CNRL WSW EL01 Kirby 16-29-73-7</td>
<td>Domestic Source</td>
<td>1F1/16-29-73-7W4M</td>
</tr>
<tr>
<td>CNRL WSW EL02 Kirby 15-29-73-7</td>
<td>Domestic Source</td>
<td>No UWI</td>
</tr>
<tr>
<td></td>
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<td>No license required</td>
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Kirby North Source Wells – Non-Saline

<table>
<thead>
<tr>
<th>Well Name</th>
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<tbody>
<tr>
<td>ETHEL LAKE Formation - Source Well</td>
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<td>CNRL WSW QT01 Kirby NW-21-74-8</td>
<td>Domestic Source</td>
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<td>BONNYVILLE Formation - Source and Standby Wells</td>
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<tr>
<td>CNRL WSW BNY01 Kirby NW-26-74-9</td>
<td>Domestic Source</td>
<td>No UWI</td>
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<tr>
<td>CNRL WSW BNY02 Kirby NW-26-74-9</td>
<td>Domestic Source</td>
<td>No UWI</td>
</tr>
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</table>
Kirby South McMurray Pressure Balance Scheme Update
Kirby South Pressure Balance Scheme Update

- McMurray Fm Basal Aquifer pressures Kirby South 10-33 well area

- Current pressures in all observation wells slightly above the initial pressures (~140kPa)
- Current pressures similar a year ago in all observation wells
Kirby South McMurray Pressure Balance Scheme Update

- McMurray Fm Basal Aquifer pressure near 10-17-74-8 disposal area

- Pressure increased early on during cavern washing
- Decreased to ~3,000kPa and holding since 2014
- Approximately 400kPa above original static pressure
Kirby South McMurray Pressure Balance Scheme Update

- Chemistry analysis
  - All saline water source wells (annually)

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<tr>
<th></th>
<th>1F1/10-33-073-08W4</th>
<th>1F3/13-21-73-07W4 (Grand Rapids)</th>
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<tbody>
<tr>
<td>Date</td>
<td>October 3, 2016</td>
<td>October 3, 2016</td>
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<tr>
<td>Total Dissolved Solids</td>
<td>15,100 mg/L</td>
<td>4,640 mg/L</td>
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</table>

- McMurray Observation wells (every five years)

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<thead>
<tr>
<th></th>
<th>00/15-28-073-08W4</th>
<th>00/01-17-074-08W4</th>
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<tbody>
<tr>
<td>Date</td>
<td>March 10, 2014</td>
<td>March 16, 2014</td>
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<tr>
<td>Total Dissolved Solids</td>
<td>16,800 mg/L</td>
<td>12,500 mg/L</td>
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</table>
The McMurray pressure balance numerical model was updated in November, 2016 and results were presented to AER in January, 2017.

Data used to update the numerical model:
- Production and disposal volumes up to September 30, 2016 added to model.
- Pressure data at observation wells up to September 30, 2016 used for history matching.
- Periodic disposal volumes at 100/9-34-73-8w4.

The calculated pressure responses in observation wells matched new observation data without changes to the model geology and boundary conditions.
## Kirby South Disposal Wells

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Use</th>
<th>Unique Well Identifier</th>
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<tbody>
<tr>
<td><strong>McMurray Disposal Wells</strong></td>
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<tr>
<td>RAX Kirby 9-34-73-8</td>
<td>Disposal (used periodically)</td>
<td>00/09-34-073-08W4M</td>
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<tr>
<td>CNRL WDW01 Kirby 8-17-74-8</td>
<td>Disposal</td>
<td>00/08-17-074-08W4M</td>
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<td>CNRL WDW02 Kirby 10-17-74-8</td>
<td>Disposal</td>
<td>02/10-17-074-08W4M</td>
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<tr>
<td>CNRL WDW03 Kirby 15-17-74-8</td>
<td>Disposal</td>
<td>00/15-17-074-08W4M</td>
</tr>
<tr>
<td>CNRL WDW HZ MCM05 Kirby 13-20-73-8</td>
<td>Disposal</td>
<td>00/13-20-073-08W4M</td>
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<tr>
<td>CNRL WDW MCM06 Kirby 9-19-73-8</td>
<td>Disposal</td>
<td>100/09-19-073-08W4M</td>
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<td><strong>Salt Cavern Wells</strong></td>
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<tr>
<td>CNRL CAVERN VERT KIRBY 13-21-73-7</td>
<td>Prairie Evaporate</td>
<td>00/13-21-073-07W4M</td>
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<tr>
<td>CNRL CAVERN DD KIRBY 4-28-73-7</td>
<td>Lotsburg</td>
<td>02/04-28-073-07W4M</td>
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</tbody>
</table>
Kirby South Disposal

- Injectivity decline caused by:
  - Solids
  - Oil in water
  - Scale

- Implemented improvements
  - Caverns operated in series to remove more solids
  - Second set of filters improved solids removal
  - Second ISF reduced OIW numbers < 20ppm
  - Excess PW with OIW >20ppm has to go through caverns
  - Antiscale injection
  - Regular pigging plan to evaluate Antiscale effectiveness
  - 9-19 conversion; currently best well

- Results
  - Injectivity stopped declining
Kirby South Disposal

- 8-17 Pressure, Disposal Rates and Temperature
- 10-17 Pressure, Disposal Rates and Temperature
- 15-17 Pressure, Disposal Rates and Temperature
Kirby South Disposal
Kirby South Waste Disposal

Top 10 Waste Streams (Kgs)

- Filters - Leachable: 61,843
- Scrap Metal: 75,640
- Domestic Garbage: 39,170
- Soil & Debris NR Chemicals: 59,760
- Cardboard: 7,190
- Wood Waste: 6,640
- Lab Waste NR HC: 41,220
- Soil & Debris NR HC Refined: 2,043
- SF #82432 Sludge HC LW - Soil...: 137,747
- Total: 190,250
Kirby South Waste Disposal

Top 10 Disposal Facilities (Kgs)

- Absolute Edmonton Deepwell
- General Scrap Edmonton
- GFL Edmonton Fuels
- GFL Edmonton Oil
- Tervita Janvier Landfill
- Tervita Red Deer Metals Recycling
- (blank)
- Wood Buffalo Landfill
- Clean Harbors Ryley Landfill
- Beaver Municipal Landfill
- Miller Environmental St. Jean
- Prewko Trucking Lacombe
- Van Brabant Fuels Morinville

Total: 665,057
Kirby North Waste Disposal

Top 10 Waste Streams (Kgs)

<table>
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<tr>
<th>Waste Stream</th>
<th>Quantity</th>
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<tr>
<td>SOIL &amp; DEBRIS NR HC REFINED</td>
<td>34,870</td>
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<tr>
<td>CONSTRUCTION &amp; DEMOLITION...</td>
<td>13,520</td>
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<tr>
<td>DOMESTIC GARBAGE</td>
<td>8,920</td>
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<tr>
<td>NR SOLIDS LANDFILL - CEMENT...</td>
<td>13,510</td>
</tr>
<tr>
<td>Total</td>
<td>60,740</td>
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</tbody>
</table>
Kirby North Waste Disposal

Top 10 Disposal Facilities (Kgs)

- Tervita Janvier Landfill: 48,380 Kgs
- Wood Buffalo Landfill: 22,440 Kgs

Canadian Natural
Environmental Summary
Monitoring Programs

• Wildlife Mitigation Plan and Monitoring Program

  – Monitoring mitigation efficacy (above ground pipelines, barriers to wildlife movement, effects of human presence)

  – 27 remote cameras deployed throughout the project
    ▪ 13 species detected, including three provincially sensitive species and one federally threatened species (woodland caribou)
    ▪ Frequent caribou sightings near Kirby South Plant reported by onsite staff

  – 23 camera stations monitoring linear deactivation (initiated in Feb 2015)
    ▪ 10 mammal species recorded
    ▪ Noted correlation between low carnivore detections along treated lines

  – 22 species of concern (17 bird species, 5 mammals) observed in the Kirby Project area in 2015

  – Comprehensive wildlife report completed and submitted in 2017
Environmental Summary
Monitoring Programs

- Wetland and Waterbody Monitoring Program
  - Two monitoring stations showed water level response is sensitive to discharges of industrial waste water from nearby pads or the Kirby South CPF.
  - One culvert surveys completed at Kirby South and Kirby North in 2017.
    - Mitigation measures to be applied to most problematic culverts following the surveys.
    - Additional mitigation measures being applied throughout the year to meet target of repairing all damaged culverts within one year from time of assessment.
  - Overall indication that project infrastructure has some effect on wetlands in Kirby South.
    - Corrective measures include improvements to road and culvert design in problematic areas to alleviate water impoundment
Environmental Summary
Monitoring Programs

• Groundwater Monitoring Program
  – Well pad monitoring program to monitor potential effect of steam injection on mineral solubility and mobilization of trace elements
    ▪ 1 monitoring well on each Pad B, Pad D, Pad F
    ▪ No impacts to groundwater quality identified
    ▪ Sub-regional groundwater monitoring program focusing on deeper, Quaternary- and Tertiary-aged aquifers.
  – Central Plant monitoring program monitors groundwater conditions within shallow sediments
    ▪ 20 groundwater monitoring wells at CPF
    ▪ Increase in chloride concentration in monitoring well P12-06.
      ▪ Continued monitoring to evaluate Cl concentration trends
Environmental Summary
Monitoring Programs

• Air Monitoring
  – Source Monitoring
    ▪ Two RATAs conducted on Generator 1 in 2017
    ▪ CEMS at steam generator measures SO2 and NO2
    ▪ Two cylinder gas audits conducted in 2017
      ▪ Results show CEMS code is met
    ▪ One manual stack survey conducted on Generator 3 in 2017
    ▪ No significant trends in emissions data
  – Ambient Air Monitoring
    ▪ Continuous ambient air monitoring station located 0.7 km from plant site on G-Pad
    ▪ Five passive monitoring stations located around the plant site
      ▪ All passive exposure monitoring results for SO2, H2S, NO2 and O3 were low for the monitoring period
Environmental Summary
Reclamation Activities

• Reclamation Activities
  – Re-vegetation Program consisted of reforesting 3 ha in spring 2017
  – Reclamation certificate application submitted for SML100131

• Reclamation Monitoring
  – Objectives are to ensure:
    ▪ land is reclaimed to an equivalent land capability
    ▪ appropriate replacement of all salvaged topsoil on re-contoured areas
    ▪ sustainable, diverse vegetation growth on all disturbed areas
    ▪ pre-disturbance wildlife carrying capacities are obtained
  – Regular site monitoring throughout reclaimed areas within the Project Area

• Reporting
  – 2016 Annual C&R Report was submitted on March 31, 2017
  – PLRCP due to AER October 31, 2017
Environmental Summary
Reclamation Activities

- Reclamation Compliance (under EPEA)
  - Subsoil stockpiles were capped with topsoil and revegetated for erosion control
    - Non-compliance identified during AER audit
    - EPEA Approval Schedule IX, Condition 5 states “stockpile all topsoil separately from subsoil”
    - The practice of capping subsoil stockpiles with topsoil has ceased
Environmental Summary
Provincial/Federal Programs

• Lower Athabasca Regional Plan (LARP)
  – Participation in the South Athabasca Oil Sands (SAOS) area for Groundwater Management

• Provincial and Federal Woodland Caribou Recovery Policies
  – Participating in GOA processes to develop and implement range-level caribou recovery plans and province-wide action plan (CAPP).
  – Participating in caribou research (COSIA, RICC, FLMF)
  – Engaging with the GOA and Government of Canada to understand opportunities for knowledge transfer and to address data gaps (COSIA and CAPP).

• Alberta Wetland Policy
  – Participating in discussions with AEP and the AER regarding implementation of the policy in the Green Area of Alberta (CAPP)

• Alberta’s Climate Leadership Plan (CLP)
  – Working with AER and GOA on development of various aspects of the CLP including the oil sands emission limit and performance standards
### Approvals

#### Commercial Oil Sands Scheme

<table>
<thead>
<tr>
<th></th>
<th>Date</th>
<th>Description</th>
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<tbody>
<tr>
<td>11475</td>
<td>September 2010</td>
<td>Commercial Oil Sands Scheme Approval</td>
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<tr>
<td>11475A</td>
<td>November 2010</td>
<td>Revise initial development Pads A to G</td>
</tr>
<tr>
<td>11475B</td>
<td>November 2011</td>
<td>Change inter-well spacing Drainage Area D</td>
</tr>
<tr>
<td>11475C</td>
<td>December 2011</td>
<td>Change inter-well spacing in Drainage Area B</td>
</tr>
<tr>
<td>11475D</td>
<td>May 2012</td>
<td>Change inter-well spacing in Drainage Area E</td>
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<tr>
<td>11475E</td>
<td>June 2012</td>
<td>Evaluation of on-lease McMurray brackish water</td>
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<tr>
<td>11475F</td>
<td>August 2012</td>
<td>Change inter-well spacing in Drainage Area G</td>
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<td>11475G</td>
<td>September 2012</td>
<td>Change inter-well spacing in Drainage Area F</td>
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<td>Addition to Drainage Area D</td>
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<td>11475H</td>
<td>April 2013</td>
<td>Evaluation of off-lease Clearwater brackish water</td>
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## Approvals
### Commercial Oil Sands Scheme

<table>
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<tr>
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<tr>
<td>11475I</td>
<td>January 2014</td>
<td>Operational Strategy amendment</td>
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<td>11475J</td>
<td>March 2014</td>
<td>Trajectory and lateral length modifications in Drainage Area G</td>
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<td>11475K</td>
<td>May 2014</td>
<td>Approval of Kirby In Situ Oil Sands Expansion Project</td>
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<td>11475L</td>
<td>November 2014</td>
<td>Revise initial Kirby North development Pads KN01-KN05</td>
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<td>11475M</td>
<td>December 2014</td>
<td>Redrill well pairs A1, A2, A3</td>
</tr>
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<td>11475N</td>
<td>May 2015</td>
<td>Additional Kirby South and Kirby North disposal wells</td>
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<td>11475O</td>
<td>July 2016</td>
<td>Conversion of existing Kirby South observation well to disposal well</td>
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<tr>
<td>11475P</td>
<td>January 2017</td>
<td>Kirby South B Pad Infills and NCG Co-Injection</td>
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<tr>
<td>11475Q</td>
<td>March 2017</td>
<td>Kirby South E Pad Gas Co-Injection</td>
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<td>11475R</td>
<td>April 2017</td>
<td>Kirby South C Pad Infills/NCG Co-Injection and D10 Well Pair Extension</td>
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<tr>
<td>11475S</td>
<td>August 2017</td>
<td>Kirby North KN05b Approval</td>
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<tr>
<td>11475T</td>
<td>September 2017</td>
<td>Kirby South G Pad Step Outs Approval</td>
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## Approvals
### EPEA and Water Act

<table>
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<tr>
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<th>Date</th>
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<tr>
<td>237382-00-00</td>
<td>April 2011</td>
<td>Approval of Kirby In Situ Oil Sands Project</td>
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<tr>
<td>237382-00-01</td>
<td>July 2014</td>
<td>Approval of Kirby In Situ Oil Sands Expansion Project</td>
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<tr>
<td>237382-00-02</td>
<td>February 2015</td>
<td>Amend Kirby South steam generator NOx limit to include efficiency credit</td>
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<tr>
<td>237382-00-03</td>
<td>February 2017</td>
<td>Kirby South Daily Sulphur Dioxide Limit</td>
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### Water Act

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<th>Date</th>
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<tbody>
<tr>
<td>00334375-00-00 (Kirby South)</td>
<td>August 2013</td>
<td>Groundwater diversion license, Empress Unit 1 and Grand Rapids Formation</td>
</tr>
<tr>
<td>00334375-01-00 (Kirby South)</td>
<td>August 2015</td>
<td>Renewal of Groundwater diversion license</td>
</tr>
<tr>
<td>00334375-01-01 (Kirby South)</td>
<td>March 2017</td>
<td>Amendment to include drilling, construction, ice-roads and dust control</td>
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<tr>
<td>00288494-00-00 (Kirby South)</td>
<td>April 2011</td>
<td>Groundwater diversion license, Ethel Lake Formation</td>
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<tr>
<td>00327156-00-00 (Kirby South)</td>
<td>August 2013</td>
<td>Industrial surface runoff diversion license</td>
</tr>
<tr>
<td>00303825-00-00 (Kirby North)</td>
<td>July 2014</td>
<td>Preliminary Certificate groundwater diversion, Empress Terrace Formation</td>
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**In Compliance**
## Approvals
### EPEA and Water Act

<table>
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<tr>
<th>Approval ID</th>
<th>Date</th>
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<tr>
<td>00303820-00-00 (Kirby North)</td>
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<td>Industrial surface runoff diversion license</td>
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<td>00297299-00-00 (Kirby South)</td>
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<td>Groundwater diversion license, Muriel Lake Formation</td>
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<td>00297299-00-01 (Kirby South)</td>
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<td>Amendment to decrease allocation</td>
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<td>00390209-00-00 (Kirby North)</td>
<td>May 2017</td>
<td>Groundwater diversion license, Bonnyville Formation</td>
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<td>00391822-00-00 (Kirby North)</td>
<td>May 2017</td>
<td>Groundwater diversion license, Ethel Lake Formation</td>
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**In Compliance**
## Approvals Disposal

<table>
<thead>
<tr>
<th>Approval Code</th>
<th>Date</th>
<th>Details</th>
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<tbody>
<tr>
<td>11716</td>
<td>November 2011</td>
<td>Cavern Solution Mining</td>
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<tr>
<td>11716A</td>
<td>July 2013</td>
<td>Class 1b Cavern Disposal</td>
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<tr>
<td></td>
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<td>• Prairie Evaporites formation through well 00/13-21-073-07W4</td>
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<td>• Lotsberg formation through well 00/04-28-073-07W4</td>
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<td>11716B</td>
<td>June 2015</td>
<td>Modify testing requirements. Approval modified to reference CSA Z341.4</td>
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*In Compliance*
# Approvals Disposal

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<td>• 00/08-17-74-08W4</td>
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<td>11761A</td>
<td>April 2013</td>
<td>Modify pH requirements</td>
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<td>Amend MWHIP</td>
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In Compliance
## Approvals
**Disposal (continued)**

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<td>9594 September 2003</td>
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<td>Transferred to Canadian Natural from Rio Alto Exploration</td>
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<tr>
<td>9594A December 2011</td>
</tr>
<tr>
<td>Approval of Kirby In Situ Oil Sands Project</td>
</tr>
<tr>
<td>9594B May 2014</td>
</tr>
<tr>
<td>Approval of Kirby In Situ Oil Sands Expansion Project</td>
</tr>
</tbody>
</table>

**In Compliance**
# Approvals

## Facility License

<table>
<thead>
<tr>
<th>Facility License</th>
<th>Date</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>F42290</td>
<td>October 2010</td>
<td>Kirby South Phase 1 Central Processing Facility</td>
</tr>
<tr>
<td>F42290 amended</td>
<td>July 2013</td>
<td>Amended for KS1 CPF to reflect stream day rates and number of compressors and pumps</td>
</tr>
<tr>
<td>F44051</td>
<td>July 2014</td>
<td>Kirby North Phase 1 Central Processing Facility</td>
</tr>
</tbody>
</table>

*In Compliance*
Compliance Summary

• Reportable Spills
  – 2 reportable spills: produced water

• EPEA Contraventions
  – Two reportable flaring events October 4, 2016 and November 5, 2016
  – Two uncontrolled releases of surface water runoff as a result of heavy precipitation and berm overflow/breach July 14 & July 24, 2017

• Water Act
  – Water Act License No. 00150748: Data not reported to WURS. This license has since been cancelled*.
  – Water Act License No. 00303820: Data not reported to WURS*.

*Identified through the COA and resolved.