PennWest

Seal Main HCSS Pilot Approval 11377
Annual Performance Presentation

11-Feb-2015

Agenda

PennWest

- Introductions
- Seal Main Horizontal Cyclic Steam Stimulation (HCSS) Pilot
  - Subsurface
  - Surface
- Harmon Valley South HCSS Pilot
  - Subsurface
  - Surface
- Questions

PennWest

Seal Main HCSS Pilot Subsurface Review

Subsurface Agenda

PennWest

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

Subsurface Agenda

PennWest

1. **Background**
2. Geology
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Background – Map of Seal Main

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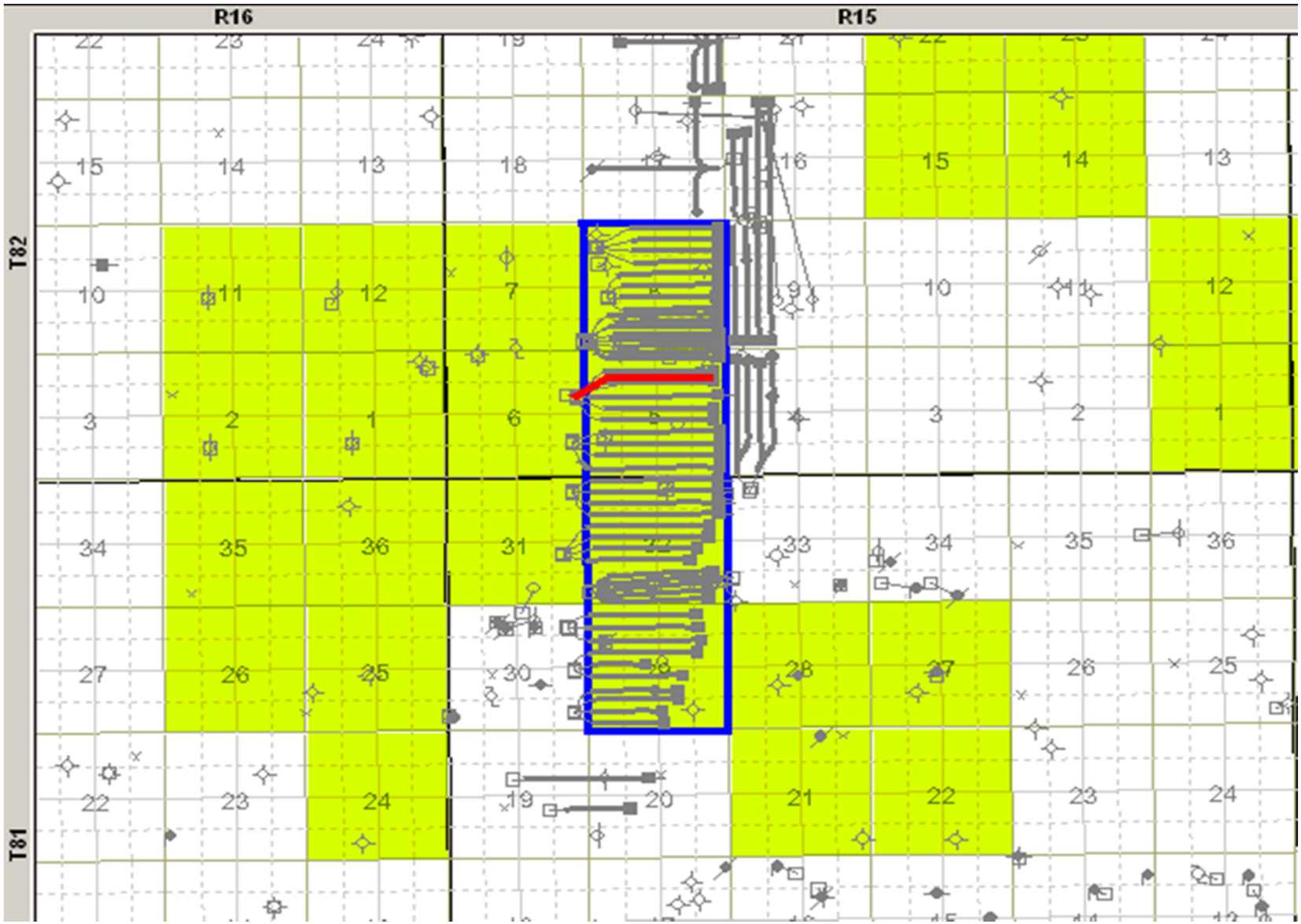

Background – Primary Development

PennWest

- Primary scheme development began in 2003
- Currently 48 primary horizontal production wells in the Seal Main area
- Most offset by 150m spacing with some at 75m spacing
- Individual well lengths range from 474m – 1,434m
- 2014 primary production 143 m^3/d gross

Background – Thermal Approval

PennWest

- 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

PennWest

- 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

Subsurface Agenda

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Geology – Bluesky Formation Overview

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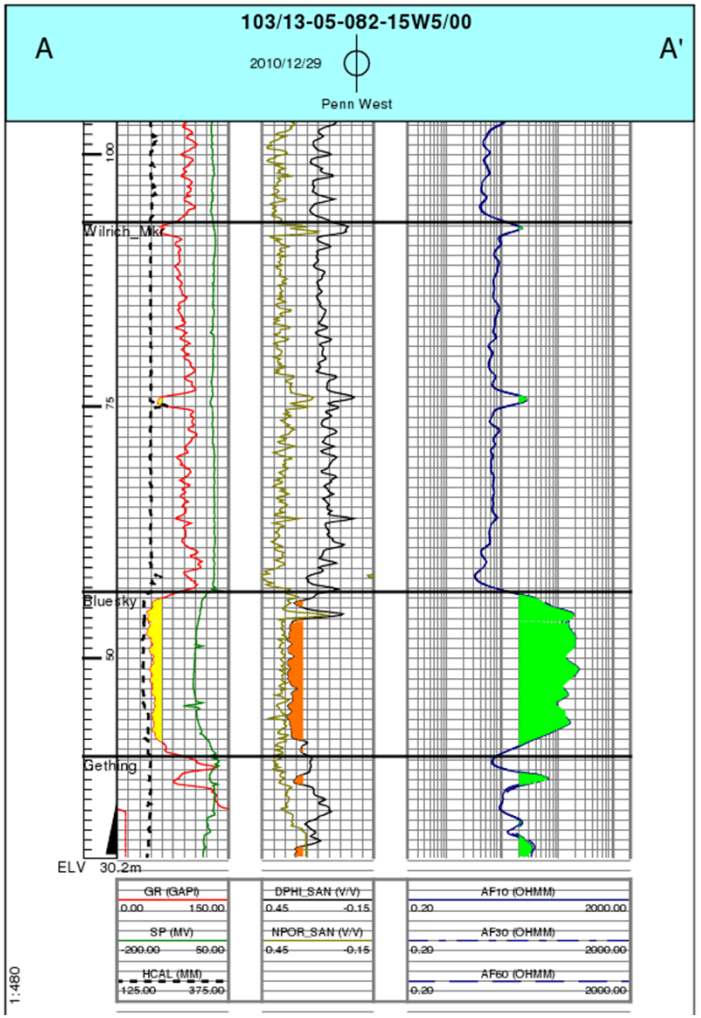
- Series of north/south oriented, stacked distributary channels that have incised into the surrounding sand dominated tidal flat sediments
- Fine to medium grained litharenite
- Average depth is 650m TVD
- Thickness up to 24m
- Porosities from 24% to 33% (Avg 28%)
- Permeability from 50 to 5,500mD
- 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

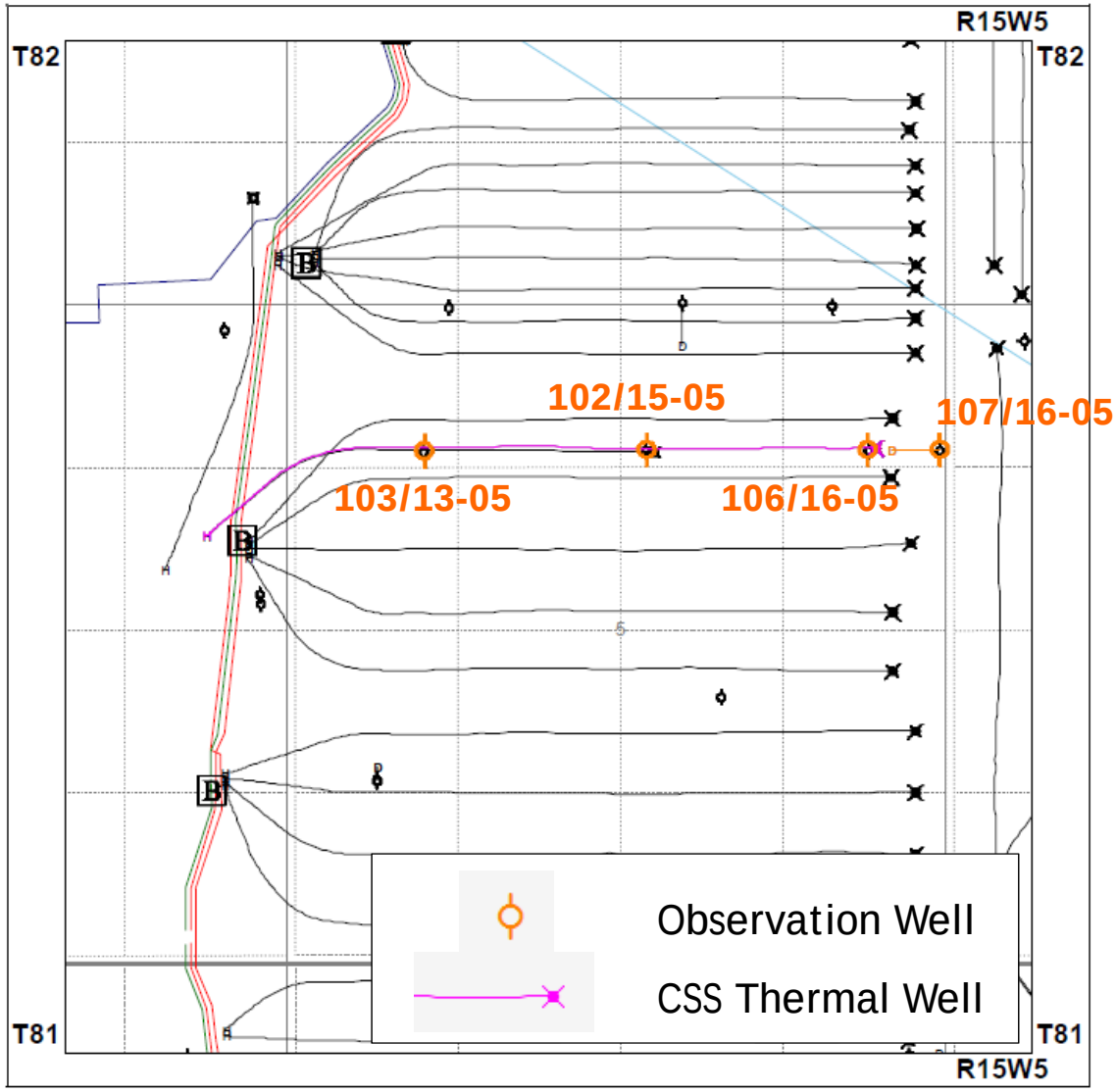
13-5-82-15W5 Type Log



Geology – Thermal Pilot Location

PennWest

- 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

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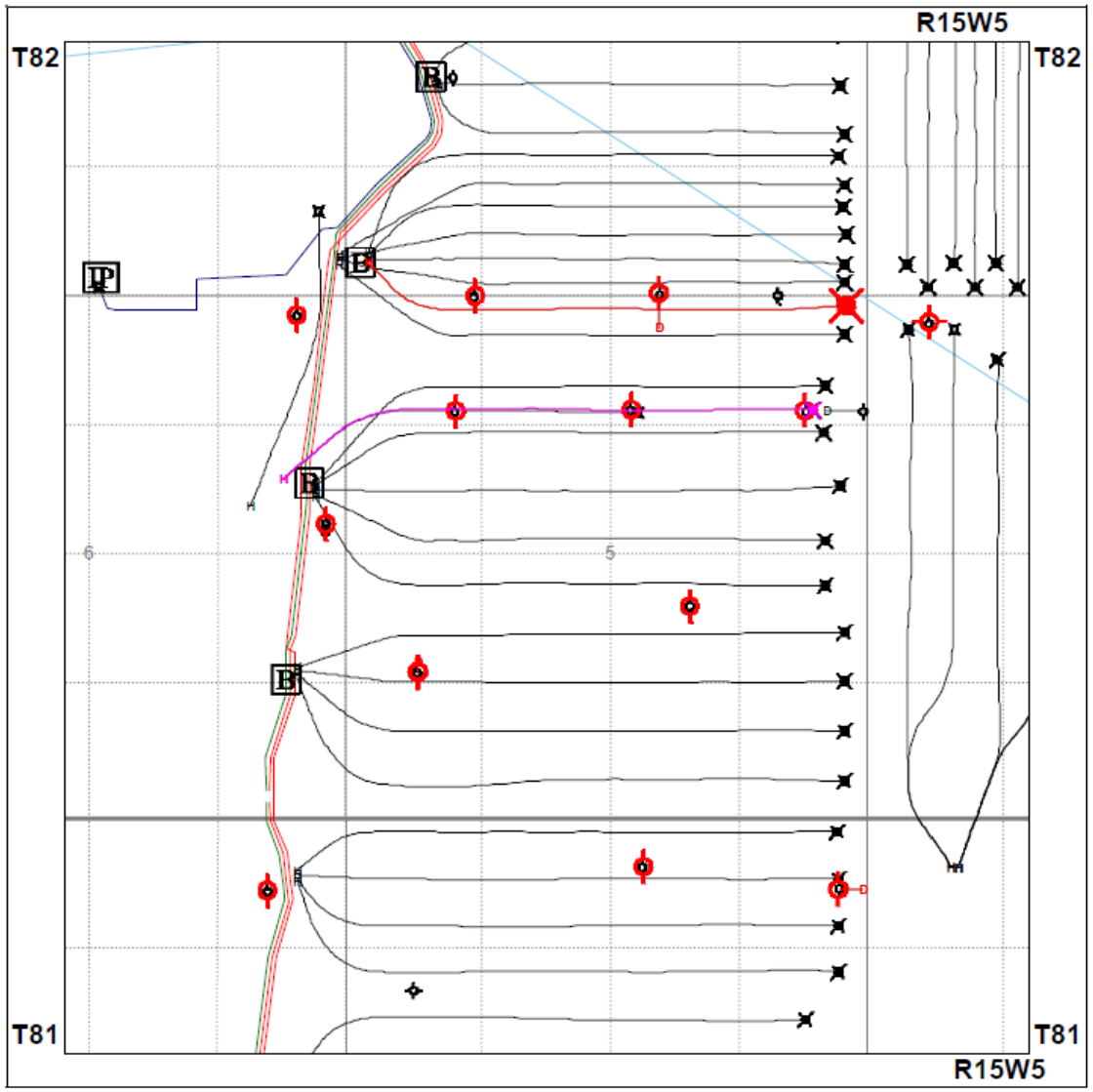
Cored Wells

CSS Thermal Well



Geology – Top Bluesky Structure Map

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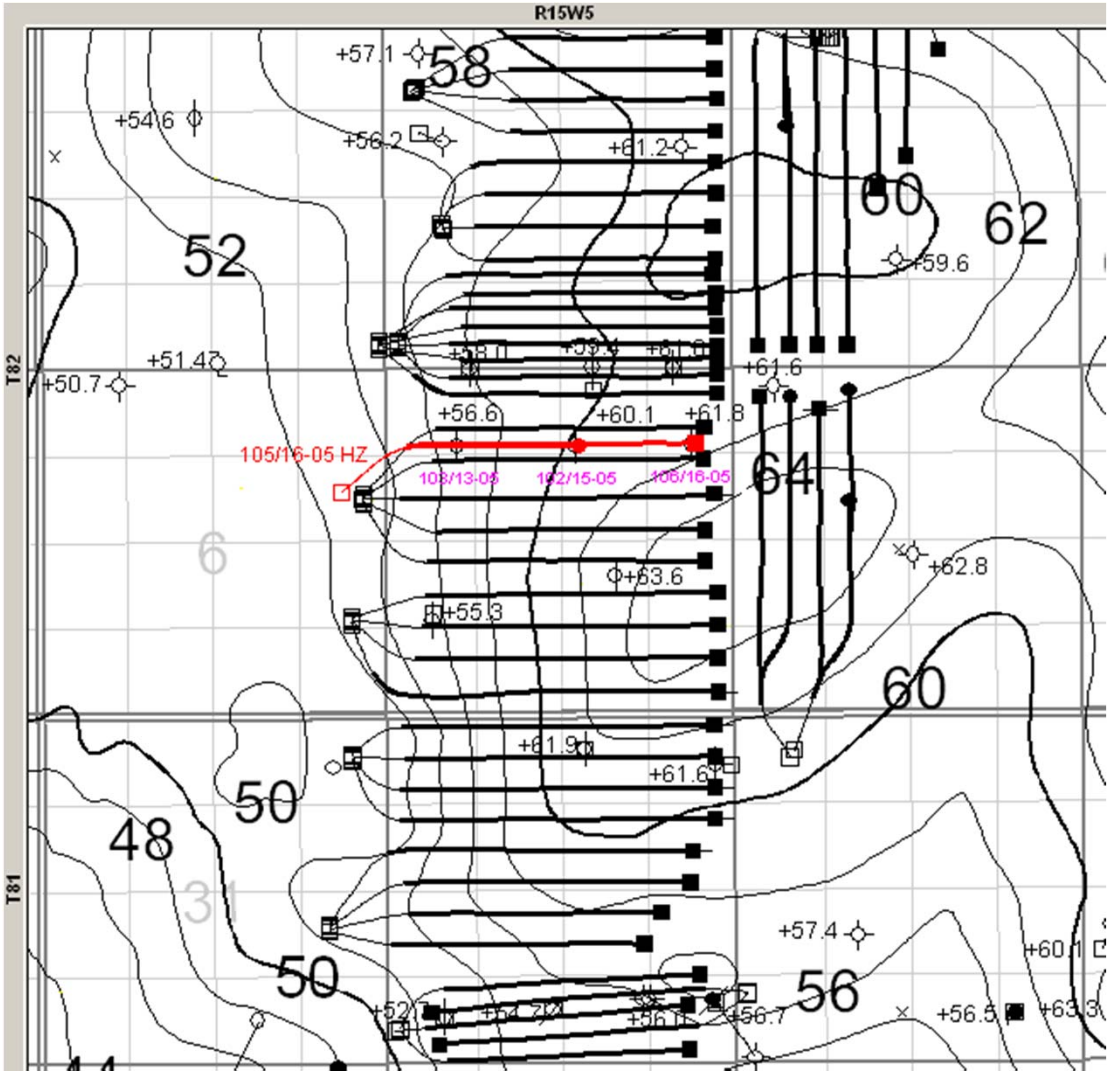


PennWest Exploration

Bluesky Structure (mss)

Licensed to : Penn West Petroleum

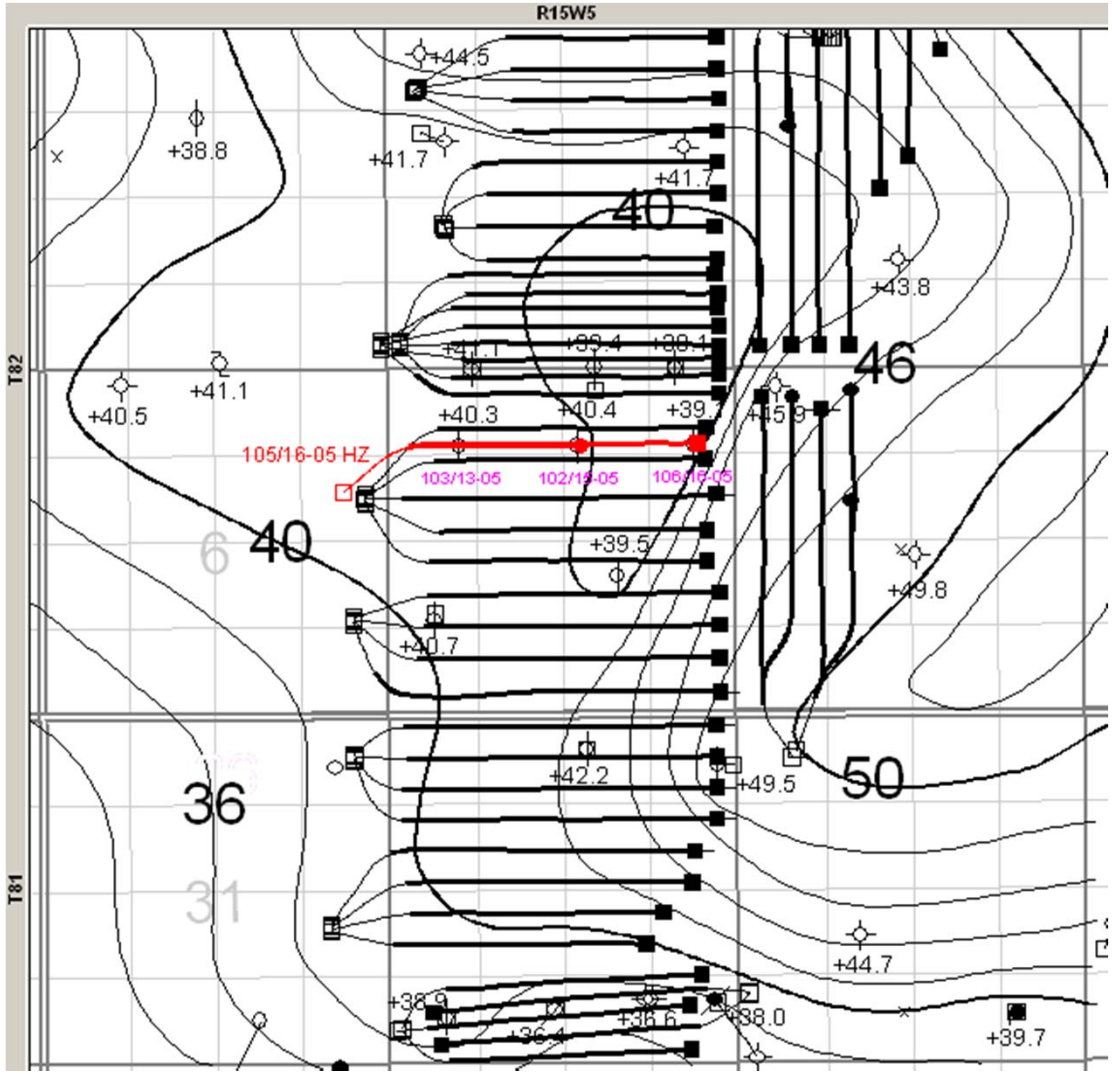
geoSCOUT

By : JW | Date : 2011/11/02

Scale = 1:20000 | Project : Seal Regional O

Geology – Base Bluesky Structure

PennWest



PennWest Exploration

Base Bluesky Structure (mss)

Licensed to : Penn West Petroleum

geoSCOUT

By : JW | Date : 2012/01/10

Scale = 1:20000 | Project : Seal Regions

Geology – Net Pay Map

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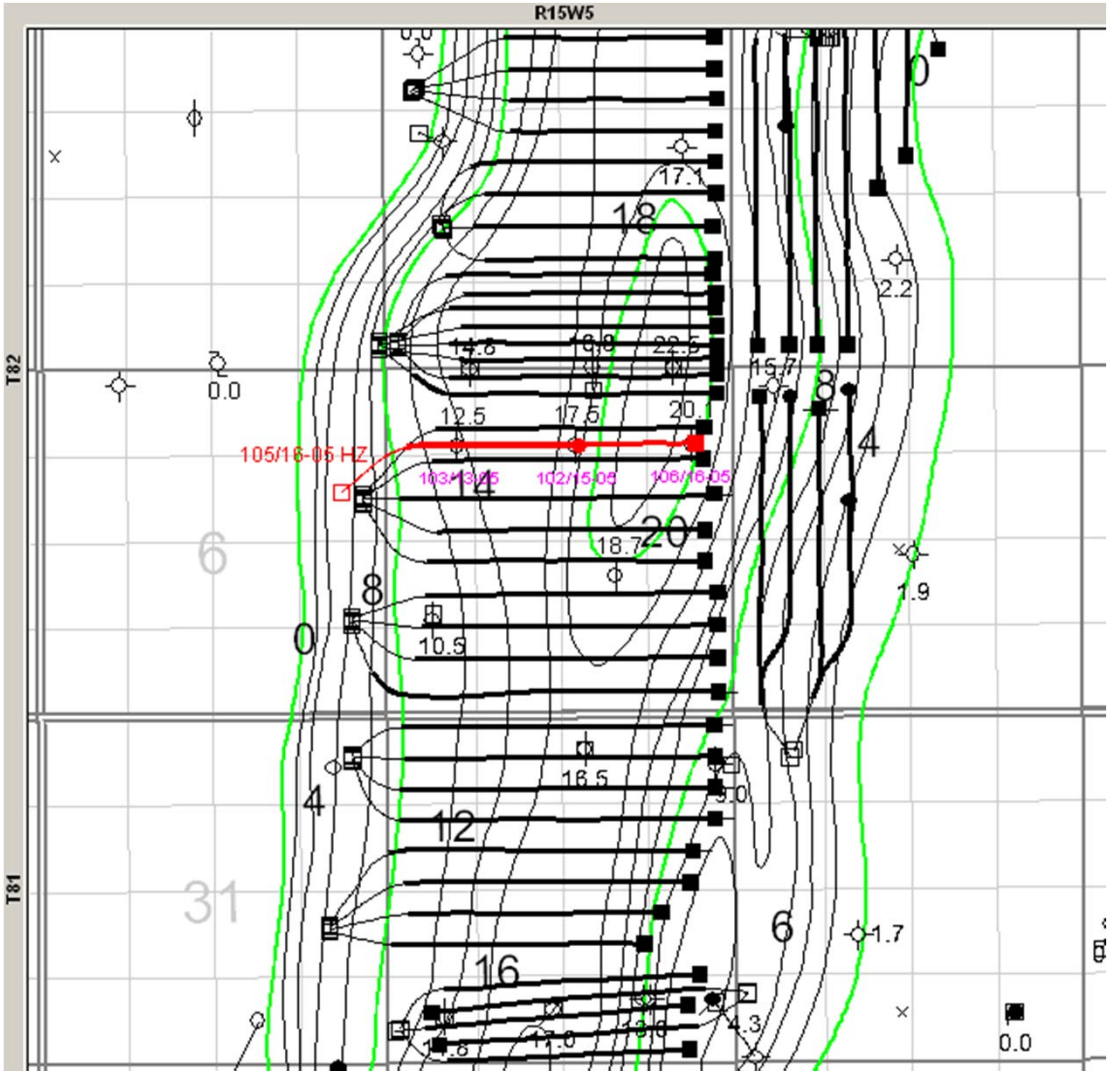
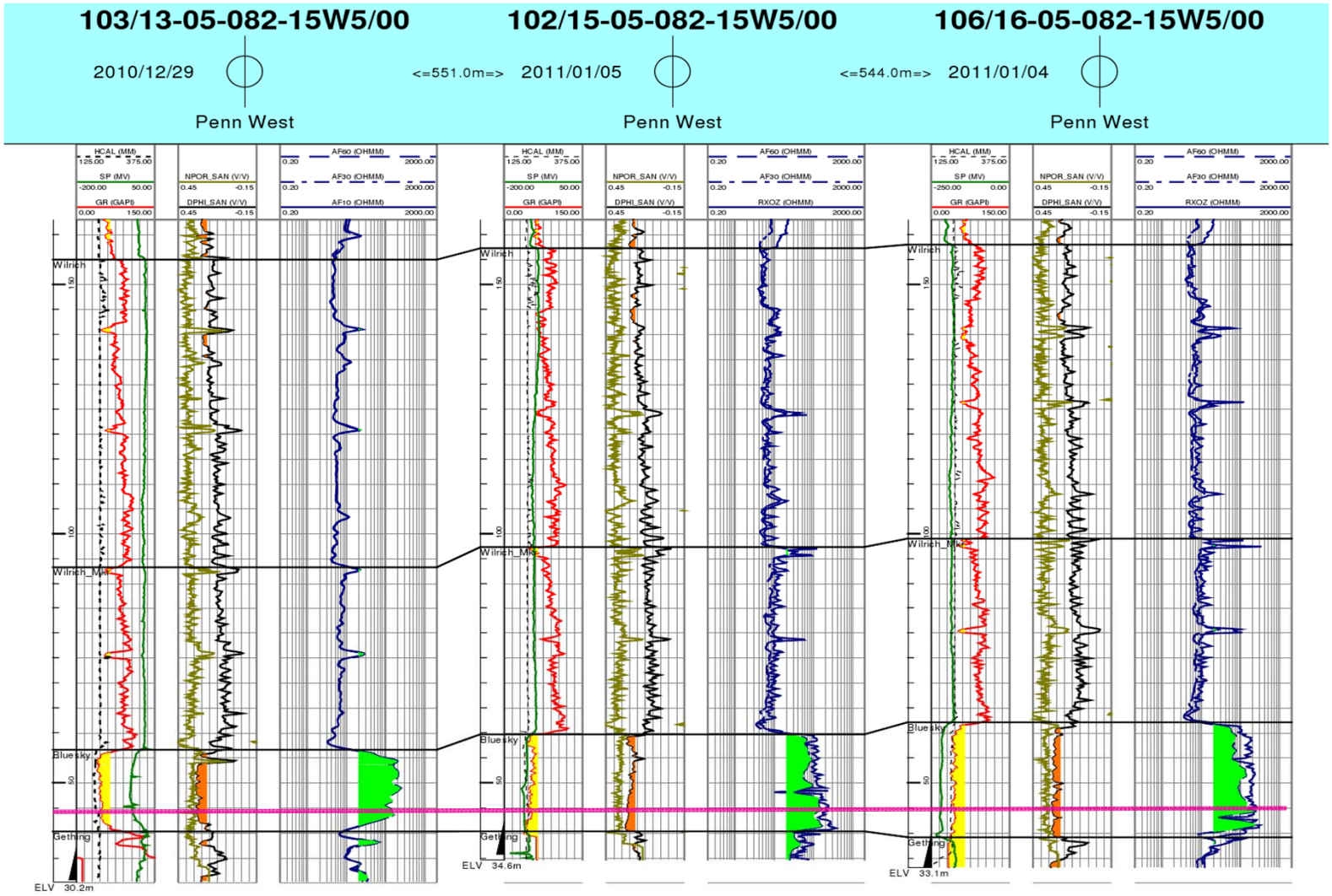


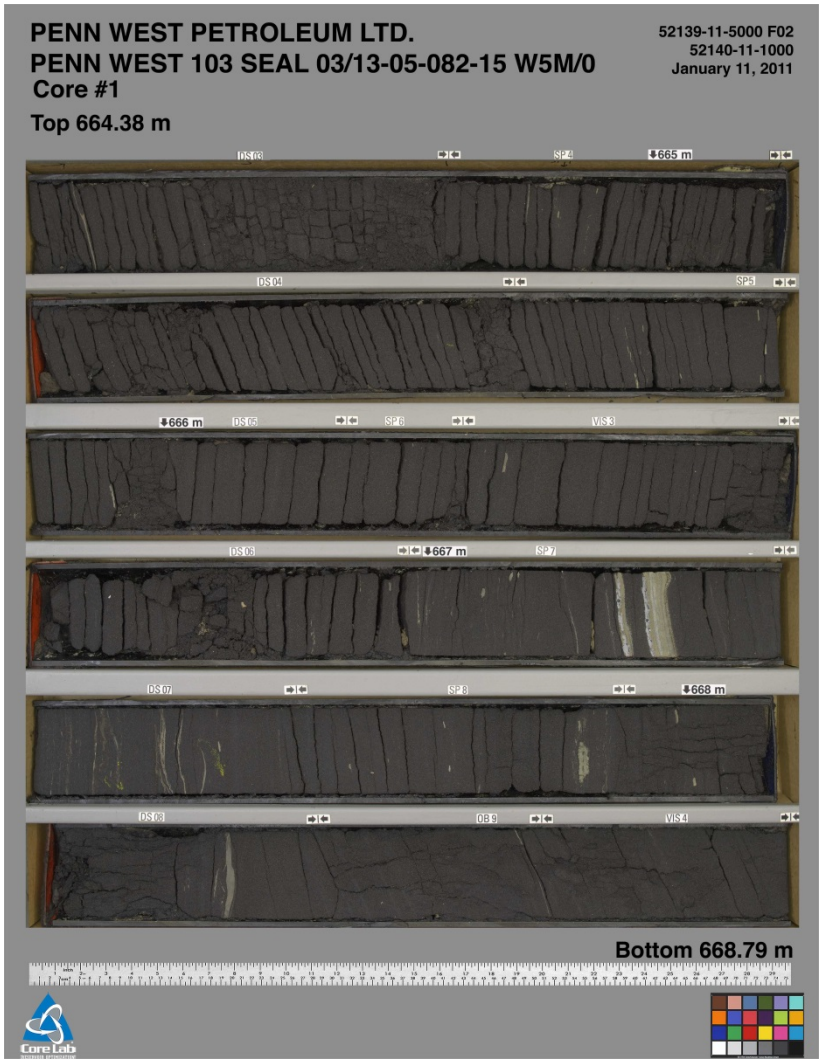
Geology – Structural Cross-Section

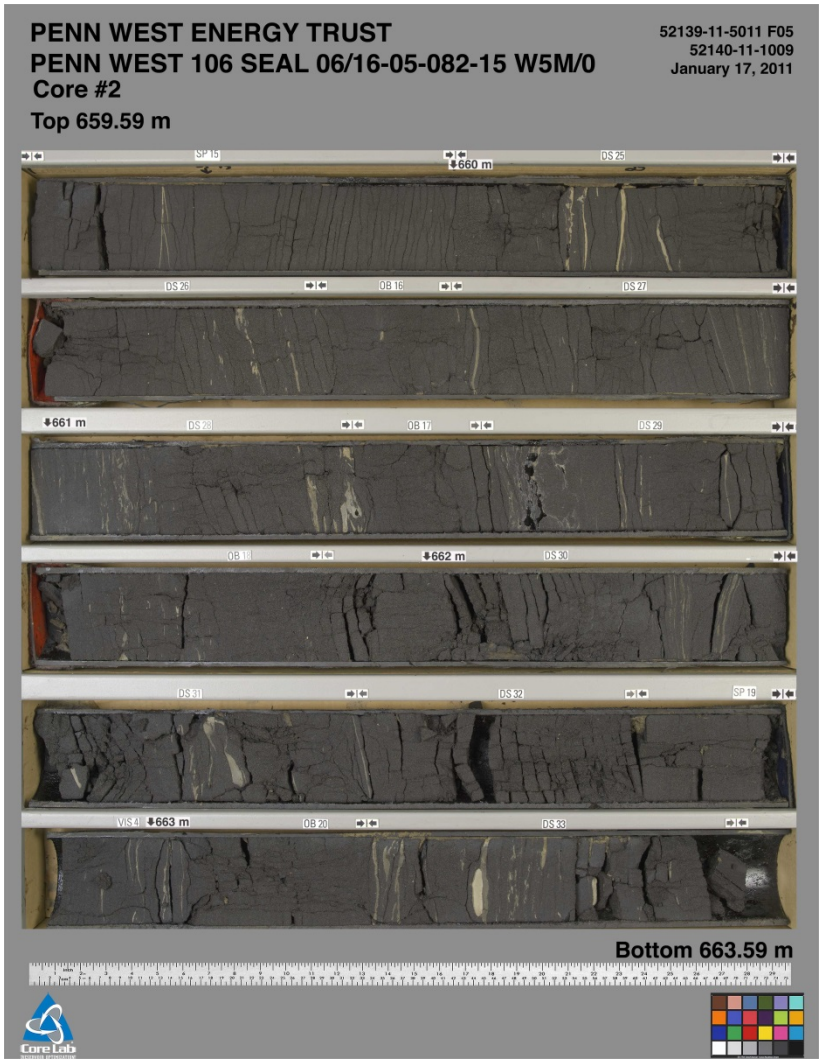
PennWest



Geology – Core Photos

PennWest





Geology – Cutoff Criteria

PennWest

- **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.**

Geology – Average Reservoir Properties

PennWest

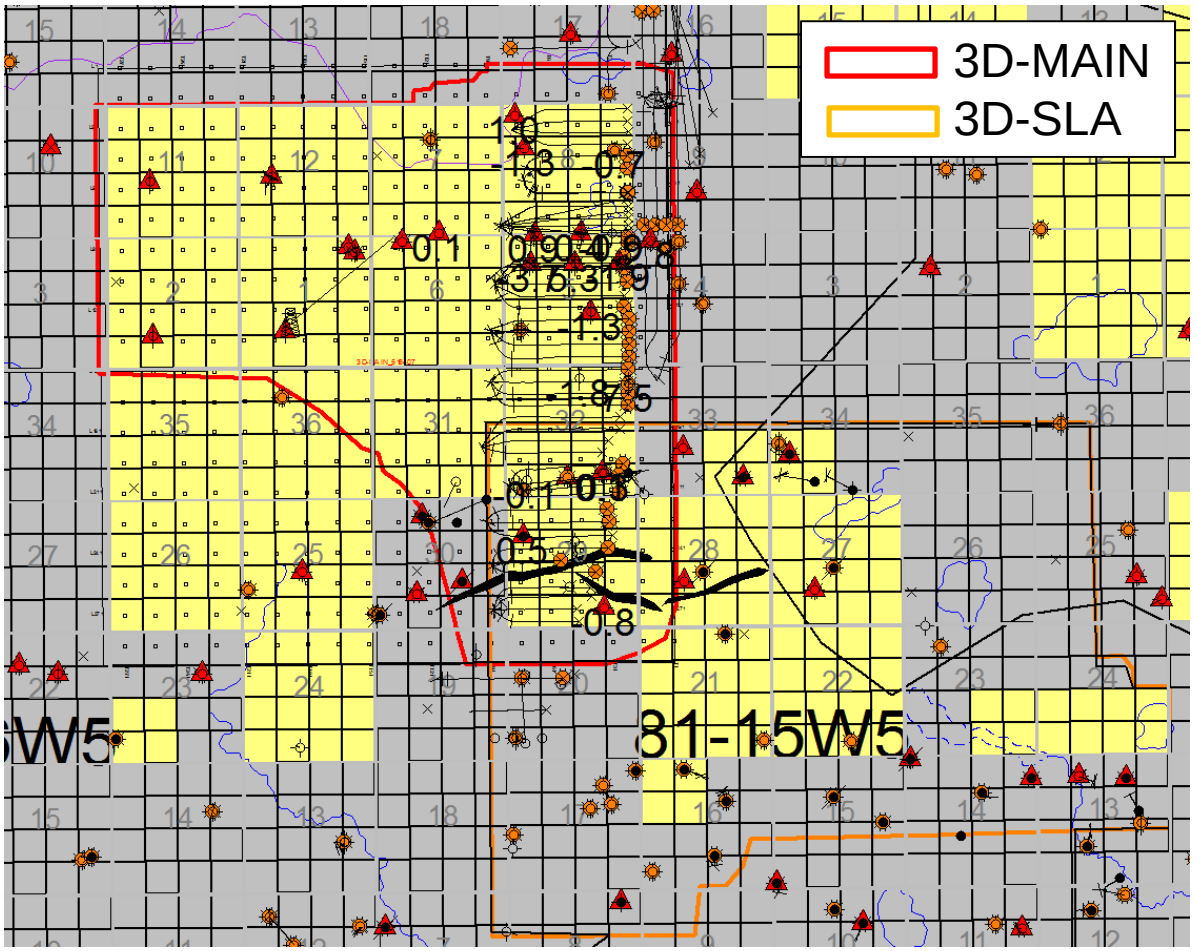
Net pay (m)	18.6
Area (ha)	20.3
Porosity (%)	27
Water Saturation (%)	21.6
Formation Temperature (˚C)	20
Formation Pressure (kPa)	4,670
Viscosity (cSt at 20^{o}C)	16,950
Permeability (mD)	2,615
Formation Volume Factor	1.02
OBIP (e^3m^3)*	782

*Based on the area immediately around the pilot well bounded by the adjacent primary wells

Geology – 3D Seismic

PennWest

- 3D-Main
  - Shot in February 2008
  - Processed in February 2008
- 3D-SLA
  - Shot in January 1999
  - Reprocessed in July 2009



Geology – Fracture Pressure

PennWest

- 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:

Stress Gradient Source	Stress Gradient kPa/m
Overburden stress (from density log)	21.3
Overburden stress (from minifrac) in Wilrich	21.4
Minimum horizontal stress in Wilrich	22.3
Minimum horizontal stress in Bluesky	18.6

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

Subsurface Agenda

PennWest

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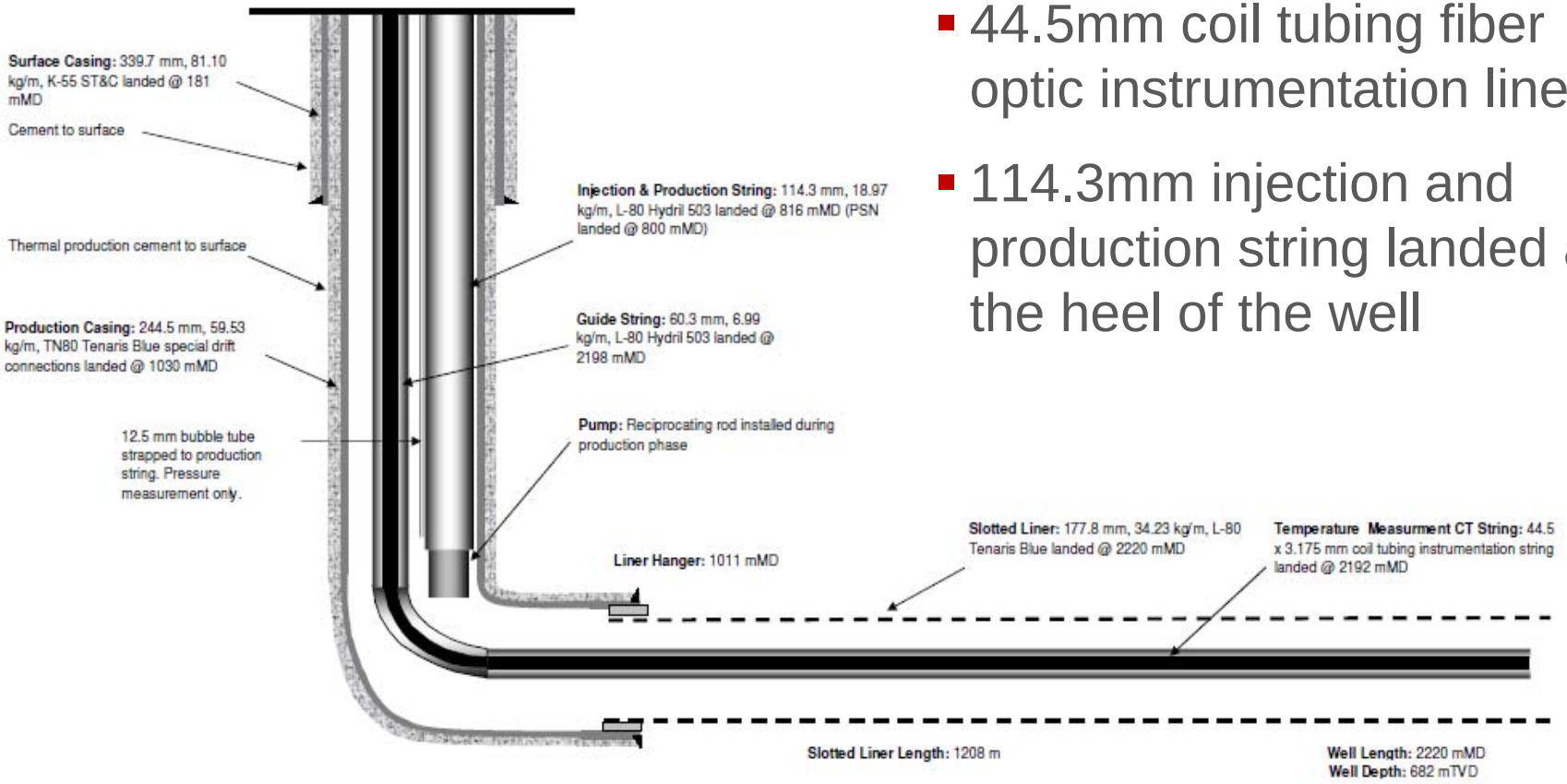
Drilling and Completions – Wellbore Design

PennWest



- 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

PennWest

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Artificial Lift

PennWest

- 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 m^3/d total fluids was installed
- For the third production cycle, a 220 MET 1000 PCP was installed
  - Intended to prove technology for future use in commercial development
  - Rated for temperatures to 350°C
  - Good success to date

Subsurface Agenda

PennWest

1. Background
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5. **Well Instrumentation**
6. 4D Seismic
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Well Instrumentation – Pilot Well

PennWest

- 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 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 N_2 purge from surface

Well Instrumentation – Observation Wells

PennWest

- 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

Subsurface Agenda

PennWest

1. Background
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6. **4D Seismic**
7. Scheme Performance
8. Future Plans

4D Seismic

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- No current plans to conduct 4D seismic at Seal Main Pilot Project

Subsurface Agenda

PennWest

1. Background
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5. Well Instrumentation
6. 4D Seismic
7. **Scheme Performance**
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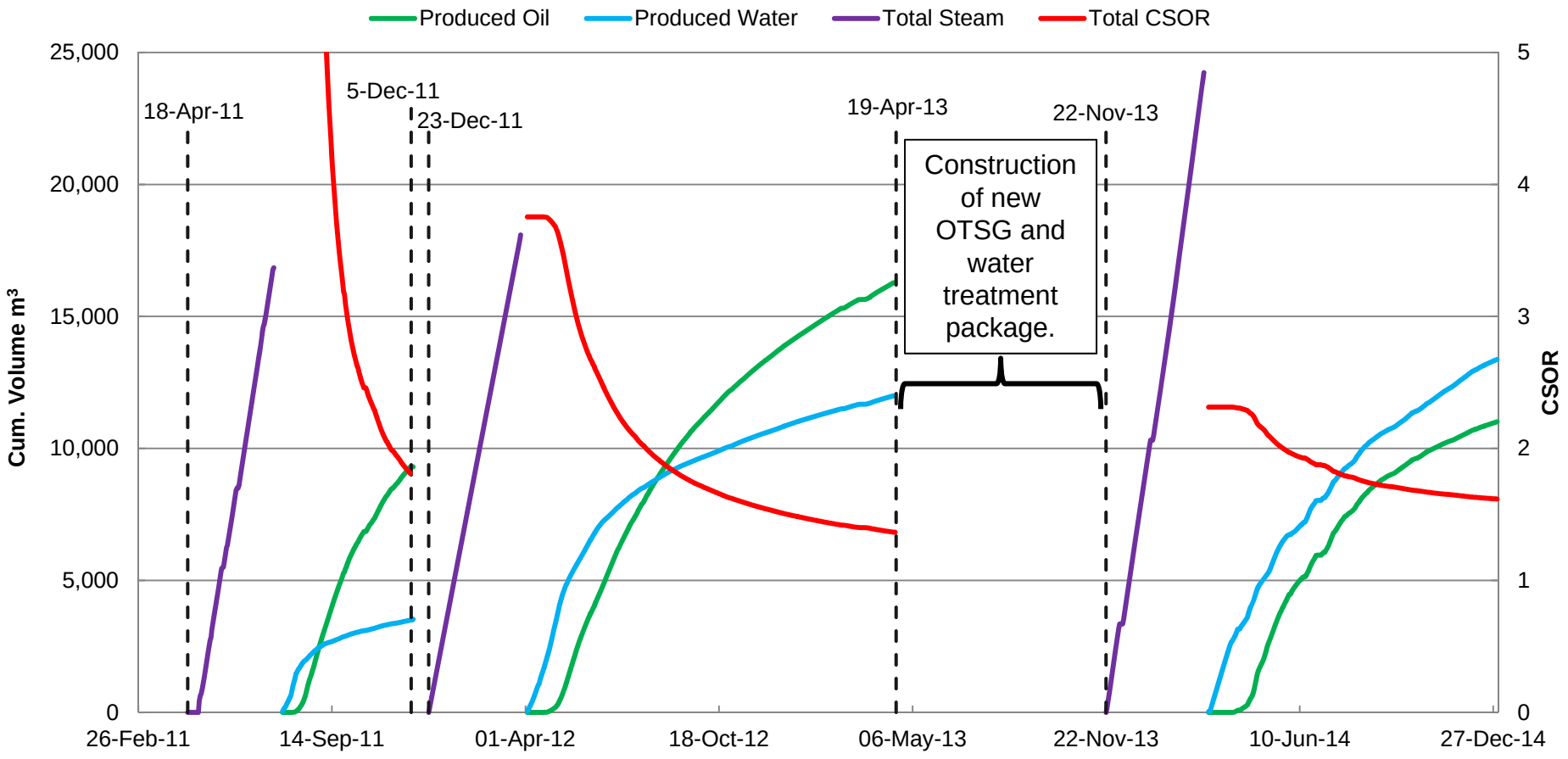
Scheme Performance – Cumulative Volumes

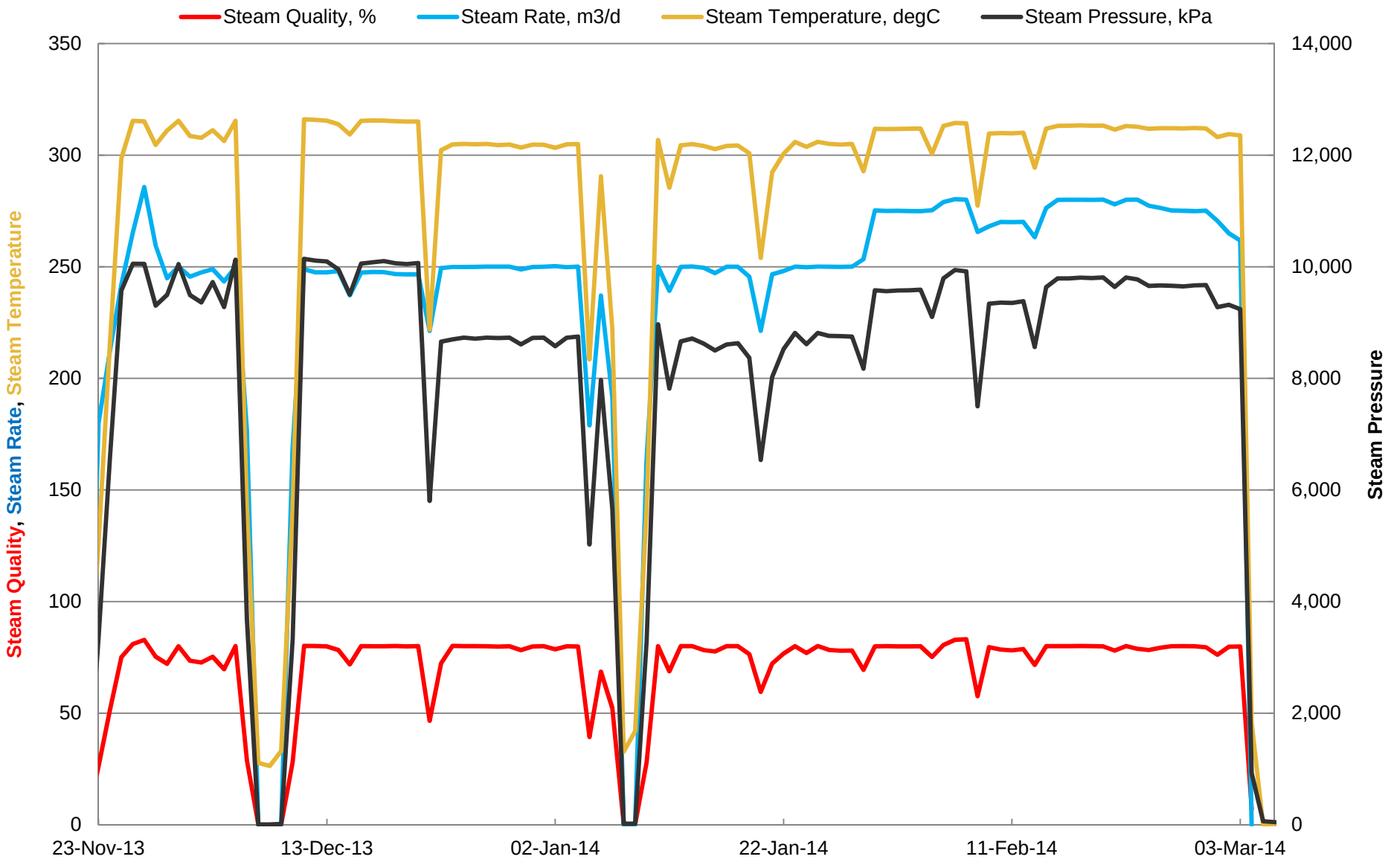
PennWest

	Steam	Oil	Water	Gas	CSOR
1st cycle	16,840 m^3	9,304 m^3	3,280 m^3	135.7 e^3m^3	1.81
2nd cycle	18,086 m^3	13,188 m^3	10,465 m^3	417.6 e^3m^3	1.37
3rd cycle	23,713 m^3	11,008 m^3	13,369 m^3	993.6 m^3	1.75



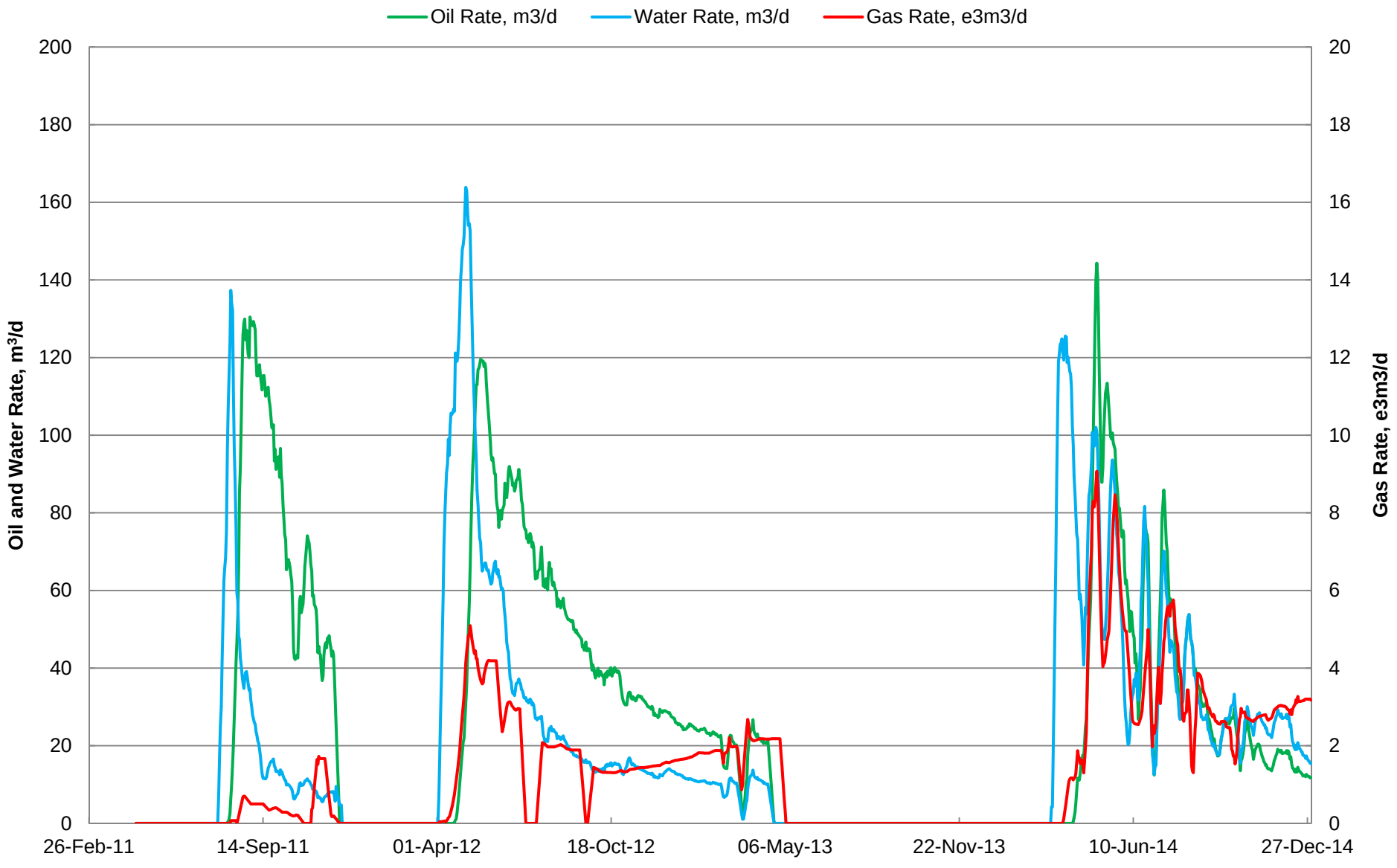
Scheme Performance – Steam Cycle 3

PennWest

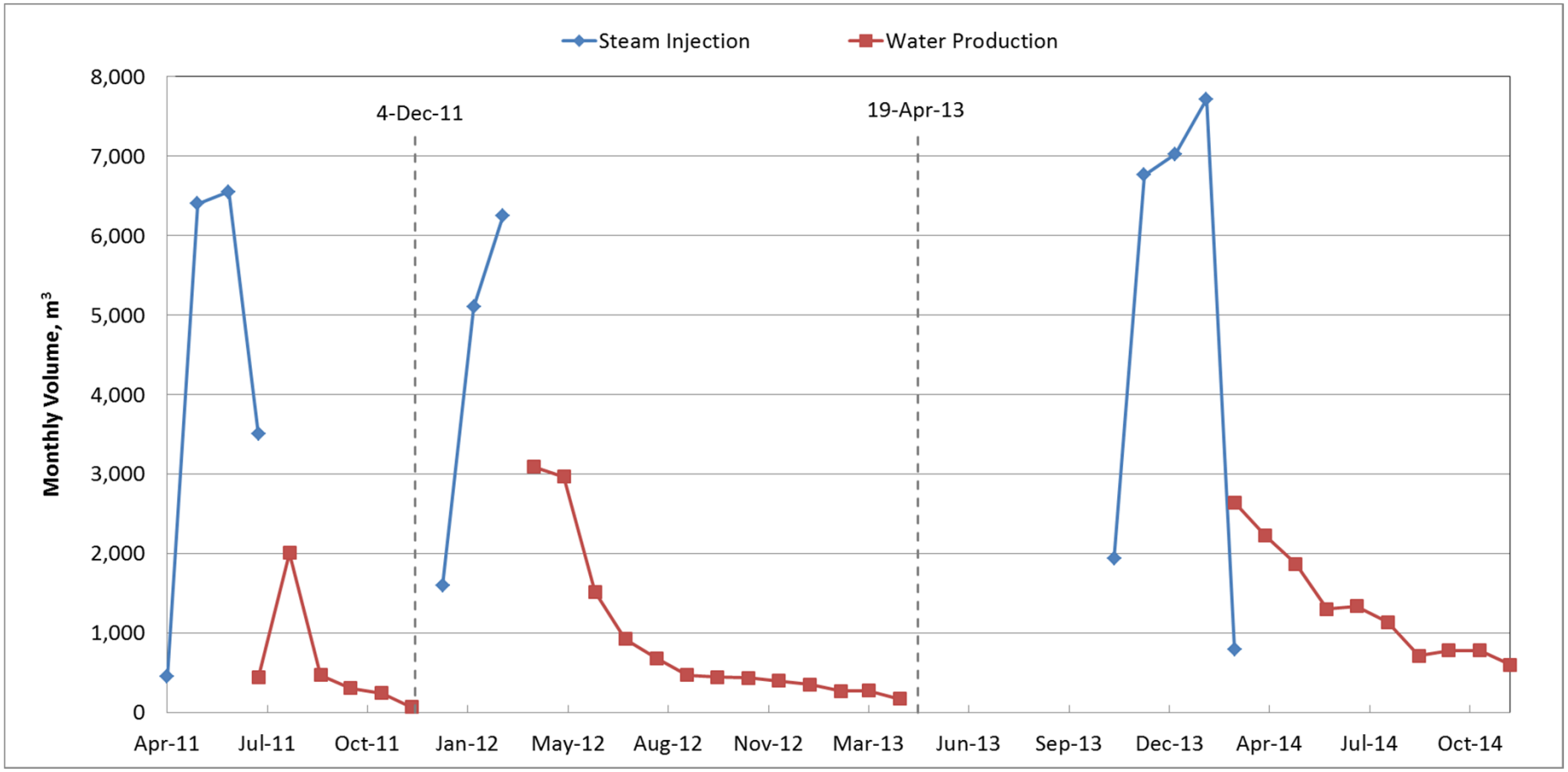


Scheme Performance – Production Rates

PennWest



Scheme Performance – Monthly Injection and Water Production



Scheme Performance – Observation Wells 103/13-05-082-15W5

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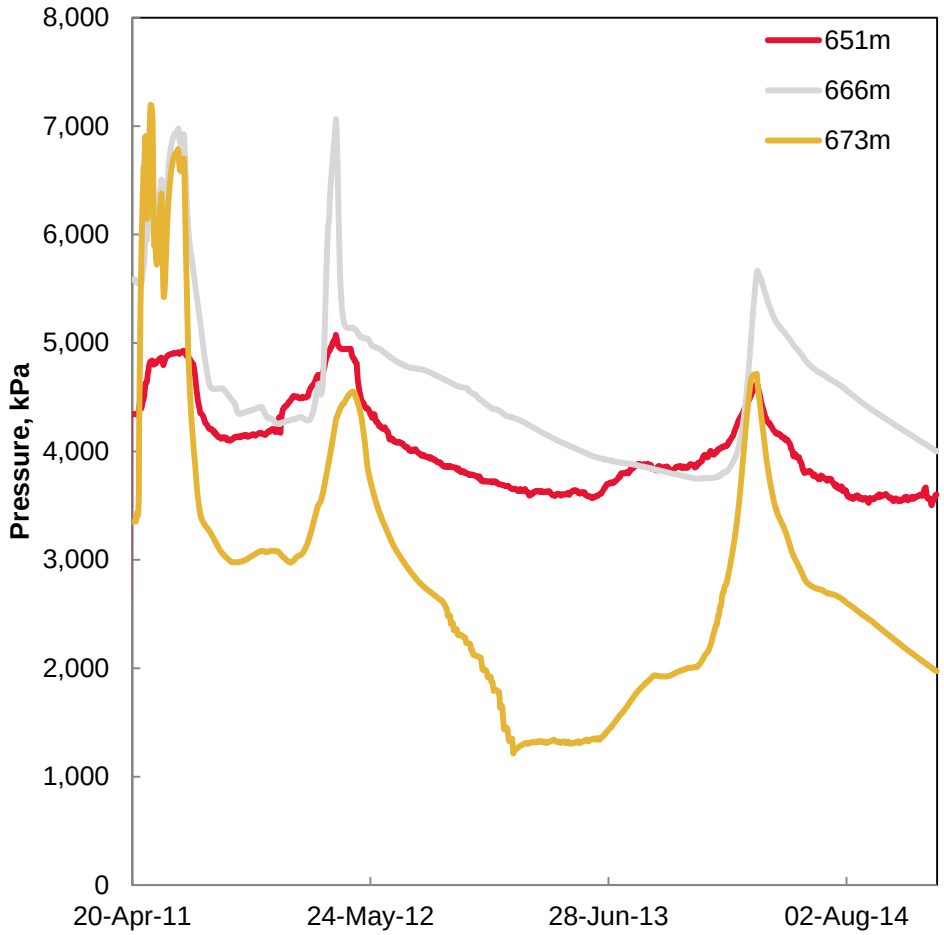

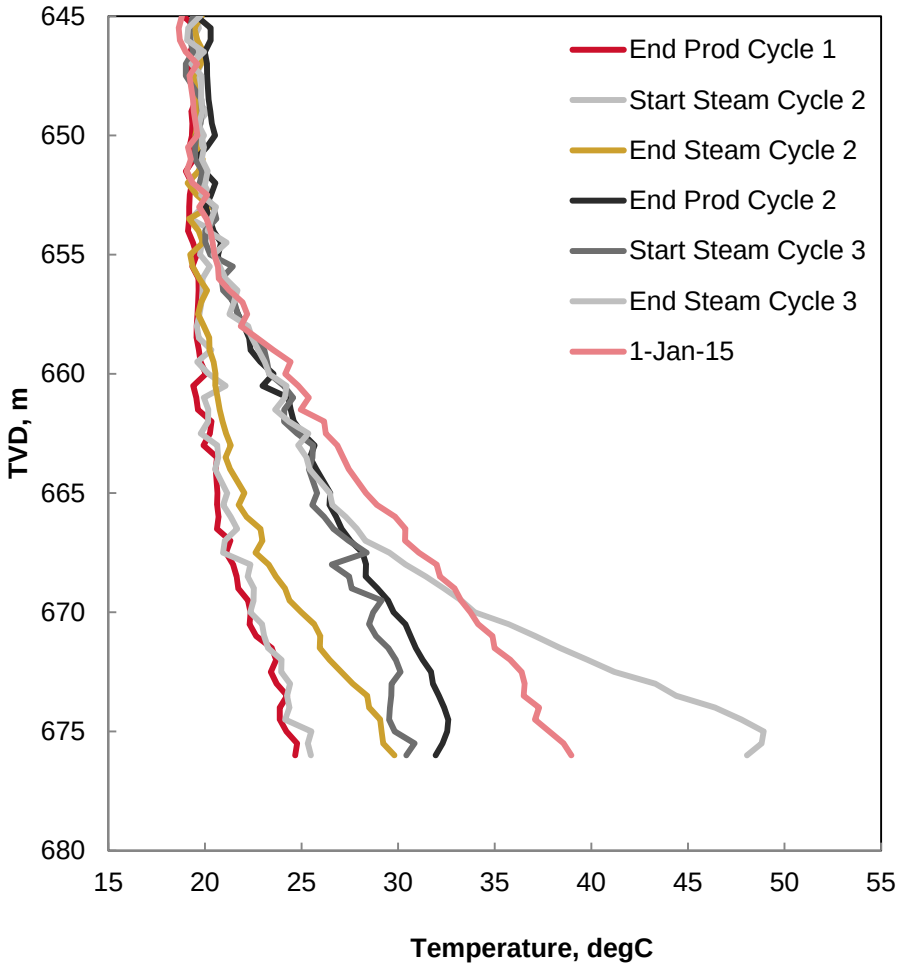

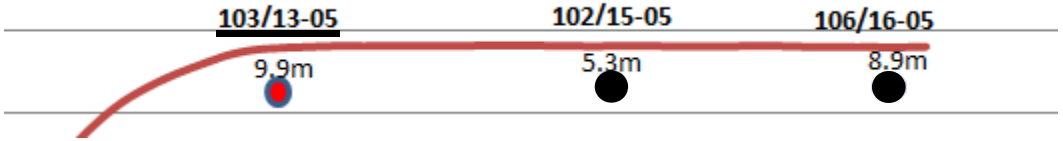

Scheme Performance – Observation Wells 102/15-05-082-15W5

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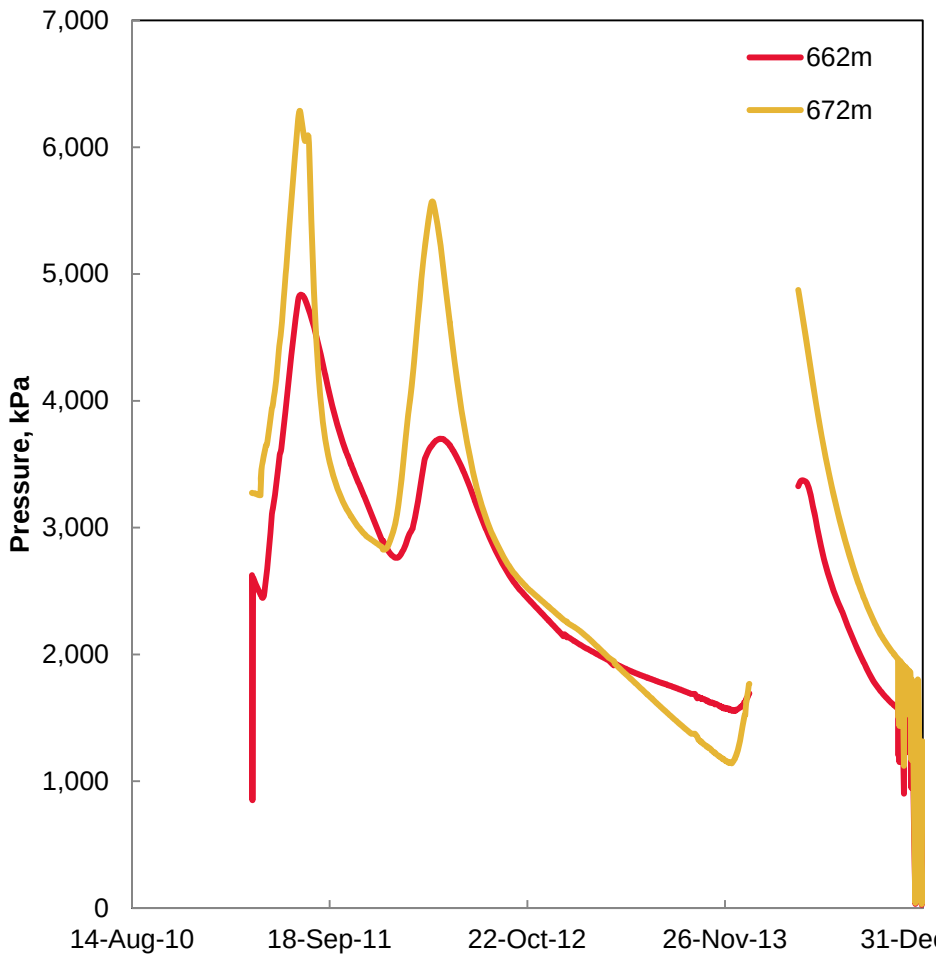
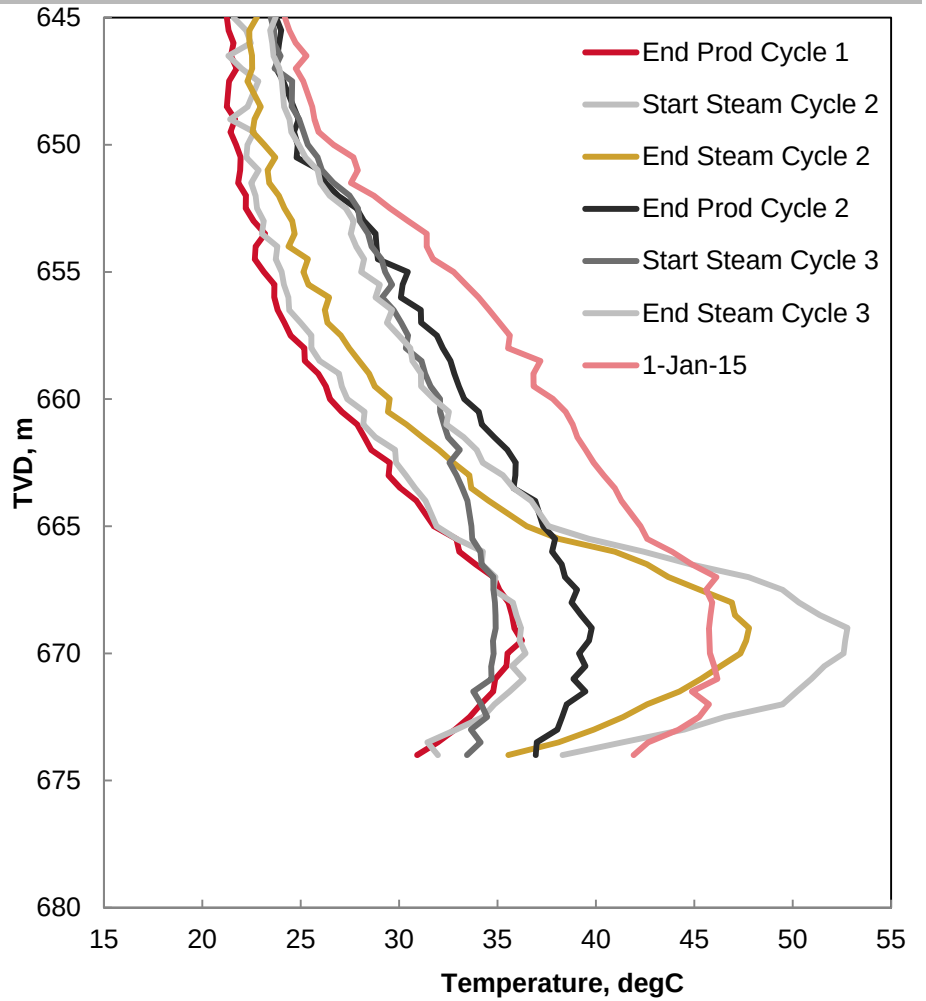
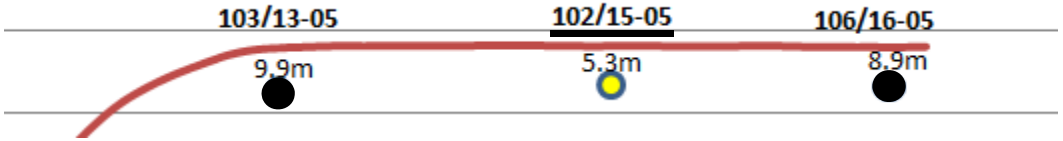
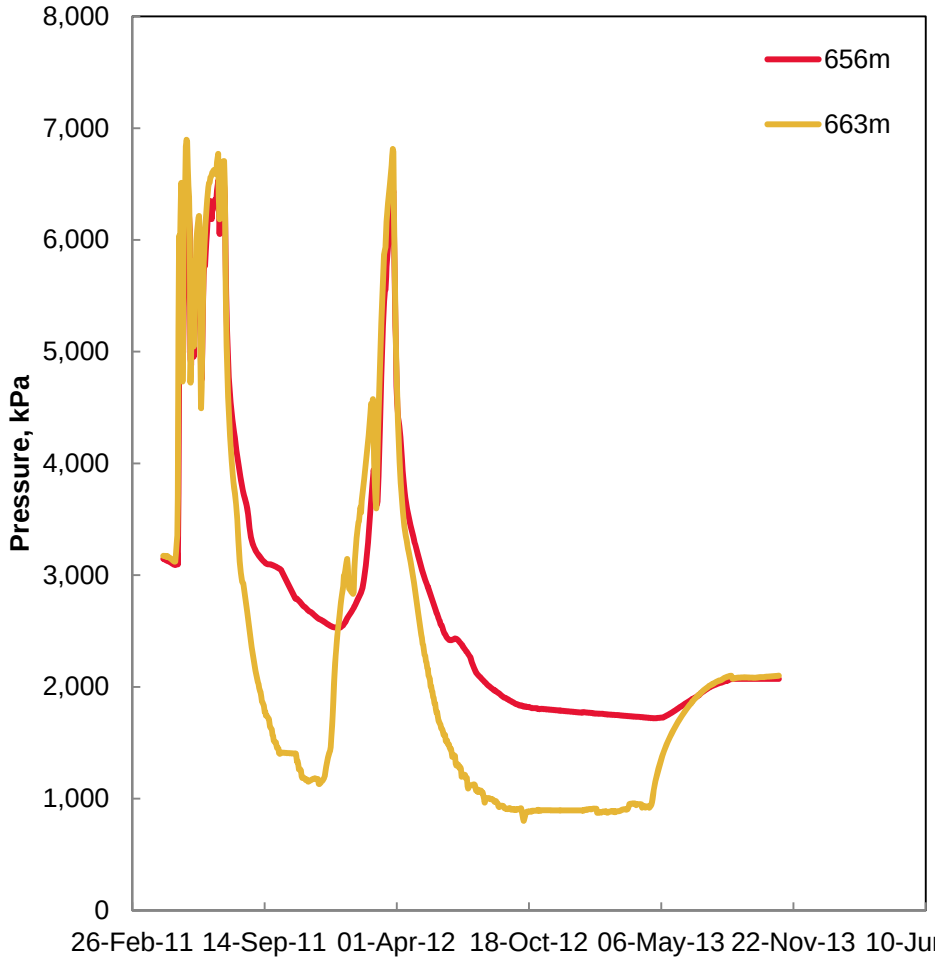


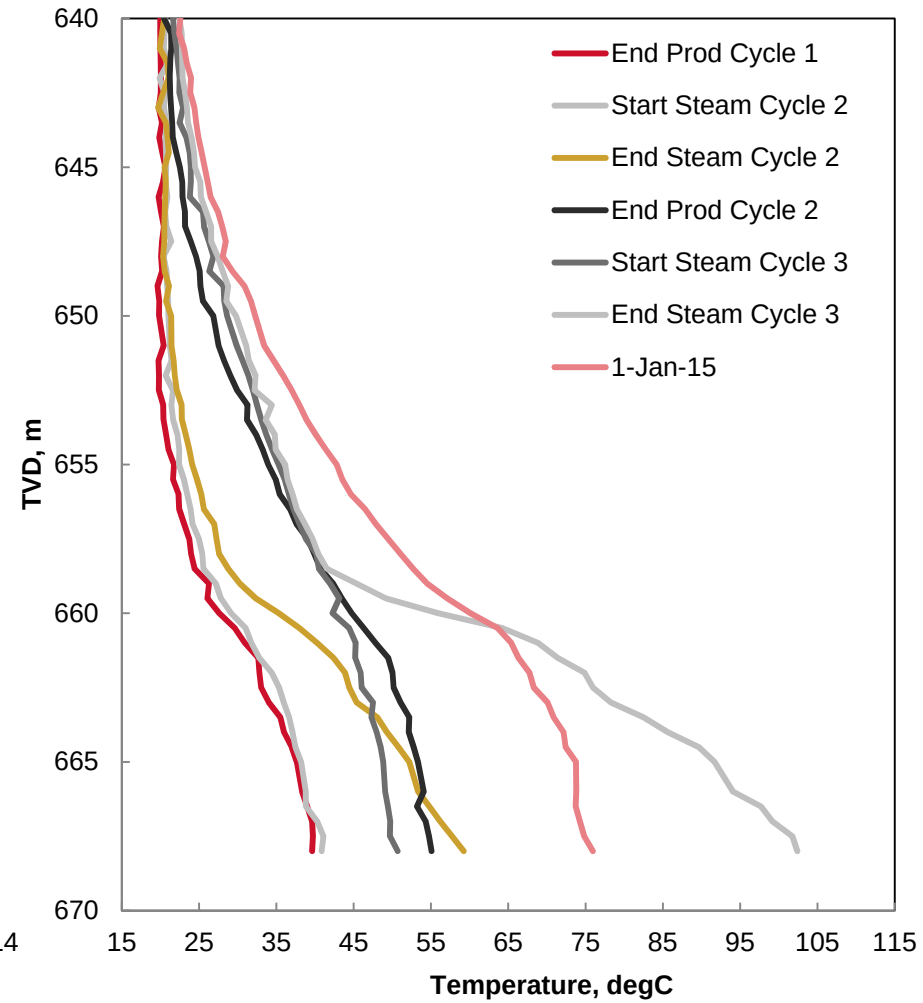


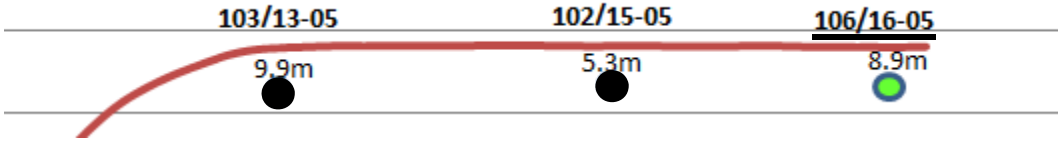


Scheme Performance – Observation Wells 106/16-05-082-15W5

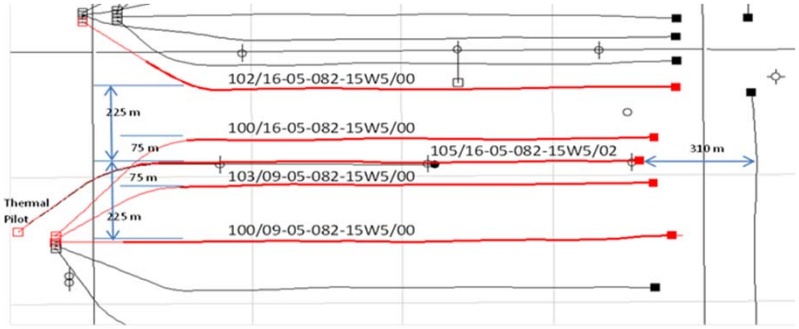
PennWest



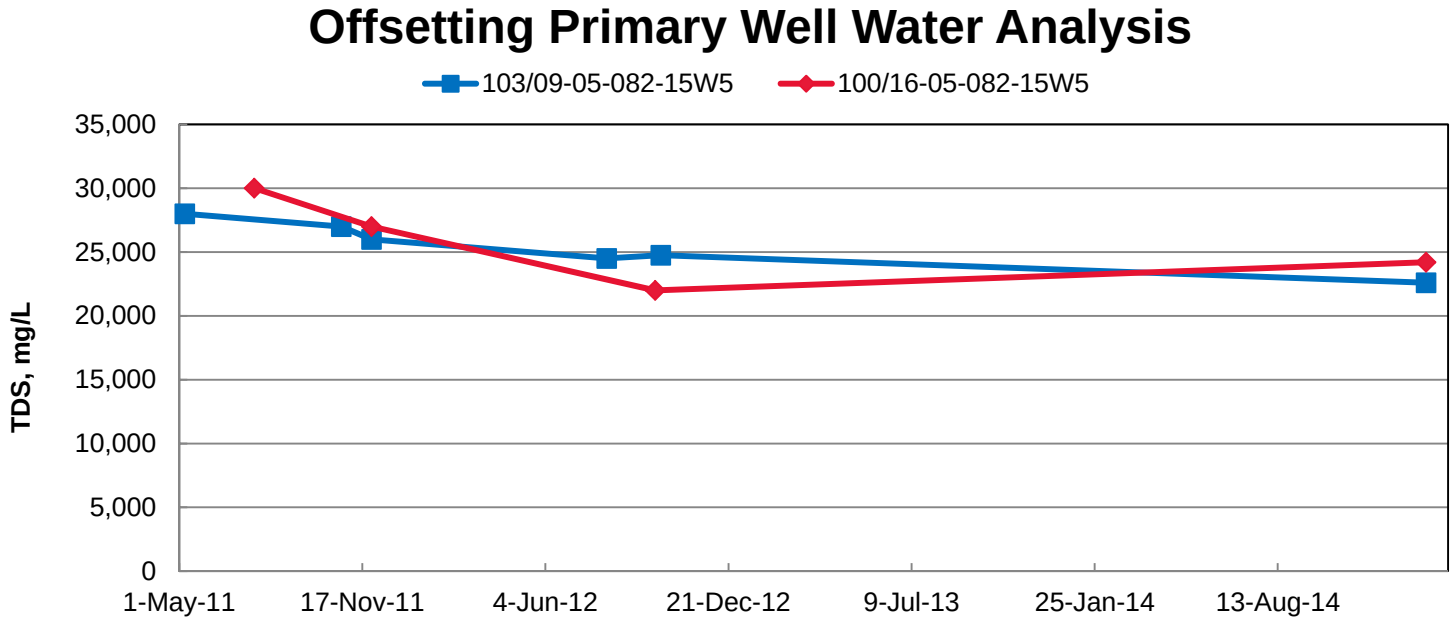




Scheme Performance – Adjacent Primary Wells



- Two adjacent primary producers (75m away from the pilot well) demonstrate a slight decrease in TDS of the produced water, which may indicate fluid migration.



Scheme Performance – Recovery Factor

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Cycle 1 Production, m^3	9,304
Cycle 2 Production, m^3	13,188
Cycle 3 Production to Date, m^3	11,008
Total Production to Date*, m^3	**33,500**
OBIP, m^3	782,000
Current Recovery, %	4.3%
Estimated Ultimate Recovery, %	12%

*Includes only thermal production.

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Future Plans

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- Currently progressing Seal Main Commercial Application
  - Submitted Third SIR Responses in November 2014
- Intend to start steam cycle 4 on pilot well in Q2 2015
  - Steam cycle of approximately 120 days, followed by production cycle 4
- Evaluating project economics in light of current market conditions
- Continuing to evaluate pilot results

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Seal Main HCSS Pilot Surface Review

Surface Agenda

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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

Surface Agenda

PennWest

1. **Facilities**
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Facilities – Pilot Plot Plan

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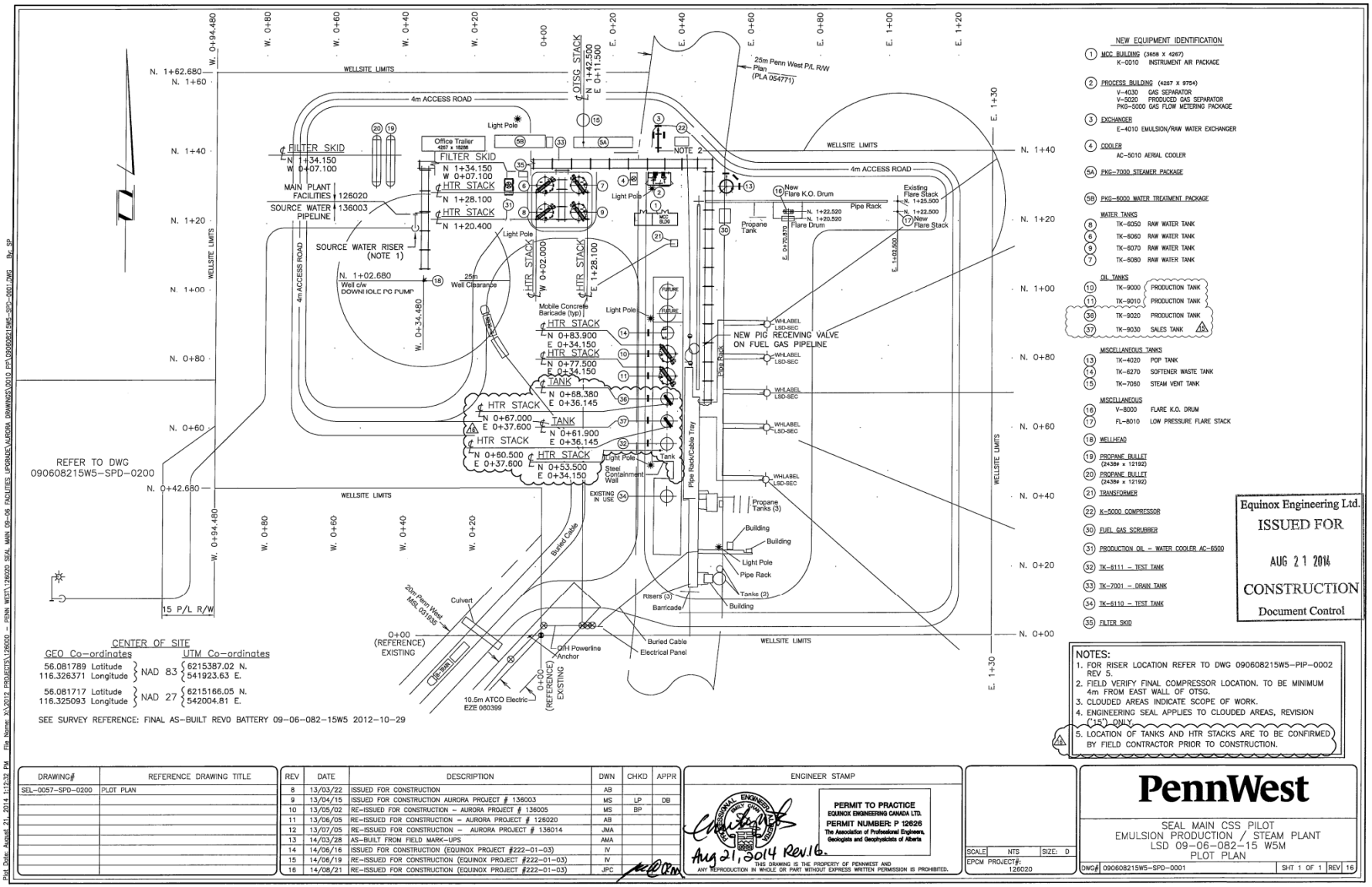

Facilities – Process Flow Diagram

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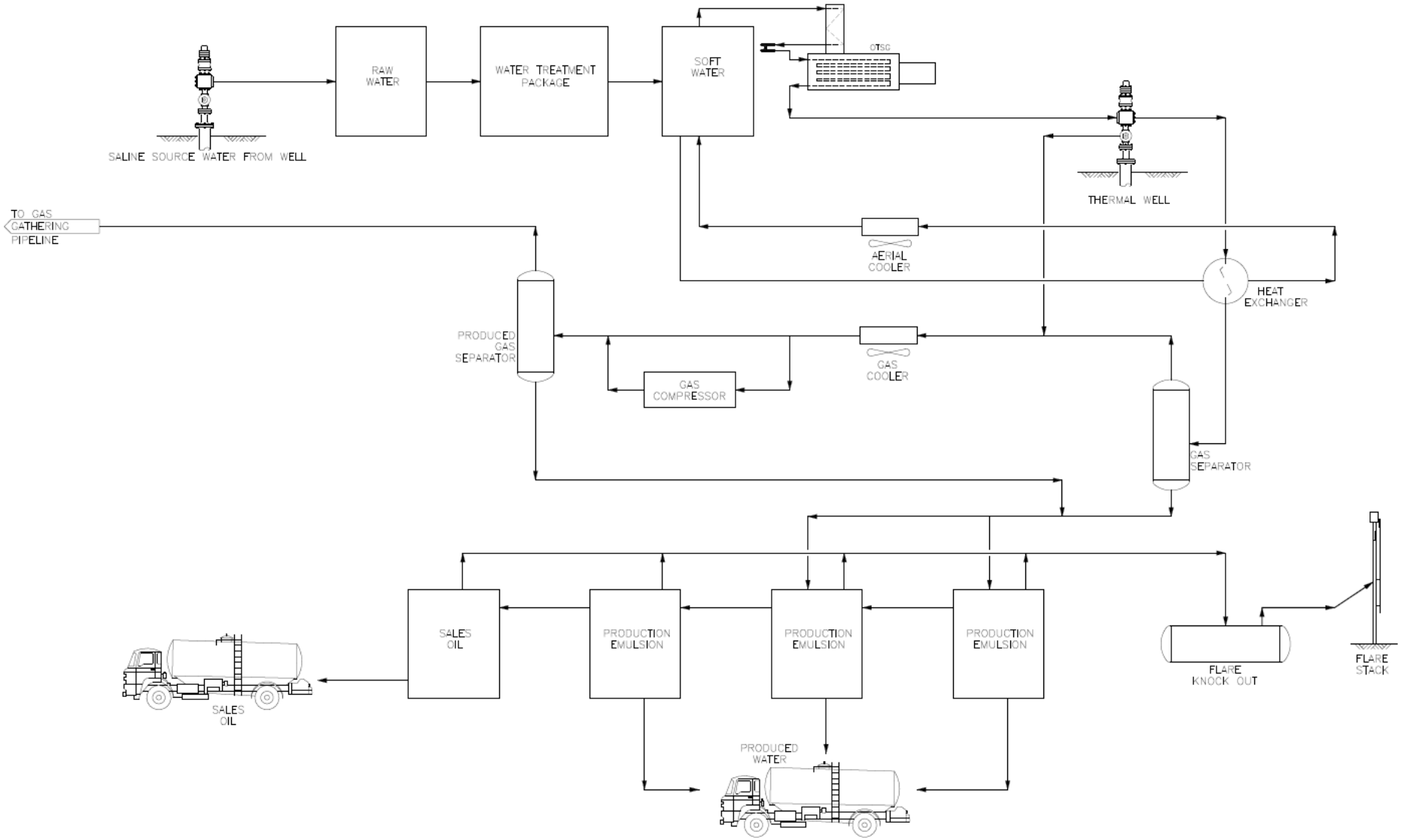

Facilities – Water Treatment System

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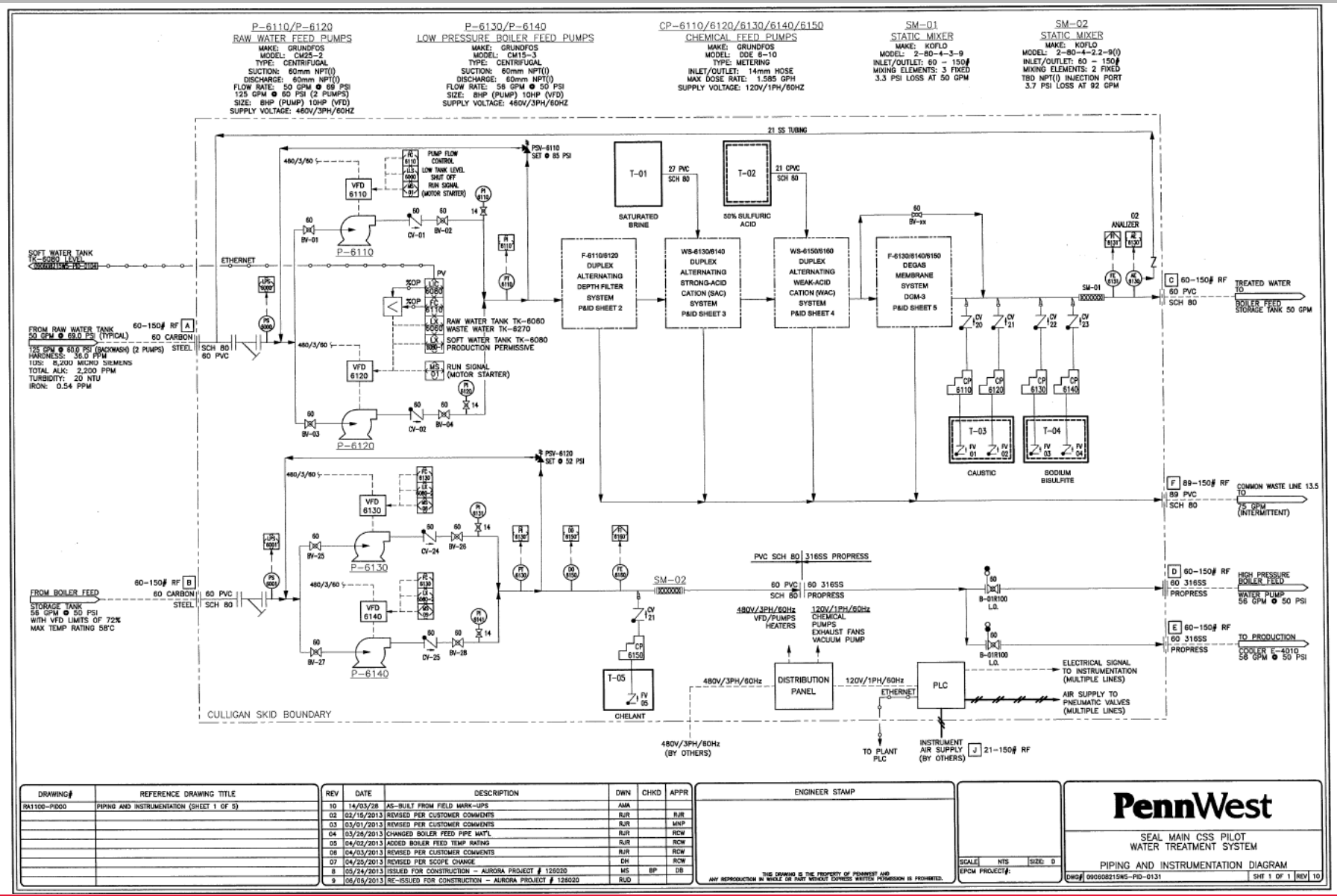

Facilities - Modifications

PennWest

- Drilled source water well on lease (bottomhole location 01-07-082-15W5) and connected to existing facility via pipeline to reduce operating costs for the new cycles.
- The new Once-Through Steam Generator (OTSG) package has been installed together with new water treatment package.
- The new aerial cooler has been installed to cool down the returned water to soft water tank.
- For the following cycles, the fuel gas from 13-08-082-15W5 (via an existing fuel gas pipeline) is going to replace Propane to conserve gas in the area and decrease operating costs. The fuel gas scrubber has been added to the system to remove any moisture.
- Added two new emulsion tanks and connected in cascade system with two existing emulsion tanks to be able to produce sales spec oil and reduce operating costs – both on trucking and treating.

Facility Performance

PennWest

- Bitumen Treatment:
  - Off-spec oil trucked to Tervita oil cleaning facility
  - Following the addition of two additional emulsion tanks, 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

Facility Performance

PennWest

- Other Equipment:
  - Heat exchanger did not perform as designed due to corrosion, downtime required to clean and repair
  - Significant work required to swing wells from steam to production service
    - In the future, use spectacle blinds instead of removable spools
- Flare Knock-Out Drum was not fitted with a separate liquid transfer pump, vacuum truck used as a solution
- Many systems have no redundancy due to design as pilot facility
- Casing gas compressor in operation

Facility Performance – Power Consumption

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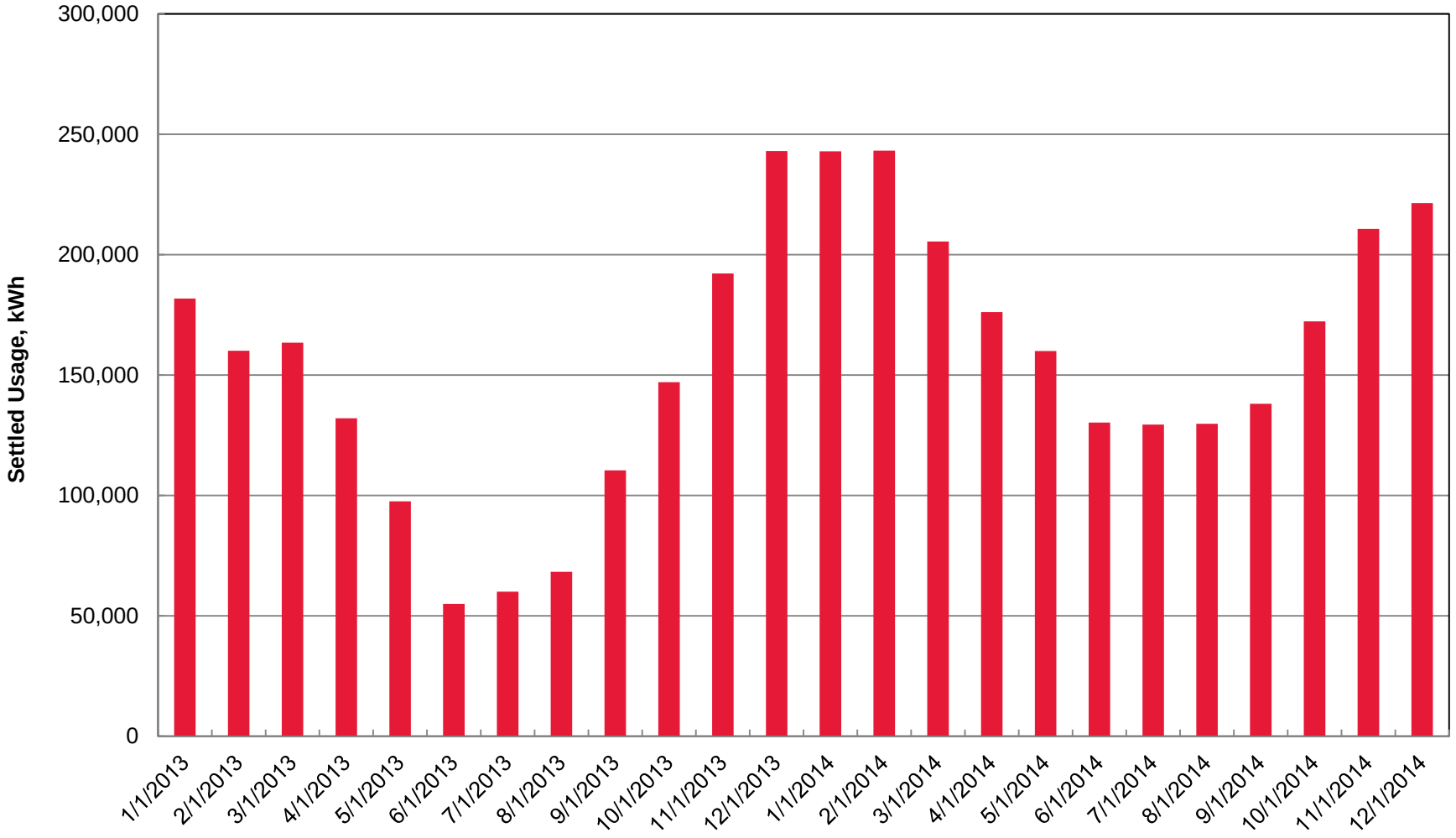

Seal Main Thermal Pilot imports and consumes power from the electrical grid.

Facility Performance – Fuel Use

PennWest

Month	Purchased Gas e^3m^3	Vent Gas e^3m^3	Flare Gas e^3m^3	Produced Gas e^3m^3	Produced Gas Recovery %
Jan-13	0	0	4	57.6	93%
Feb-13	0	0	3	55	94%
Mar-13	0	0	3	62.3	96%
Apr-13	0	0	2	67.2	97%
May-13	0	0	0	0	0%
Jun-13	0	0	0	0	0%
Jul-13	0	0	0	0	0%
Aug-13	0	0	0	0	0%
Sep-13	36	0	0	0	0%
Oct-13	0	0	0	0	0%
Nov-13	179	0	0	0	0%
Dec-13	567	0	0	0	0%
Jan-14	598	0	0	0	0%
Feb-14	668	0	0	0	0%
Mar-14	81	0	1	0.5	0%
Apr-14	17	0	8	7.8	0%
May-14	15	0	12	11.5	0%
Jun-14	32	0	0	0.1	0%
Jul-14	24	0	0	0.1	0%
Aug-14	32	0	5	0.1	0%
Sep-14	40	0	3	0.1	0%
Oct-14	42	0	3	0.1	0%
Nov-14	45	0	3	2.9	0%
Dec-14	40	0	3	2.3	0%

Surface Agenda

PennWest

1. Facilities
2. **Measurement and Reporting**
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Measurement and Reporting

PennWest

- Updated MARP submitted in August 2014 – Revision 14
- 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

Measurement and Reporting – Water Balance

PennWest

INJECTION FACILITY AB IF 0115838

Month	TOTAL IN m^3	TOTAL OUT m^3	INVENTORY ADJUSTMENT m^3	BALANCE m^3	BALANCE %
Jan-13	0	0	0	0	0.0%
Feb-13	0	0	0	0	0.0%
Mar-13	0	0	0	0	0.0%
Apr-13	0	0	0	0	0.0%
May-13	0	0	0	0	0.0%
Jun-13	0	200	-200	0	0.0%
Jul-13	0	308	-308	0	0.0%
Aug-13	0	0	0	0	0.0%
Sep-13	864	832	32	0	0.0%
Oct-13	378	32	346	0	0.0%
Nov-13	2,482	2,305	177	0	0.0%
Dec-13	6,819	6,794	25	0	0.0%
Jan-14	7,102	7,128	-26	-1	0.0%
Feb-14	7,915	8,175	-259	0	0.0%
Mar-14	744	544	200	0	0.0%
Apr-14	204	161	43	0	0.0%
May-14	0	0	0	0	0.0%
Jun-14	0	70	-70	0	0.0%
Jul-14	0	0	0	0	0.0%
Aug-14	37	267	-230	0	0.0%
Sep-14	0	55	-55	0	0.0%
Oct-14	0	0	0	0	0.0%
Nov-14	0	0	0	0	0.0%
Dec-14	0	0	0	0	0.0%

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Water Use

PennWest

- Source water well: 1F1/01-07-082-15W5
- Water Act Tier 1 Application will be submitted for continued use of this source

	Source Water, m^3
	1F1/01-07-082-15W5
Jan-13	0
Feb-13	0
Mar-13	0
Apr-13	0
Sep-13	0
Nov-13	2,372
Dec-13	6,819
Jan-14	7,102
Feb-14	7,915
Mar-14	744
Apr-14	155
May-14	0
Jun-14	0
Jul-14	0
Aug-14	37
Sep-14	0
Oct-14	0
Nov-14	0
Dec-14	0

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Water Treatment

PennWest

- 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
- Encountered freezing issues with chemicals in the Water Treatment building, and added additional heaters and skirting around the building
- Seal Main Pilot facility does not recycle produced water due to make up water requirements of less than 500 000 m^3/year

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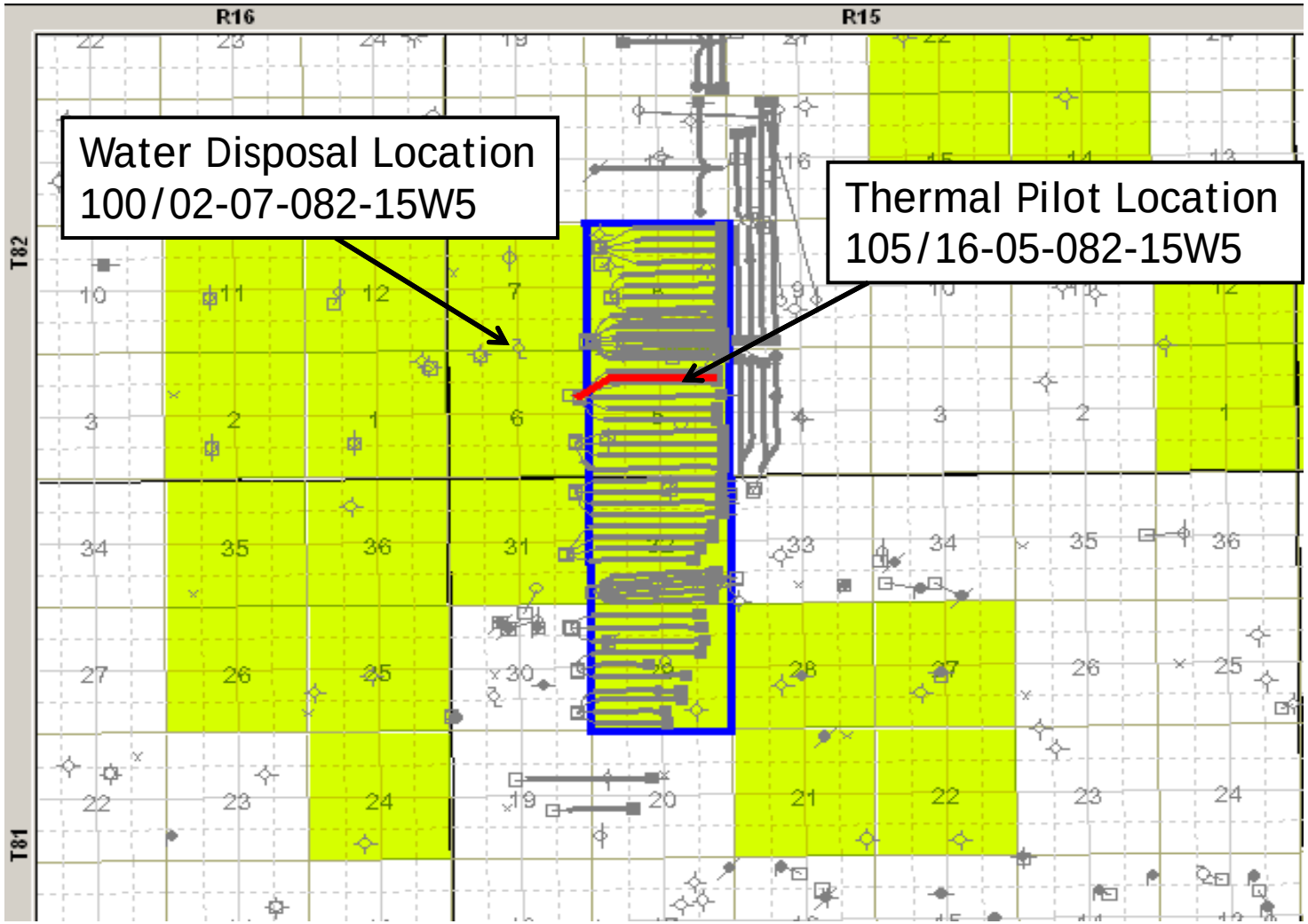
Water and Waste Disposal

PennWest

- 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)
- AER Scheme Approval No. 10213A for disposal into the Debolt Formation in the Peace River Oil Sands Area

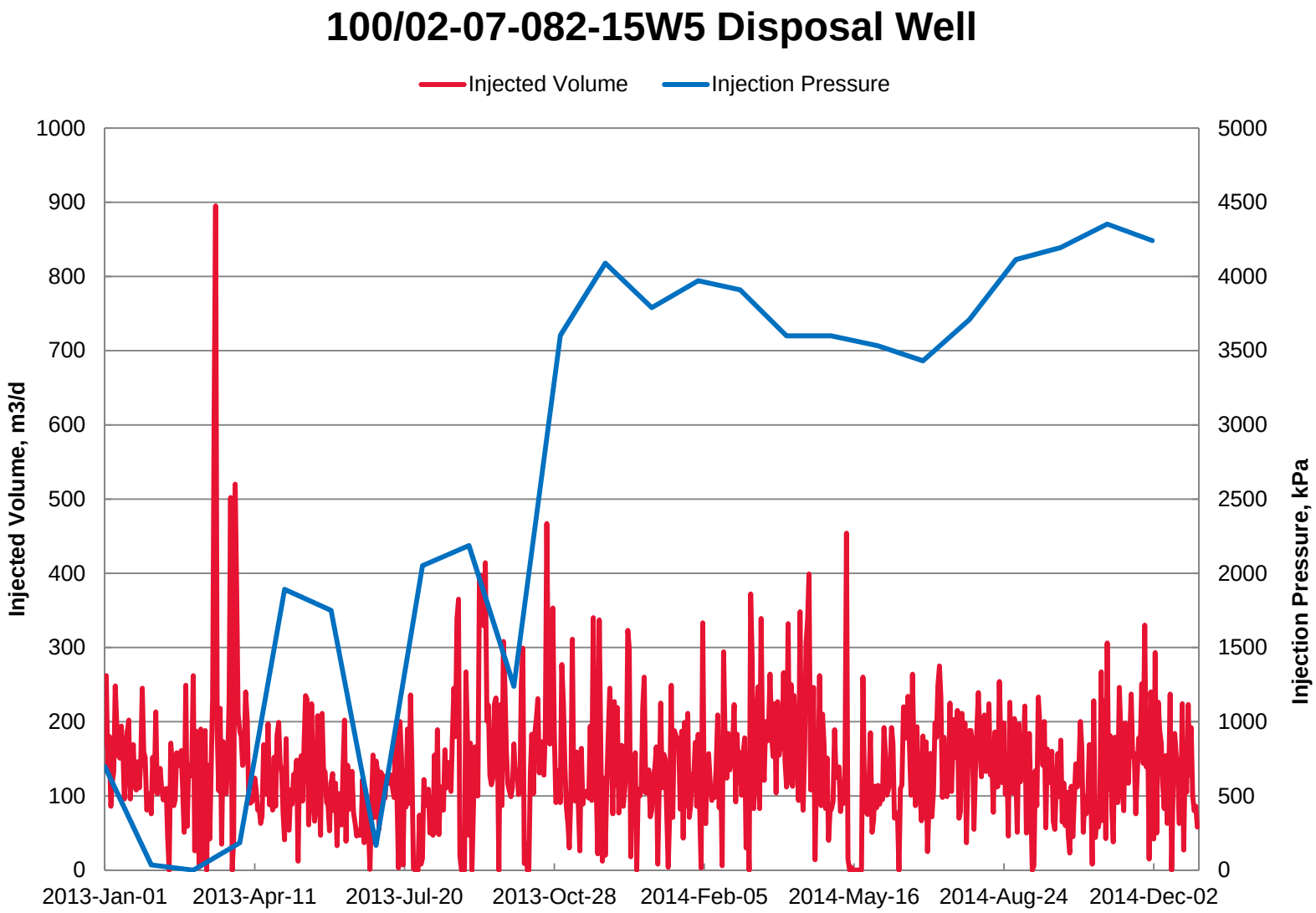
Water Disposal

PennWest



Water Disposal

PennWest



Includes all disposal water injected at 100/02-07-082-15W5

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Sulphur Balance

PennWest

Month	Sulphur Production tonne/d	Sulphur in Flared Gas tonne/d	Sulphur in Recovered Gas tonne/d
Jan-13	0.001	0.0001	0.0007
Feb-13	0.001	0.0000	0.0008
Mar-13	0.001	0.0000	0.0008
Apr-13	0.001	0.0000	0.0009
May-13	0.000	0.0000	0.0000
Jun-13	0.000	0.0000	0.0000
Jul-13	0.000	0.0000	0.0000
Aug-13	0.000	0.0000	0.0000
Sep-13	0.000	0.0000	0.0000
Oct-13	0.000	0.0000	0.0000
Nov-13	0.000	0.0000	0.0000
Dec-13	0.000	0.0000	0.0000

2013 Total Sulphur Production = 0.10 tonne

Month	Sulphur Production tonne/d	Sulphur in Flared Gas tonne/d	Sulphur in Recovered Gas tonne/d
Jan-14	0.000	0.0000	0.0000
Feb-14	0.000	0.0000	0.0000
Mar-14	0.000	0.0000	0.0000
Apr-14	0.000	0.0000	0.0000
May-14	0.000	0.0000	0.0000
Jun-14	0.000	0.0000	0.0000
Jul-14	0.000	0.0000	0.0000
Aug-14	0.000	0.0000	0.0000
Sep-14	0.000	0.0000	0.0000
Oct-14	0.000	0.0000	0.0000
Nov-14	0.000	0.0000	0.0000
Dec-14	0.000	0.0000	0.0000

2014 Total Sulphur Production = 0.01 tonne

Sulphur Sampling

PennWest

- Gas sampling is completed using a supplied gas cylinder under vacuum.
- The sample is taken directly from the wellhead.
- Once charged, the cylinder is submitted for analysis.

SO_2 Emissions

PennWest

- 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_2S) emissions
- Reports submitted monthly

SO_2 Emissions

PennWest

	Peak Reading (ppb)	Average Reading (ppb)
Aug-13	0.5	0.4
Sep-13	0.1	<0.1
Oct-13	0.1	<0.1
Nov-13	0.6	0.4
Dec-13	0.5	0.3
Jan-14	0.2	0.2
Feb-14	0.4	0.2
Mar-14	1	0.6
Apr-14	0.4	0.3
May-14	3	1.7
Jun-14	0.3	0.2
Jul-14	0.3	0.2
Aug-14	<0.1	<0.1
Sep-14	<0.1	<0.1
Oct-14	<0.1	<0.1
Nov-14	<0.1	<0.1
Dec-14	0.1	0.1

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Environmental

PennWest

- EPEA Approval No. 308922-00-00 effective May 21, 2013
  - 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
- Participation in the Three Creeks Working Group

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Statement of Compliance

PennWest

- 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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PennWest

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Non-Compliance – Voluntary Self-Declarations

PennWest

- March 2013: Exceedance of licensed inlet rates (fresh water) during steam cycle and exceedance of CO_2 emissions
  - Submitted application and received permit for increased license limits
- May 2013: Staining on lease
  - Stains cleaned up using fresh water

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Future Plans

PennWest

- Currently progressing Seal Main Commercial Application
  - Submitted Third SIR Responses in March 2014
- Evaluating project economics in light of current market conditions
- Continuing to evaluate pilot results

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