PennWest

Harmon Valley South HCSS Pilot Approval 11895 Annual Performance Presentation

11-Feb-2015

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

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Background – Primary Development

PennWest

- Primary scheme development began in 2004 under Approval No. 11060
- The Harmon Valley South (HVS) Primary field has 18 primary wells operating on 8 wellpads
- Currently there are 30 wells within 1,000m of the HVS Pilot Project, both primary producing and stratigraphic wells

Background – Thermal Approval

PennWest

Approval 11895	21-Sep-12	Original Pilot Approval
Approval 11895A	28-Nov-12	Revised bottomhole location for pilot wells
AUC Approval for Pilot Power Plant	3-Oct-12	AUC Approval received
Approval 11895B	3-Mar-14	Increase maximum bottomhole operating pressure from 14,500 kPag to 21,500 kPag and light hydrocarbon circulation prior to steam injection
Approval 11895C	11-Aug-14	Increase steam injection volume above 14,500 kPag from 2,500 m^3 to 12,500 m^3 and reduction in maximum bottomhole injection pressure from 21,500 kPag to 20,000 kPag

Background – Pilot Objectives

PennWest

- 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 CWE
- Evaluate technology in various reservoir conditions:
  - Well 100/07-36: Tight, viscous conditions
  - Well 102/15-06: High water saturation
  - Well 103/14-06: High permeability

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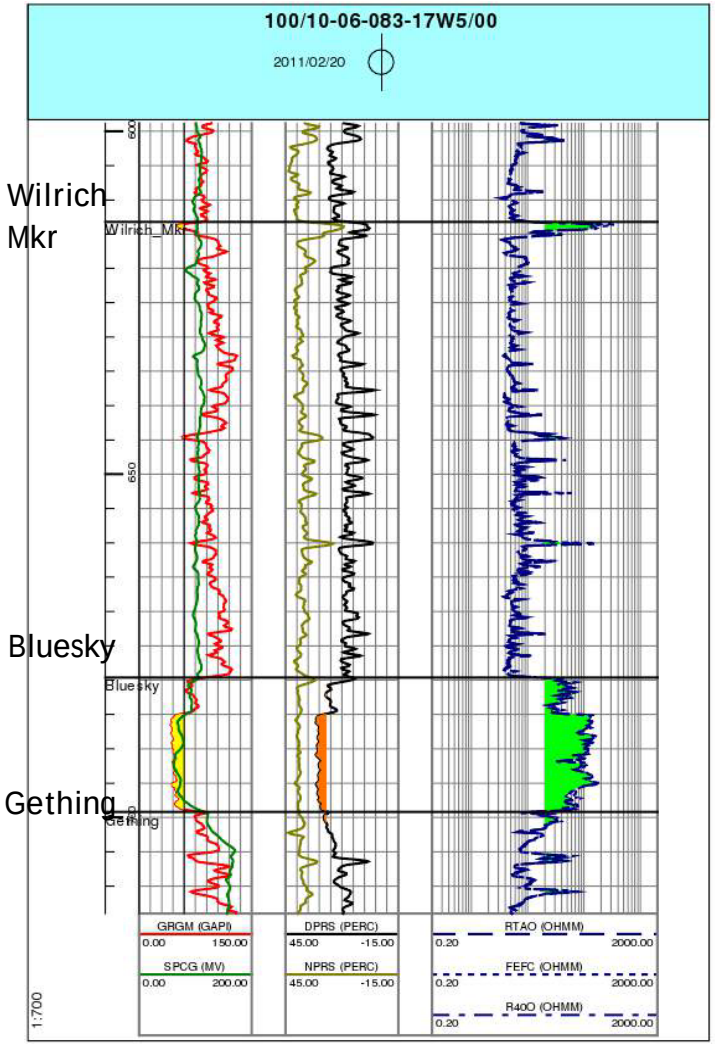
Geology – Bluesky Formation Overview

PennWest

- 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

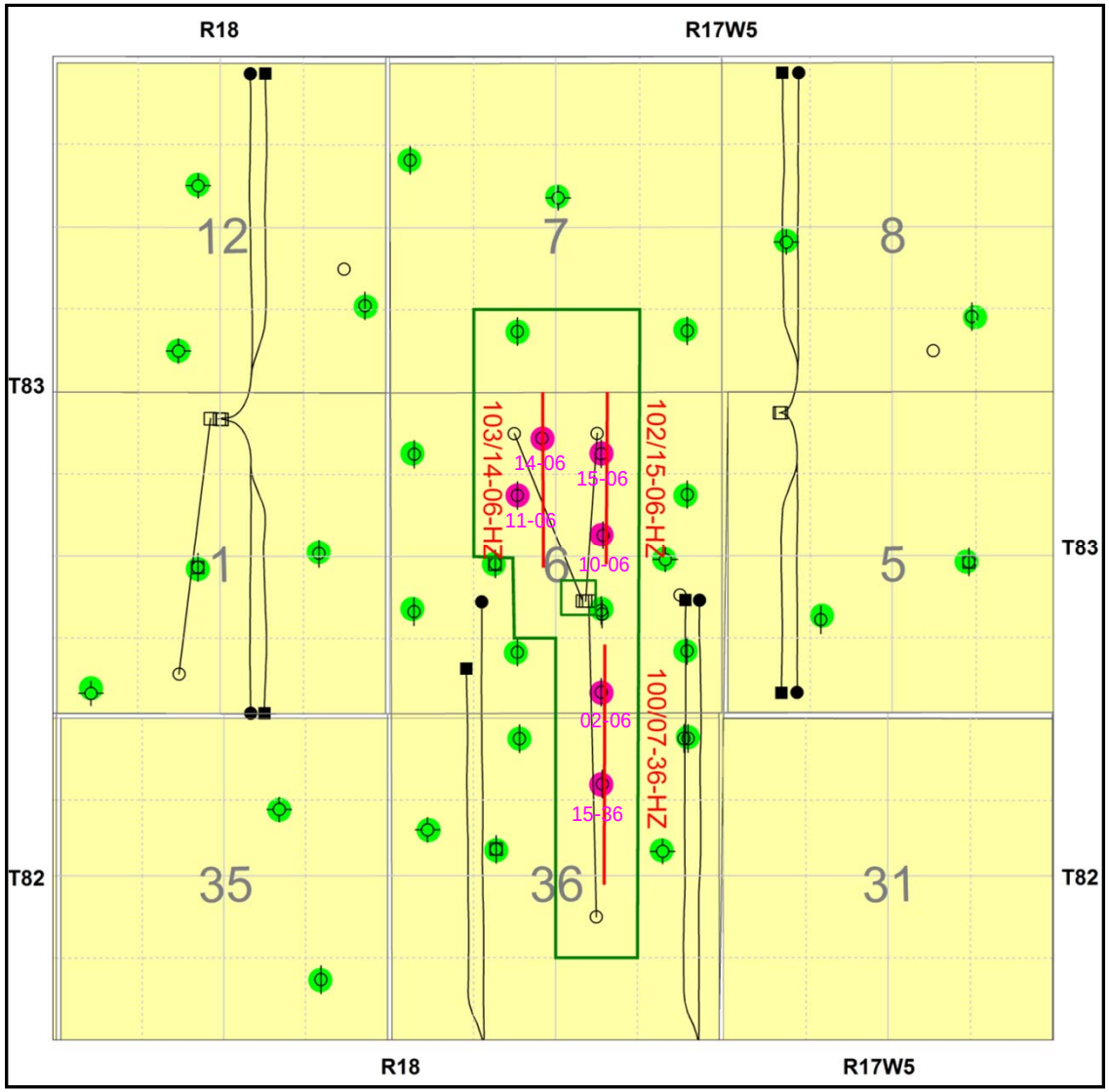
10-06-083-17W5 Type Log



Geology – Thermal Pilot Location

PennWest

- 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

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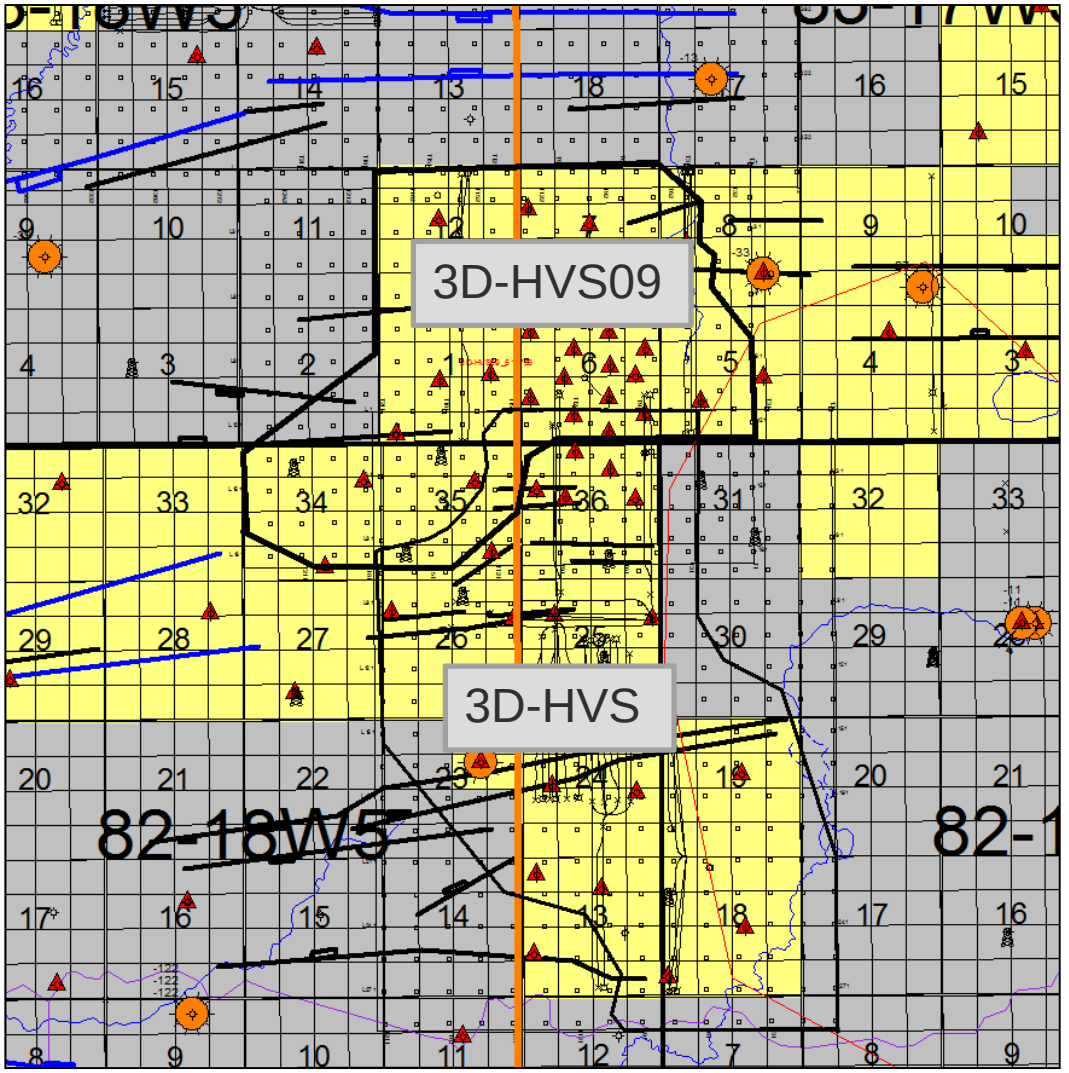
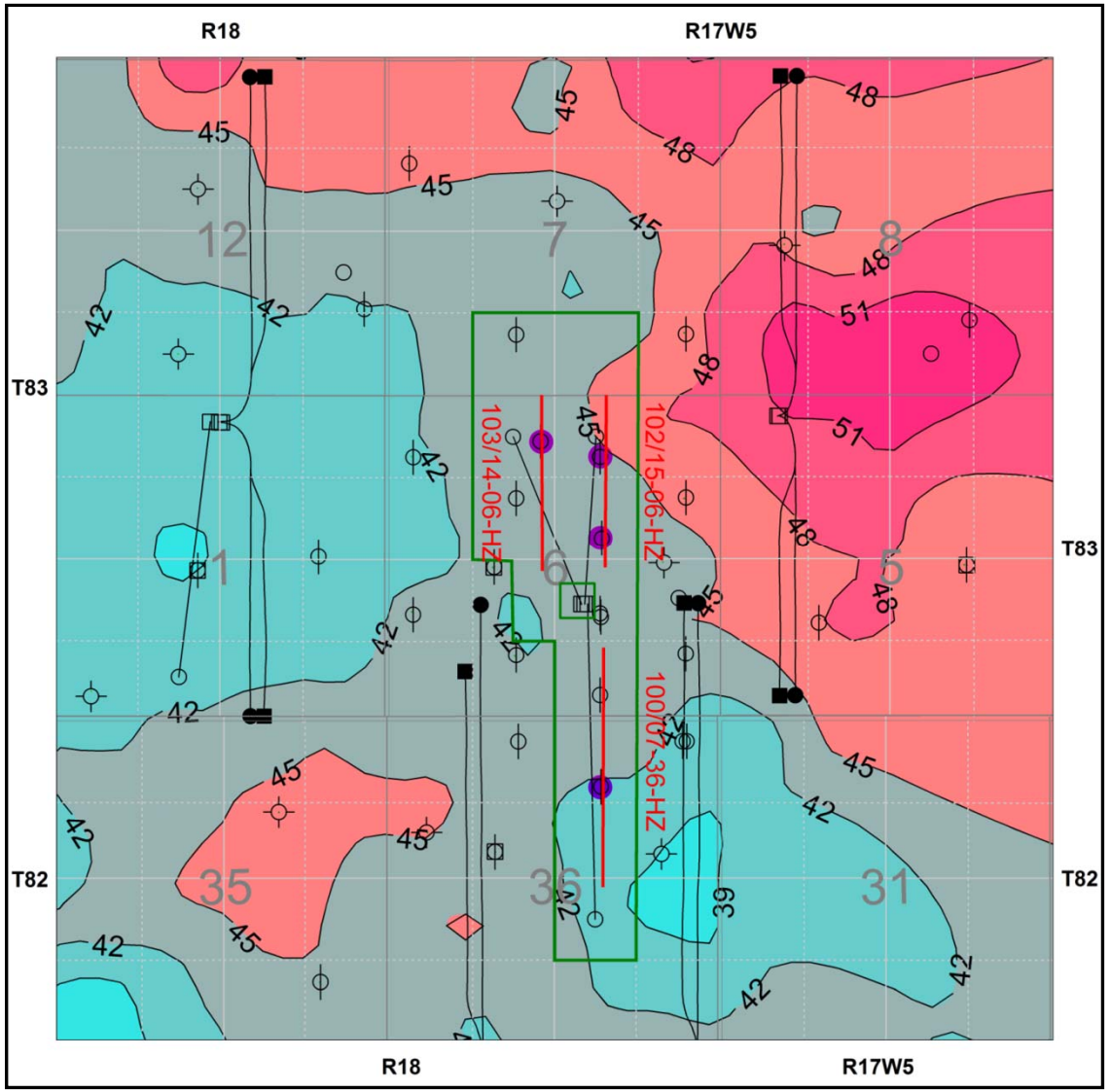
- 3D-HVS09 (North)
  - Shot in January 2009
  - Processed in January 2009
- 3D-HVS (South)
  - Shot in March 2008
  - Processed in March 2008



Geology – Bluesky Top Structure Map

PennWest



PennWest Exploration

Bluesky Structure (mss)

Licensed to : Penn West Petroleum

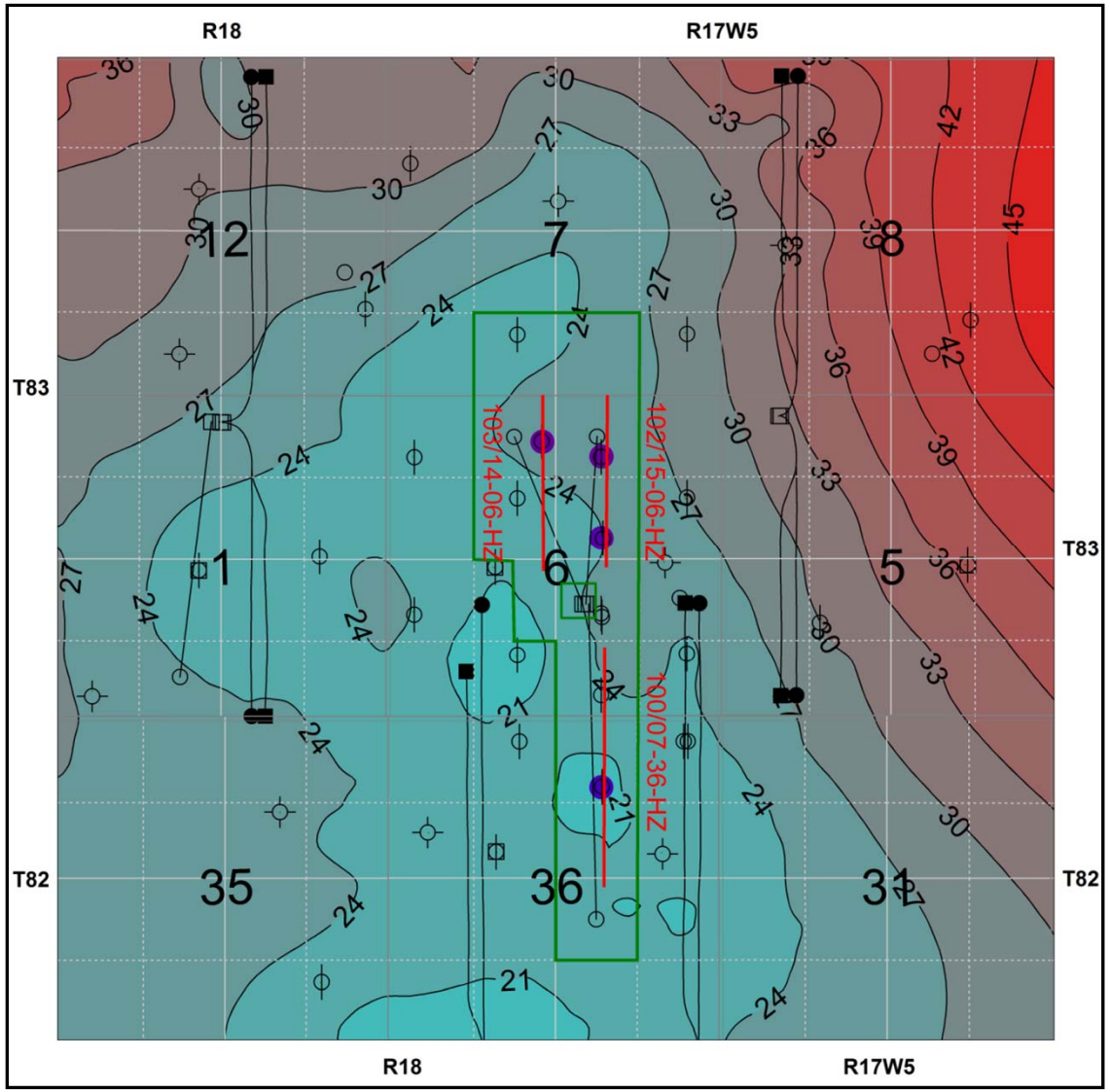
geoSCOUT

By : JW | Date : 2012/11/30

Scale = 1:12000 | Project : Seal Regional Oct 28 2011

Geology – Bluesky Base Structure Map

PennWest



PennWest Exploration

Bluesky Base Structure (mss)

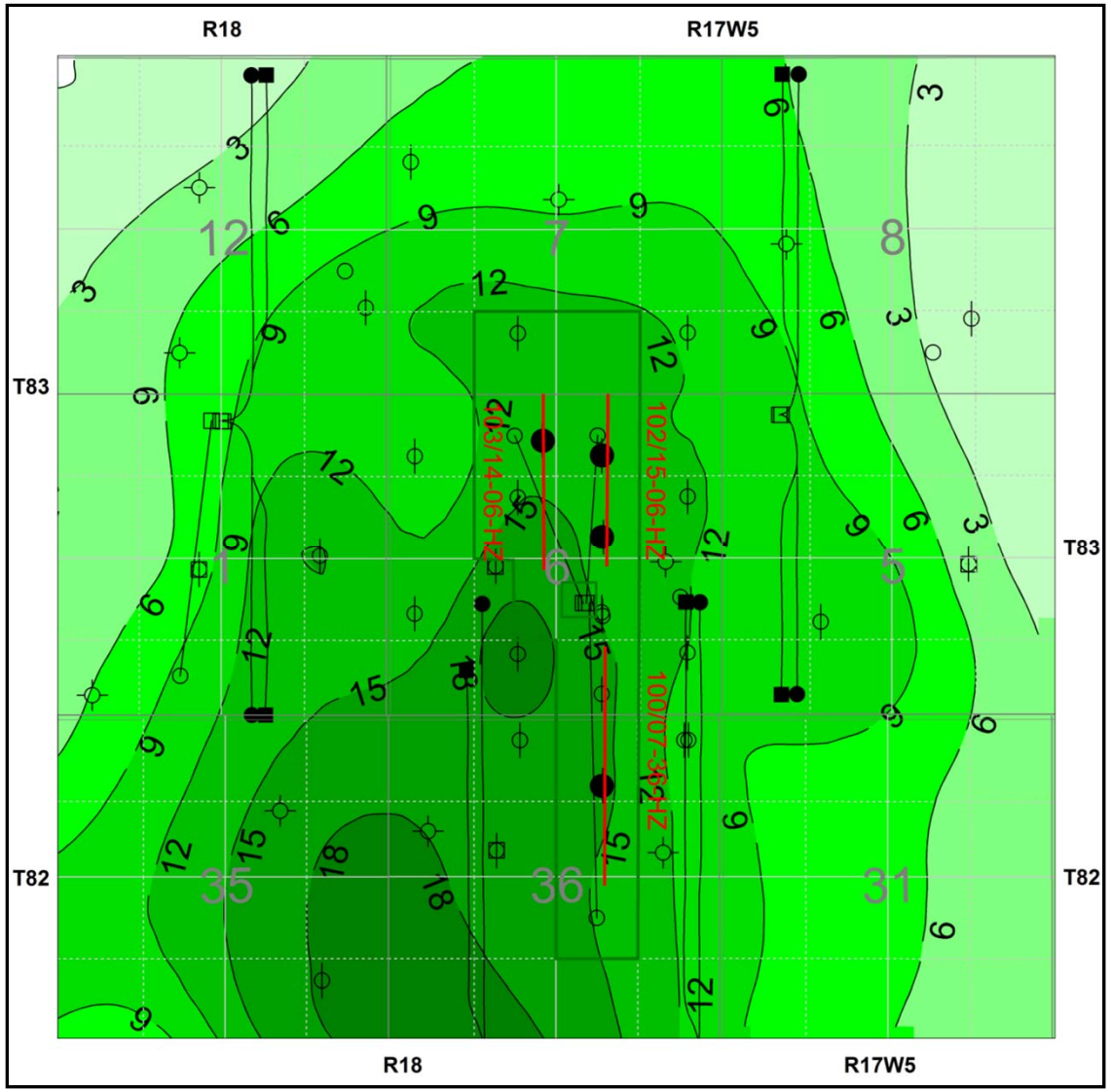
Licensed to : Penn West Petroleum

geoSCOUT

By : JW
Scale = 1:12000
Date : 2012/11/30
Project : Seal Regional Oct 28 2011

Geology – Net Pay Map

PennWest



PennWest Exploration

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

Licensed to : PennWest Petroleum

geoSCOUT

By : JW | Date : 2012/11/30
Scale = 1:12000 | Project : Seal Regional Oct 28 2011

Geology – Structural Cross-Section

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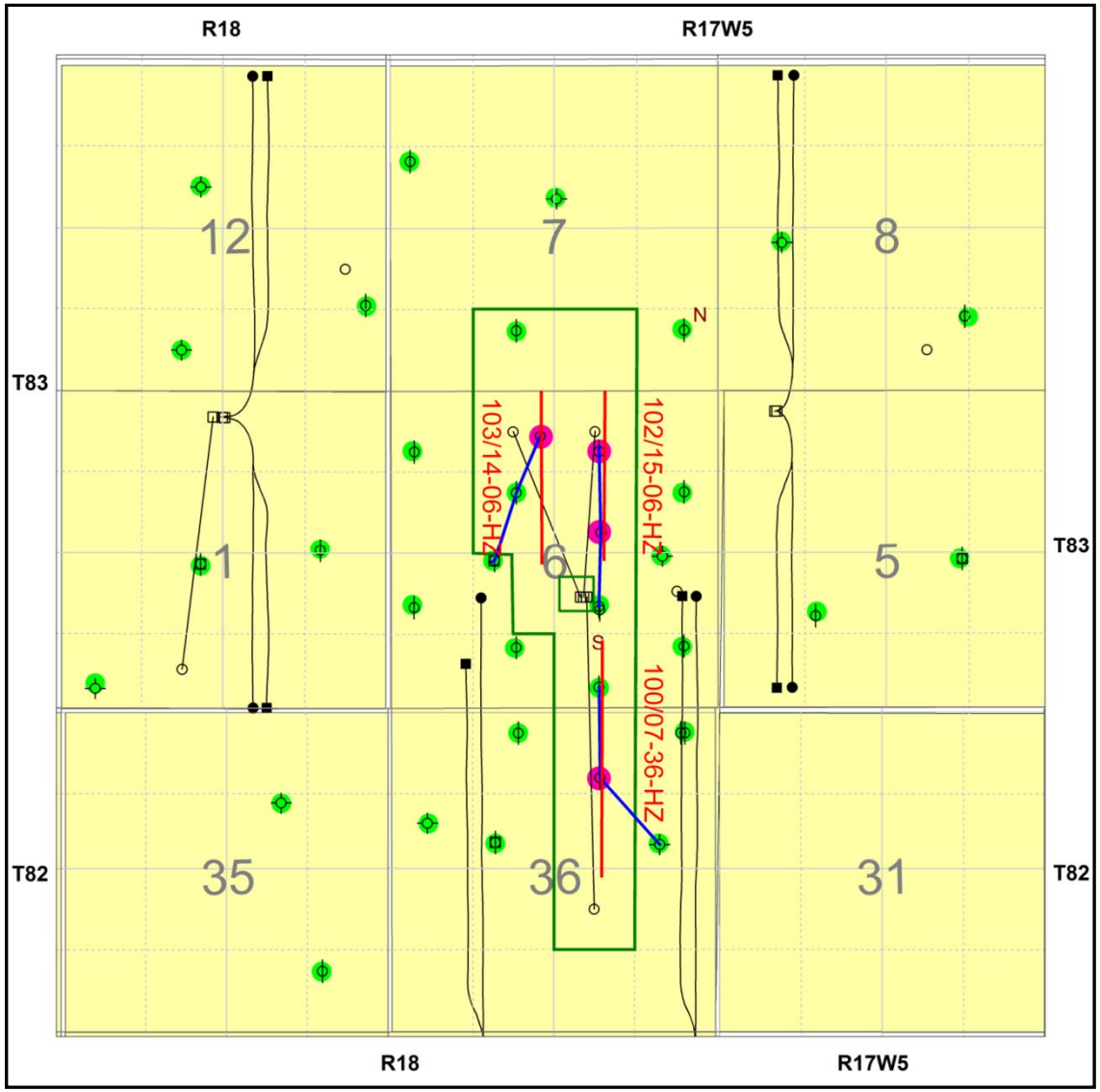

PennWest Exploration

Harmon Valley South Thermal Pilot
HCSS Structural Cross-section

Licensed to : Penn West Petroleum

geoSCOUT

By : JW
Scale = 1:12000
Date : 2012/11/30
Project : Seal Regional Oct 28 2011

Geology – Structural Cross-Section 100/07-36-082-18W5

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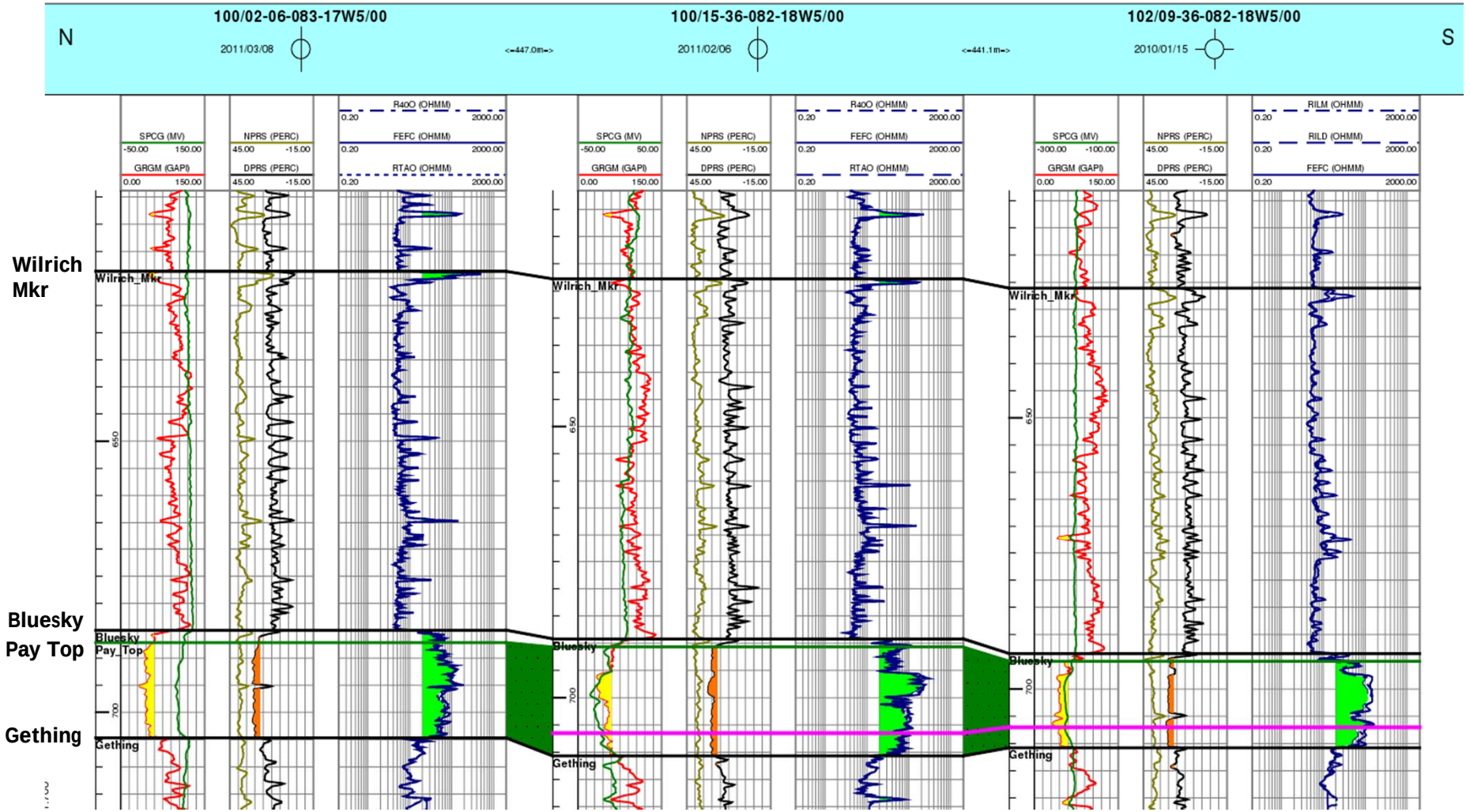

Geology – Structural Cross-Section 102/15-06-083-17W5

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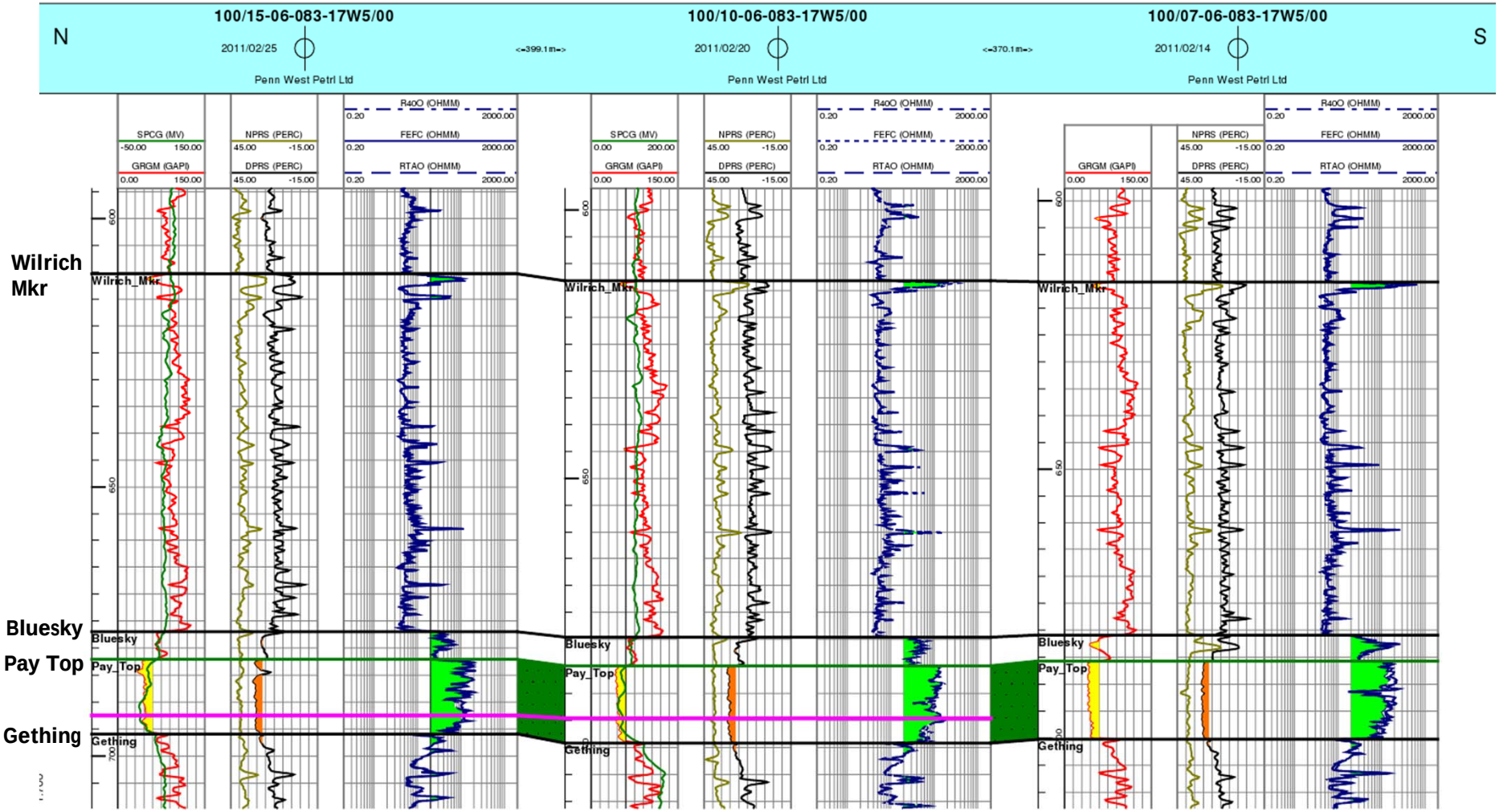

Geology – Structural Cross-Section 103/14-06-083-17W5

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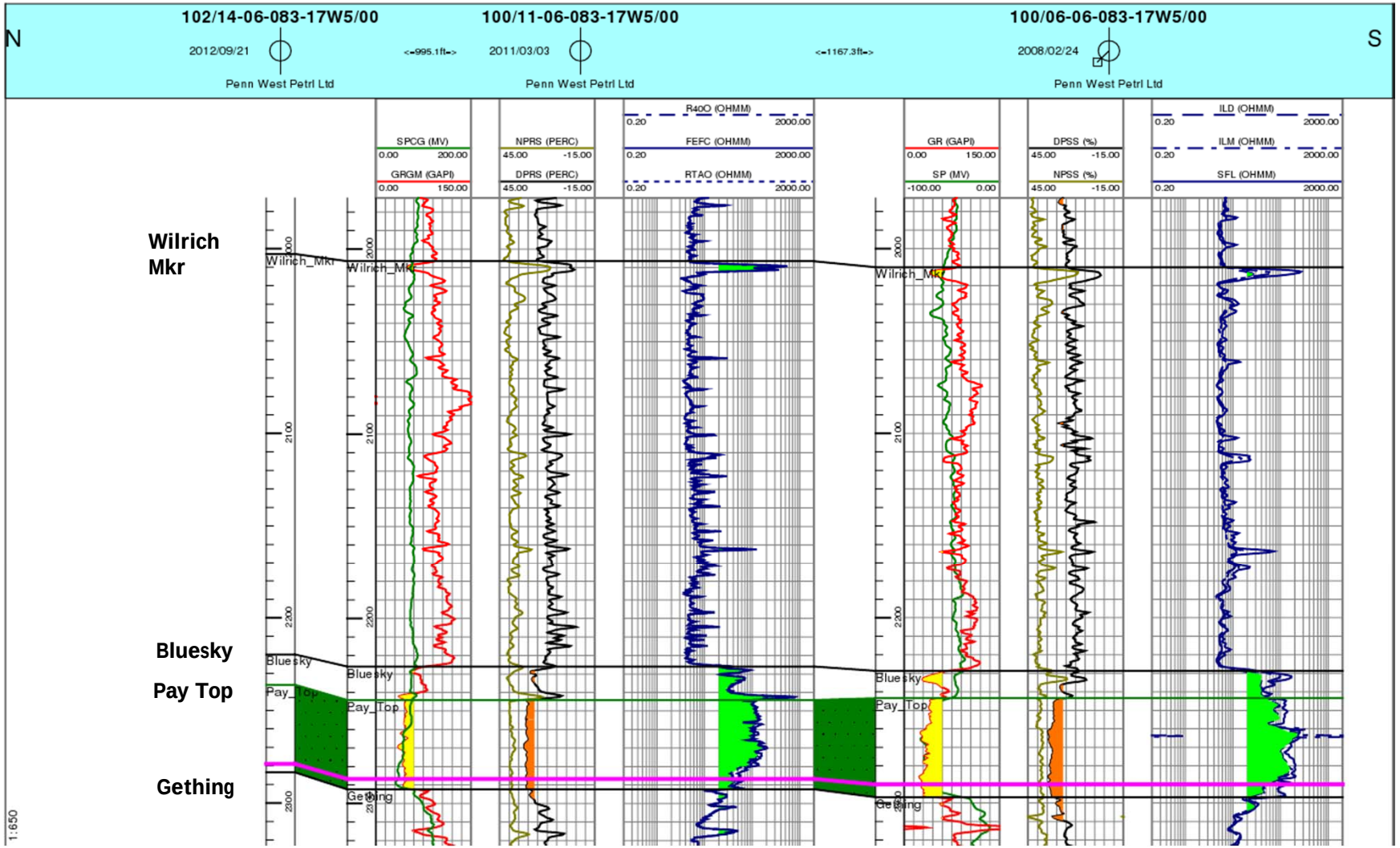
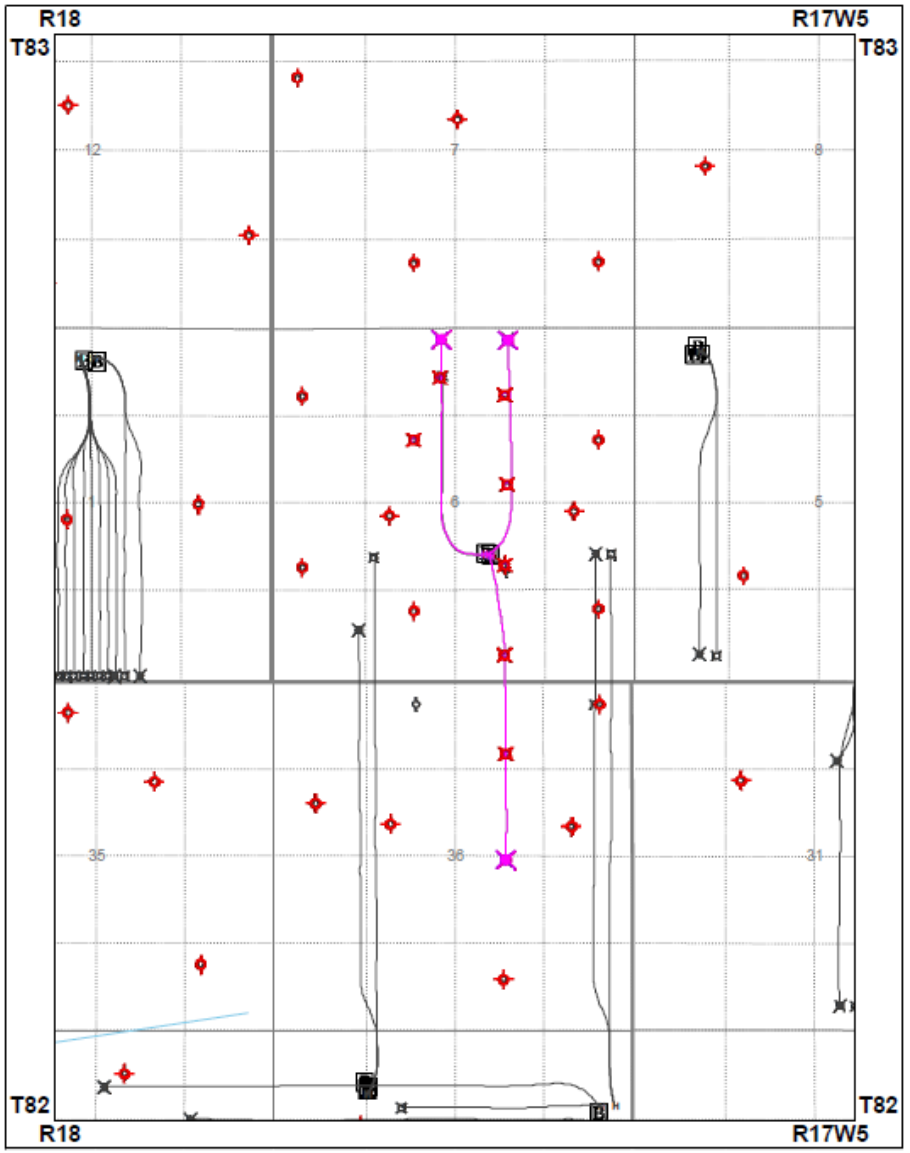


Geology - Cored Wells

PennWest

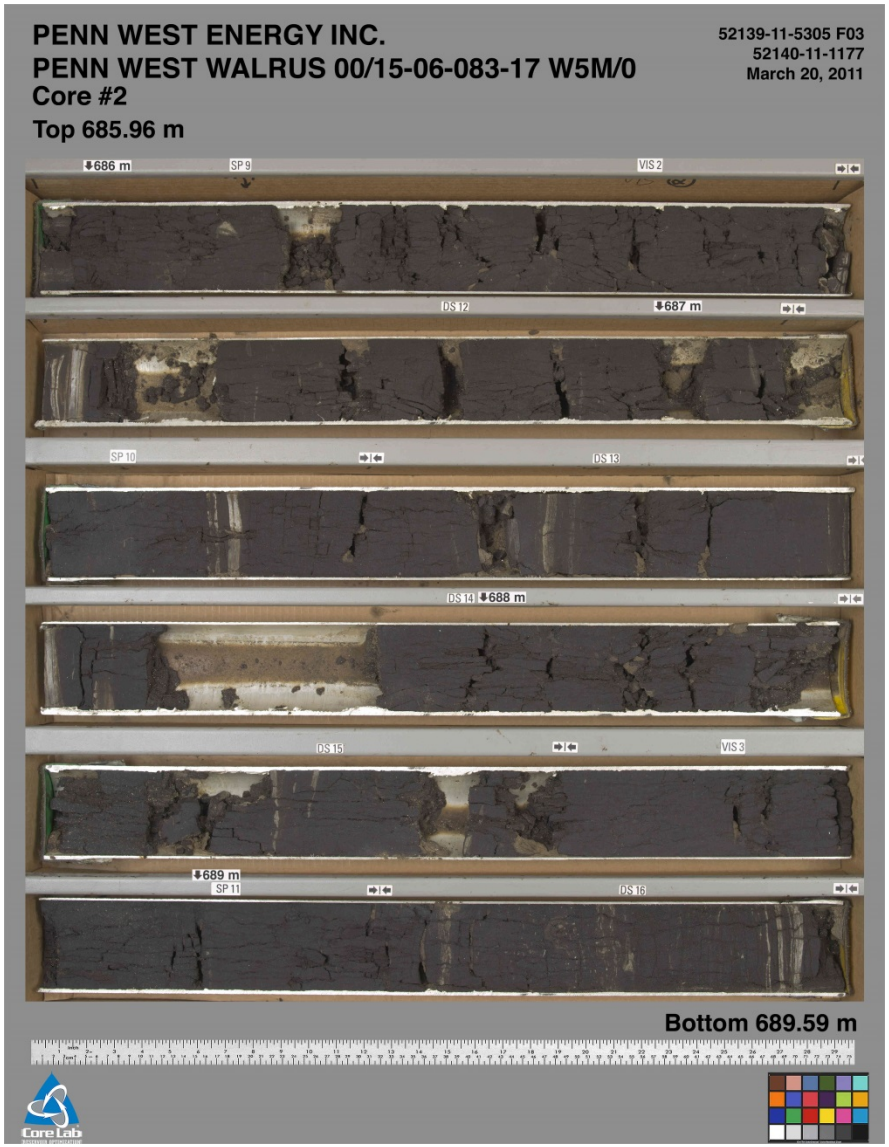
Cored Wells

CSS Thermal Well



Geology – Core Photos

PennWest



Geology – Average Reservoir Properties (Pilot)

PennWest

Net pay (m)	14.7
Area (ha)	184
Porosity (%)	27
Water Saturation (%)	24
Formation Temperature (˚C)	22
Formation Pressure (kPa)	4,800
Viscosity (cSt at 20^{o}C)	30,000
Average Hz Permeability (mD)	1,500
Formation Volume Factor	1.02
OBIP (e^3m^3)*	5,441

*Based on the pilot project area

Geology – Fracture Pressure

PennWest

- 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:

	Mini-frac Results			
Zone	Depth (m) (MD)	Min Stress (kPa)	Gradient (kPa/m)	Direction
Wilwrich	672	16,000	23.8	horizontal
Bluesky	698	12,600	18.1	vertical

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

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PennWest

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Drilling and Completions – Wellbore Design

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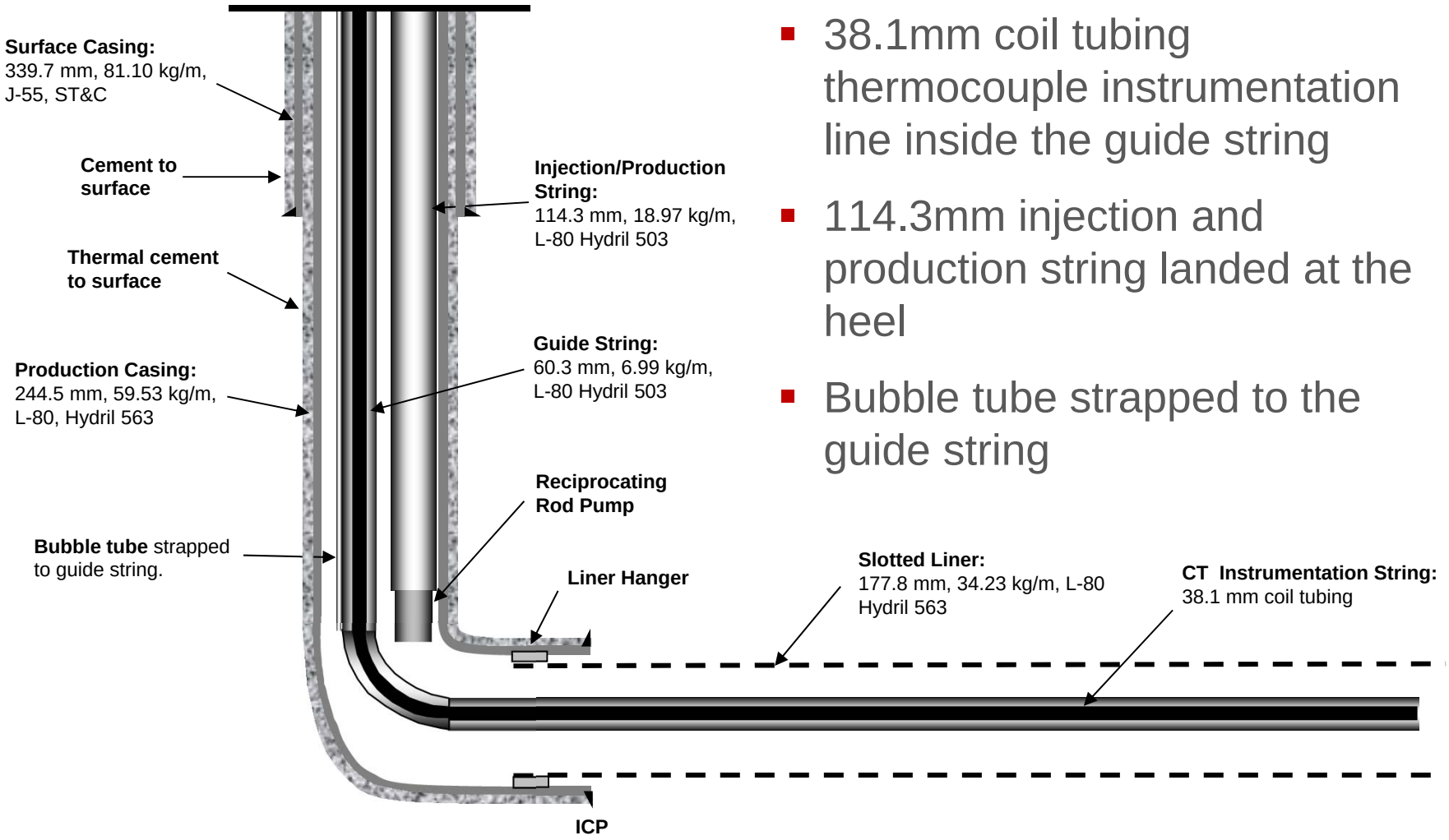

- 60.3mm guide string to the toe
- 38.1mm coil tubing thermocouple instrumentation line inside the guide string
- 114.3mm injection and production string landed at the heel
- Bubble tube strapped to the guide string

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Artificial Lift

PennWest

- 3.25” insert rod pumps run on all three wells initially
- Due to low reservoir temperatures in Well 103/14-06 following steam cycle 1, pump could not produce the viscous oil
  - Weatherford 56-1500 Insert PCP run in May 2014 to enable continued production
  - Intend to return to rod pump following second steam cycle on Well 103/14-06

Subsurface Agenda

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5. **Well Instrumentation**
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Well Instrumentation – HCSS Wells

PennWest

- 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

PennWest

- 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 caprock integrity

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6. **4D Seismic**
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4D Seismic

PennWest

- No current plans to conduct 4D Seismic at HVS

Subsurface Agenda

PennWest

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7. **Scheme Performance**
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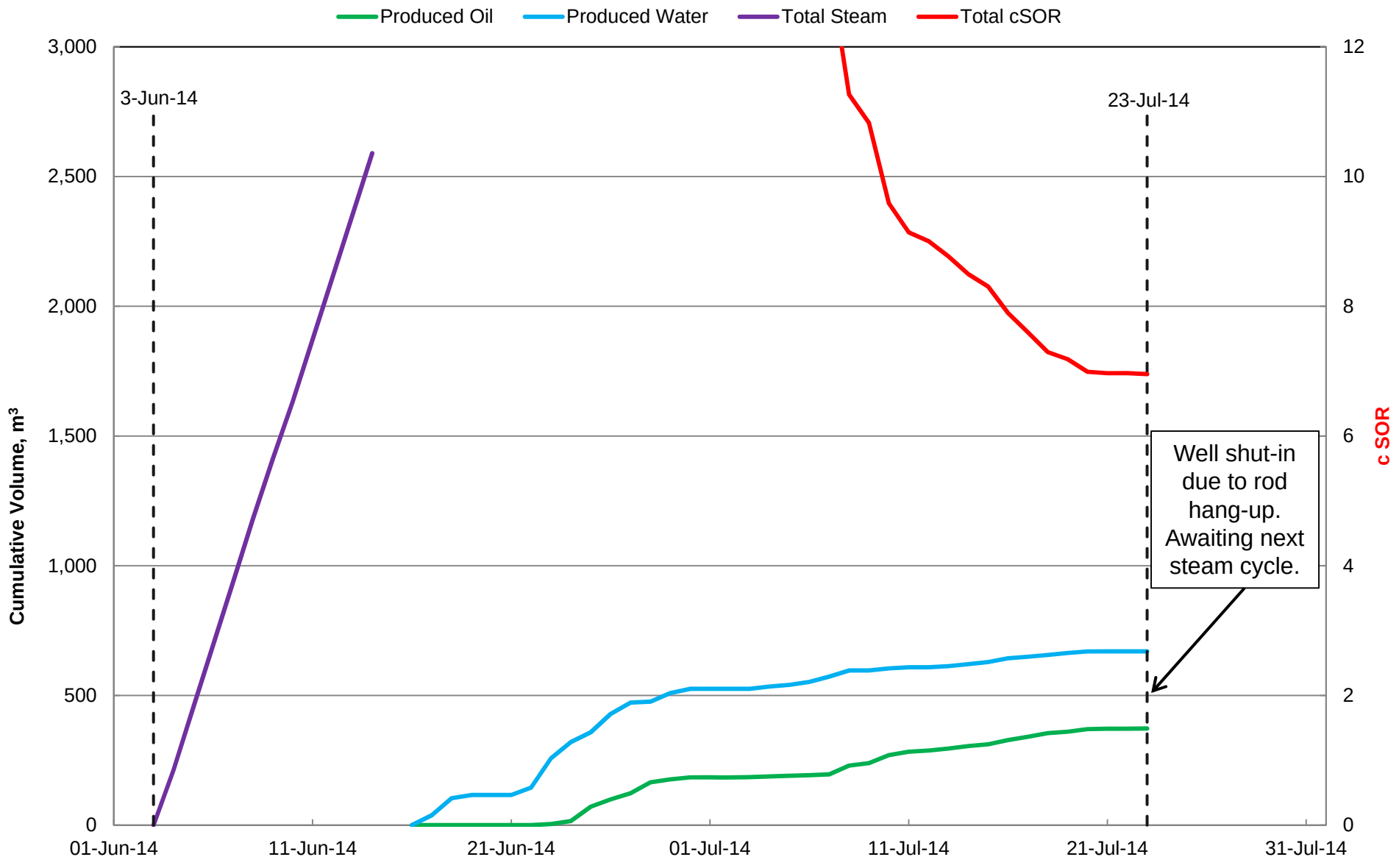
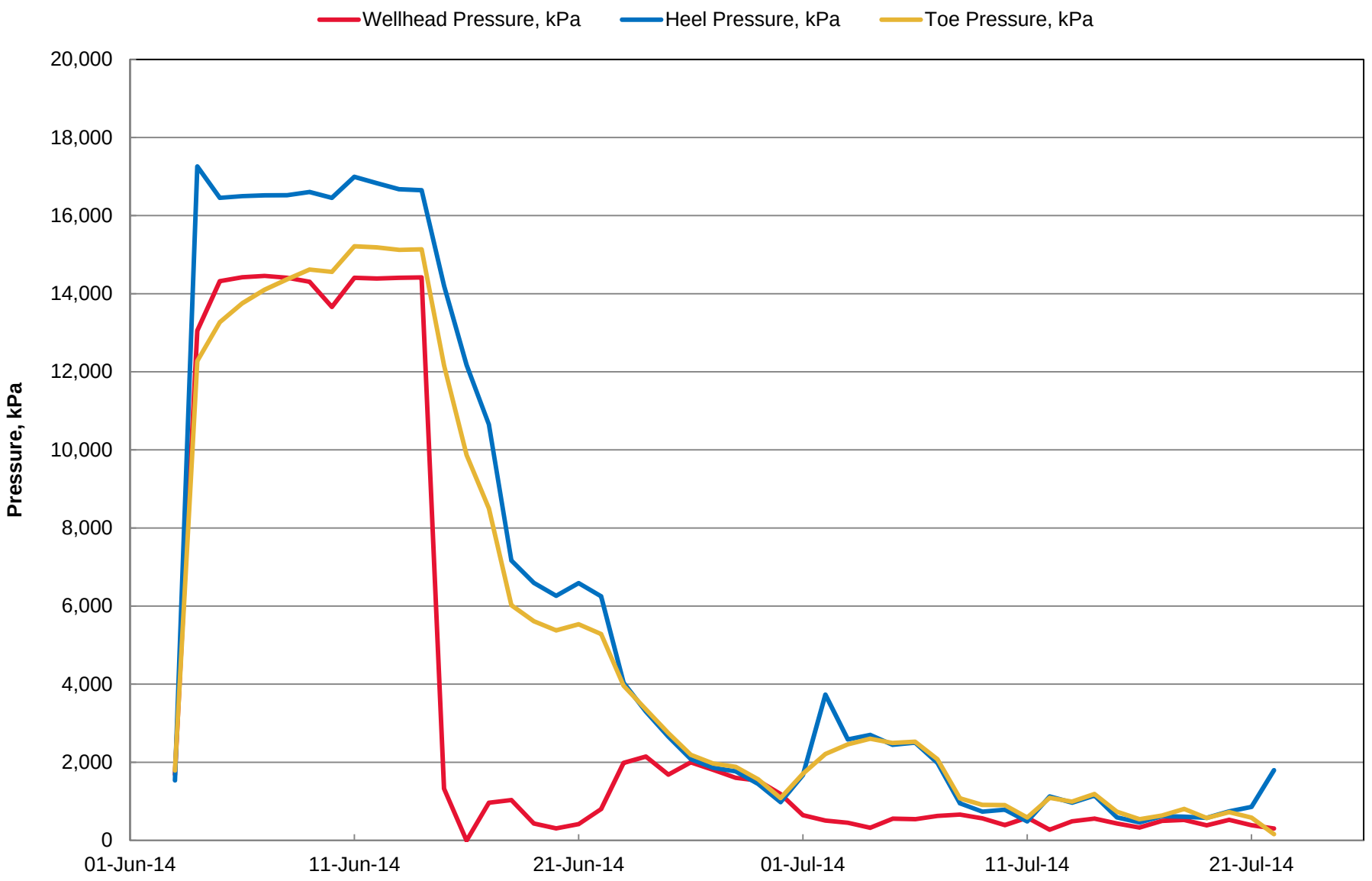
Scheme Performance – Well 100/07-36

PennWest



Scheme Performance – Well 100/07-36

PennWest



Scheme Performance – Well 100/07-36

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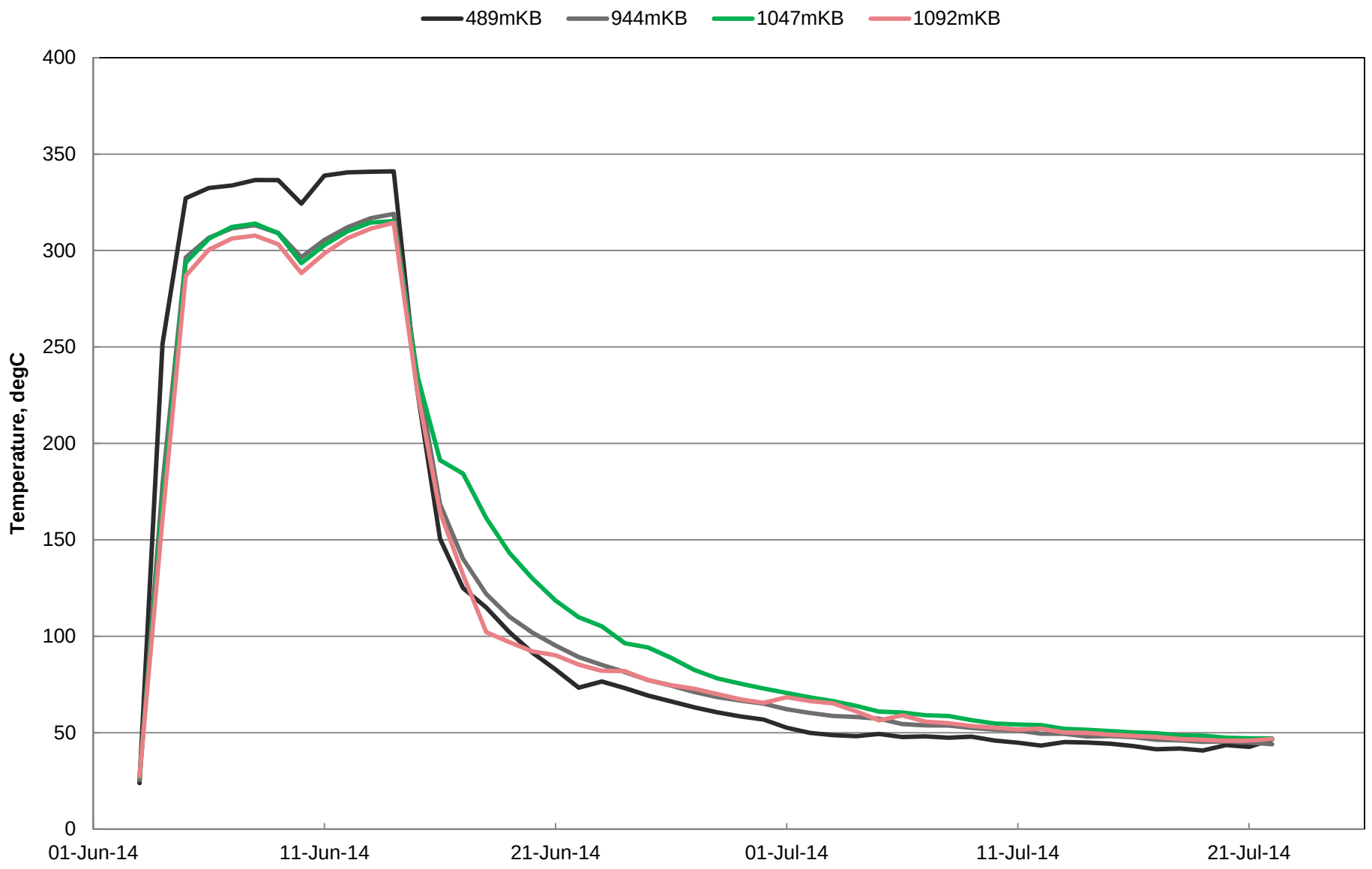

Scheme Performance – Well 100/07-36

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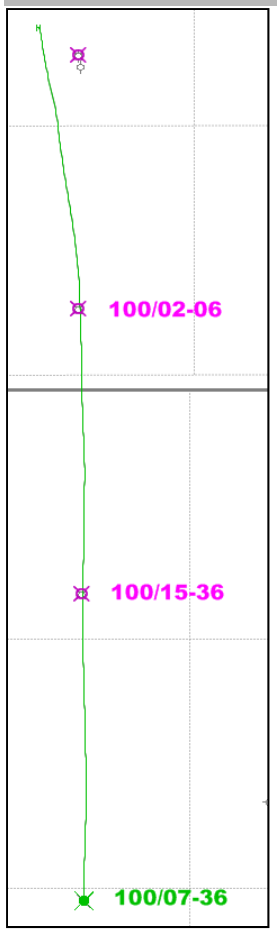
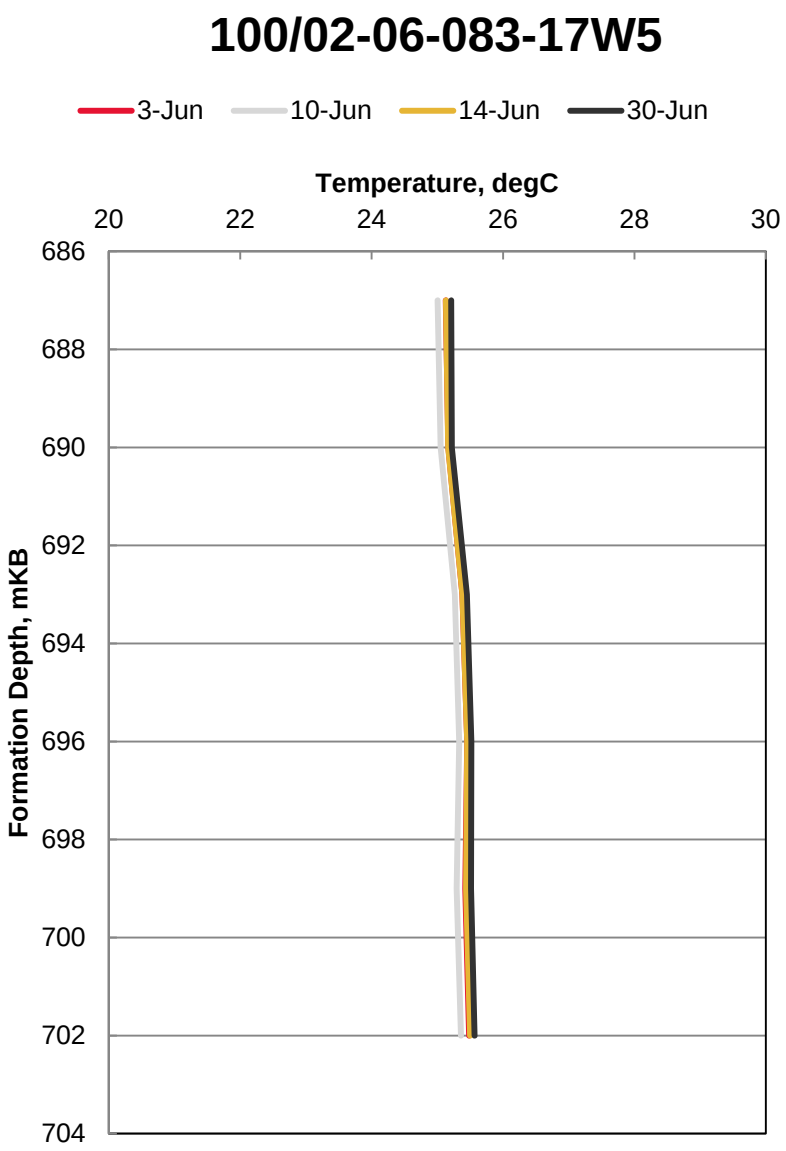
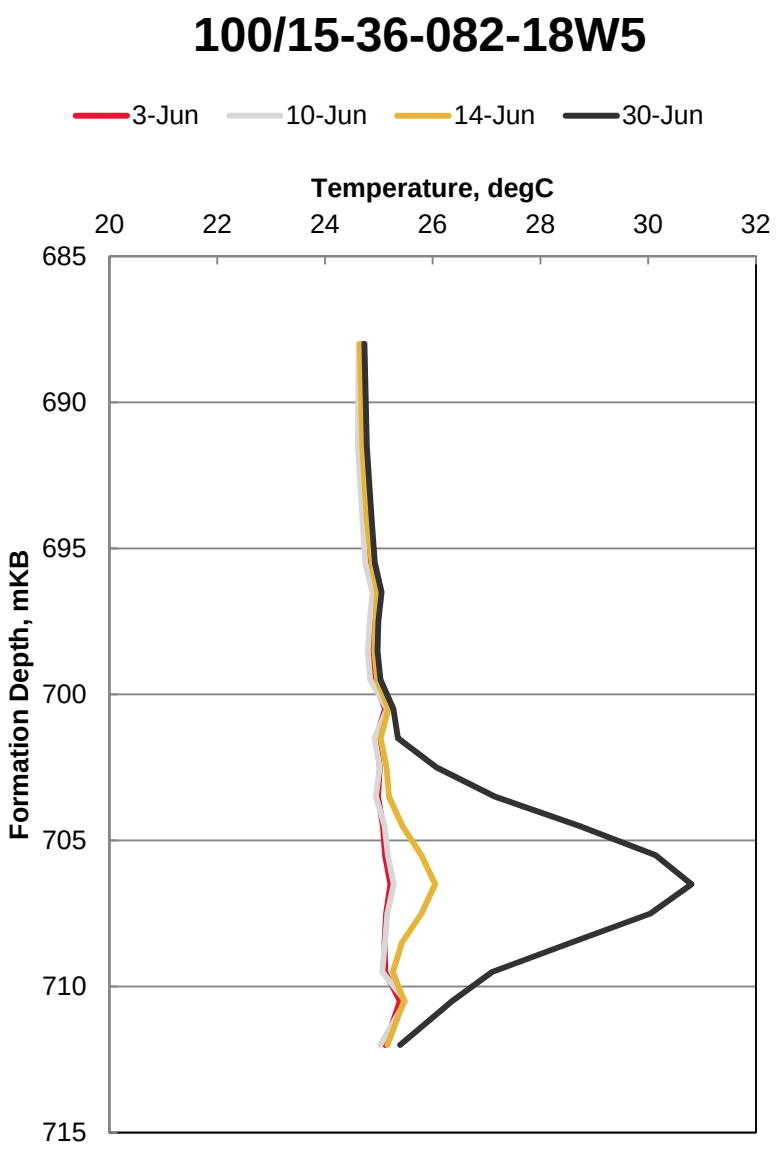
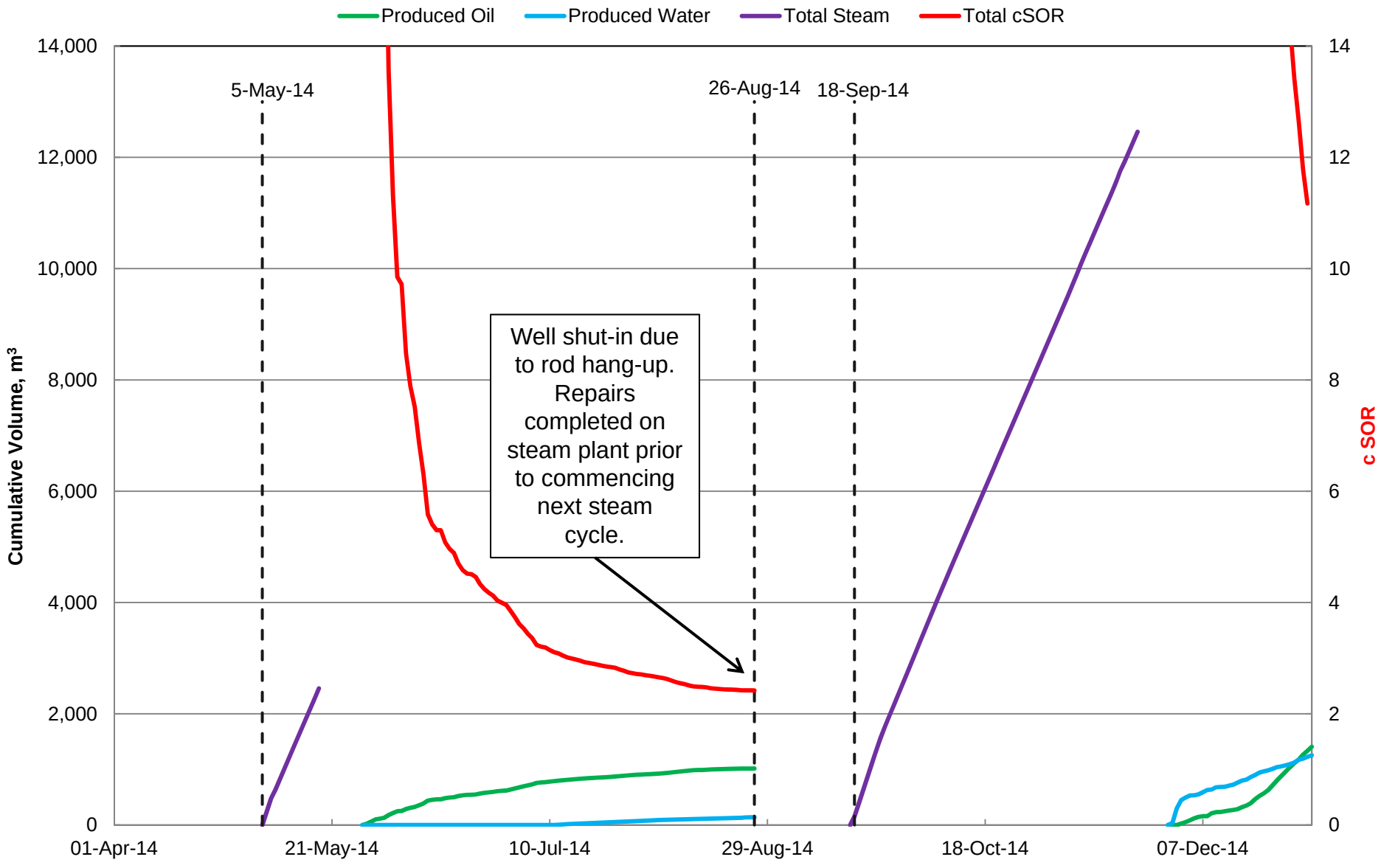






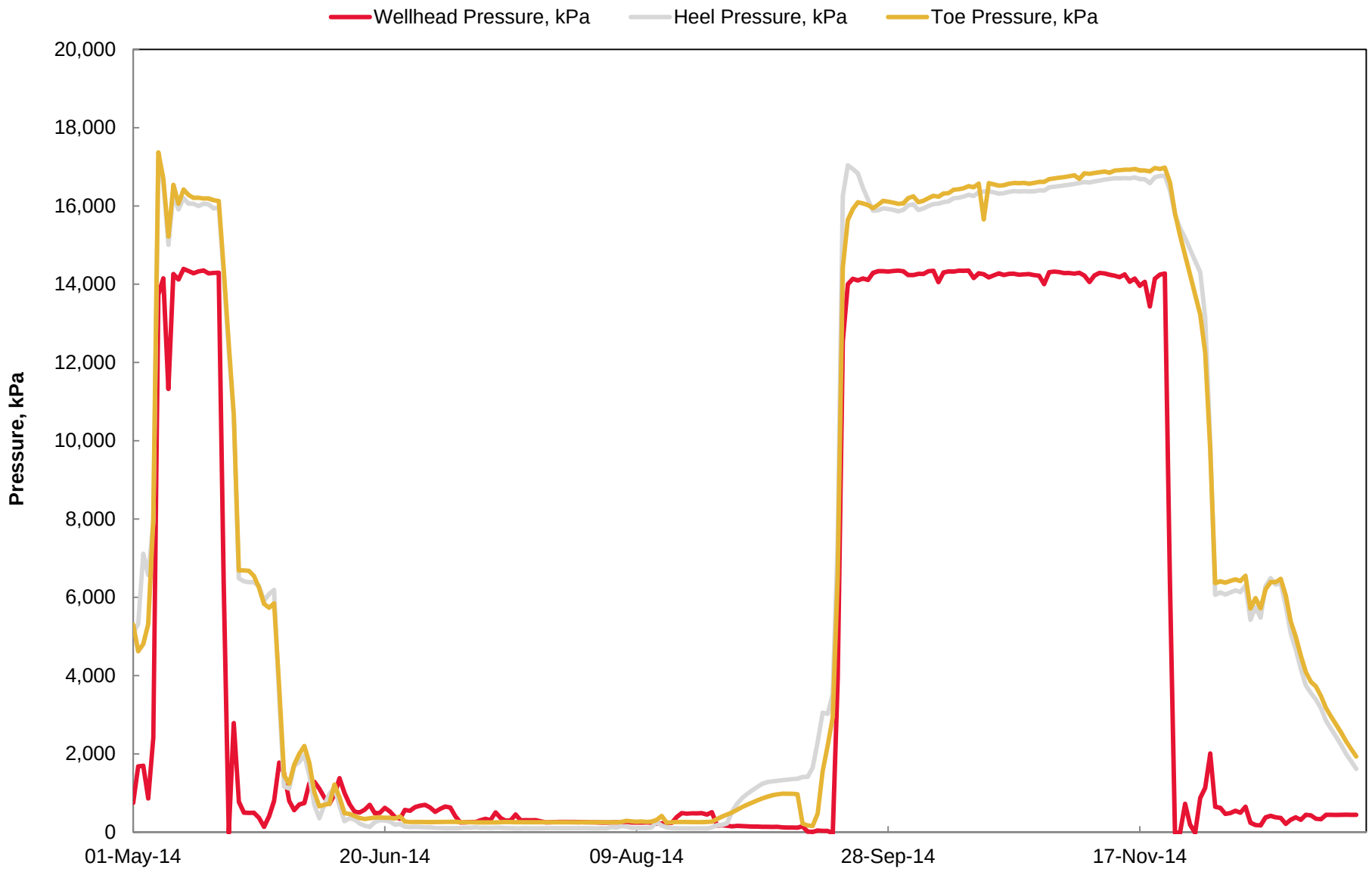
Scheme Performance – Well 102/15-06

PennWest



Scheme Performance – Well 102/15-06 Bottomhole Conditions

PennWest



Scheme Performance – Well 102/15-06 Bottomhole Conditions

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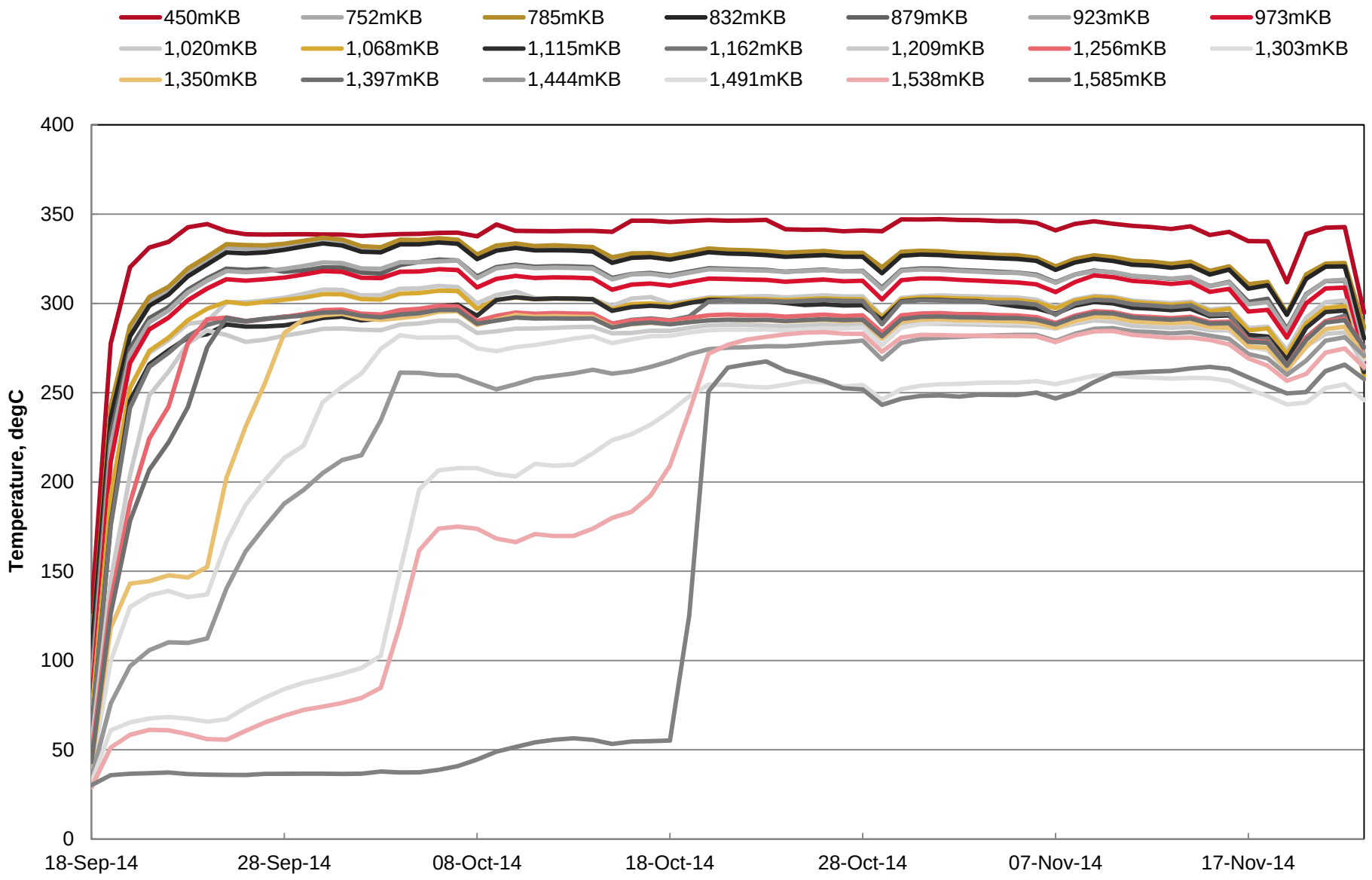

Scheme Performance – Well 102/15-06 Bottomhole Conditions

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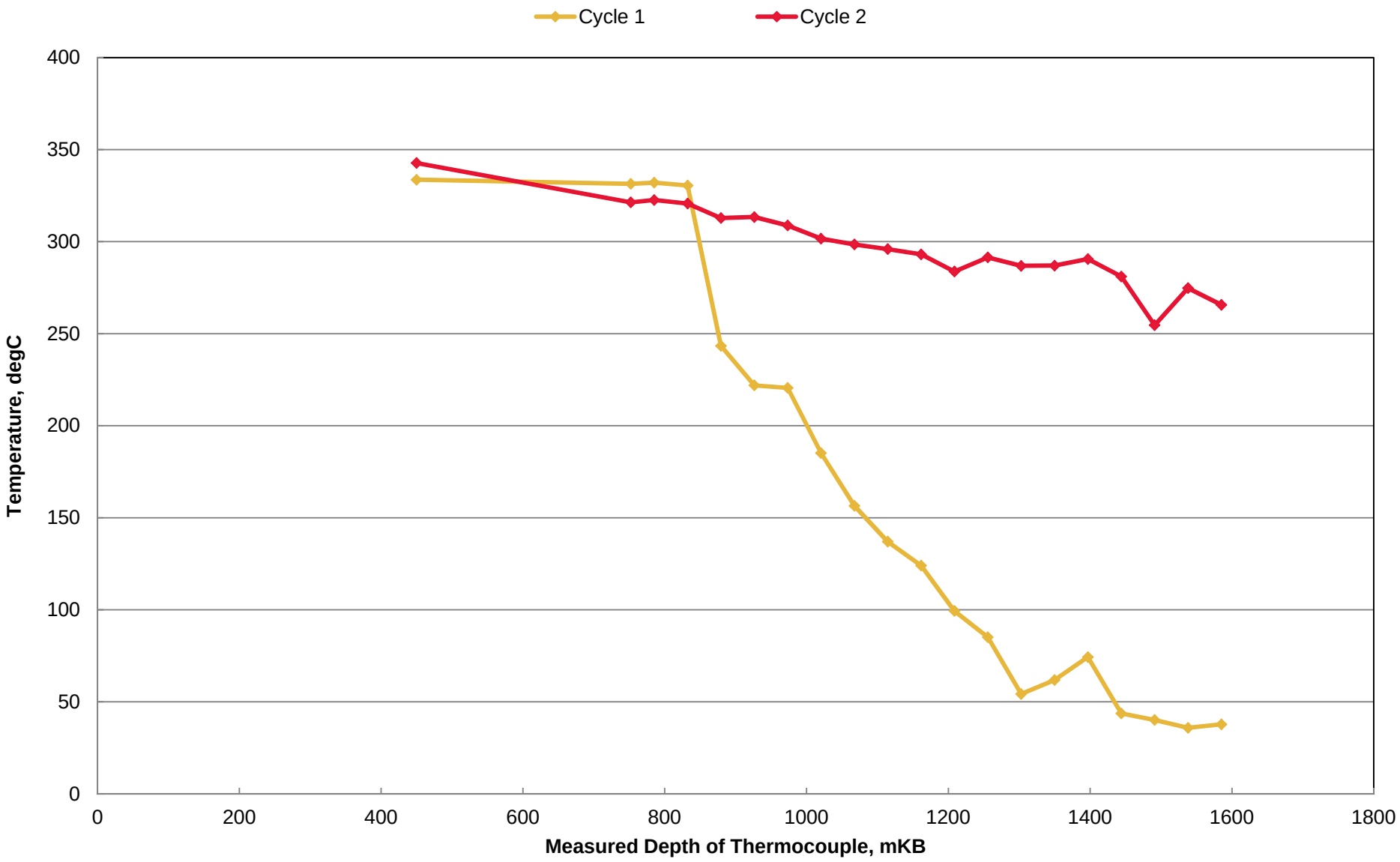

Scheme Performance – Well 102/15-06

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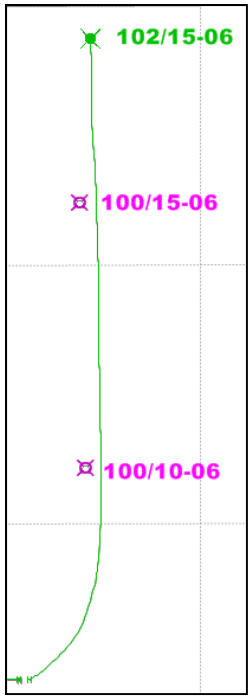

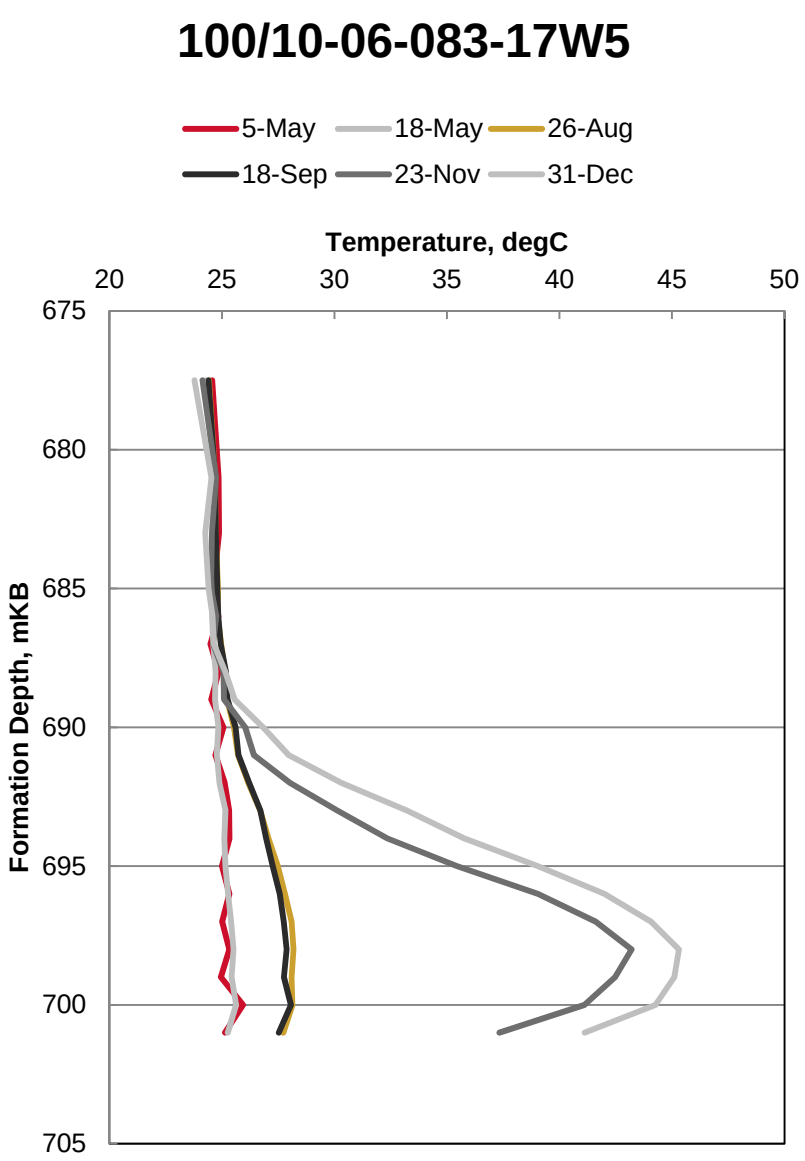

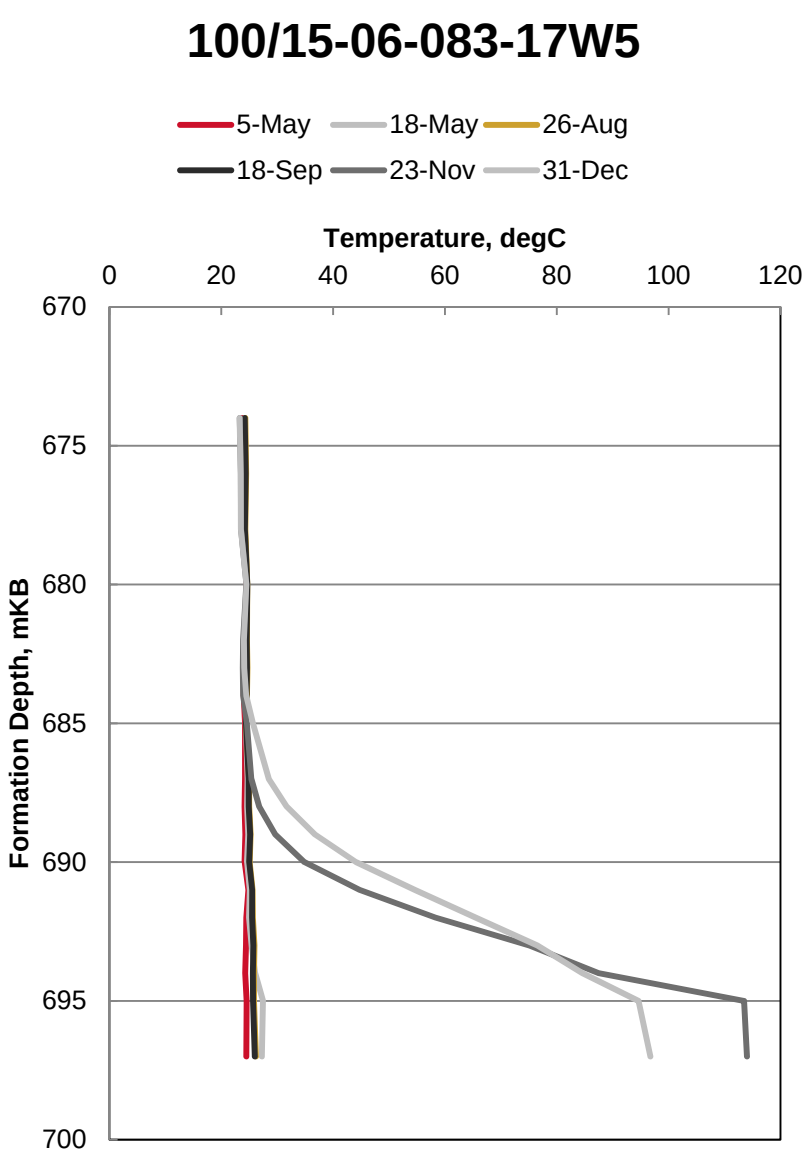

Scheme Performance – Well 103/14-06

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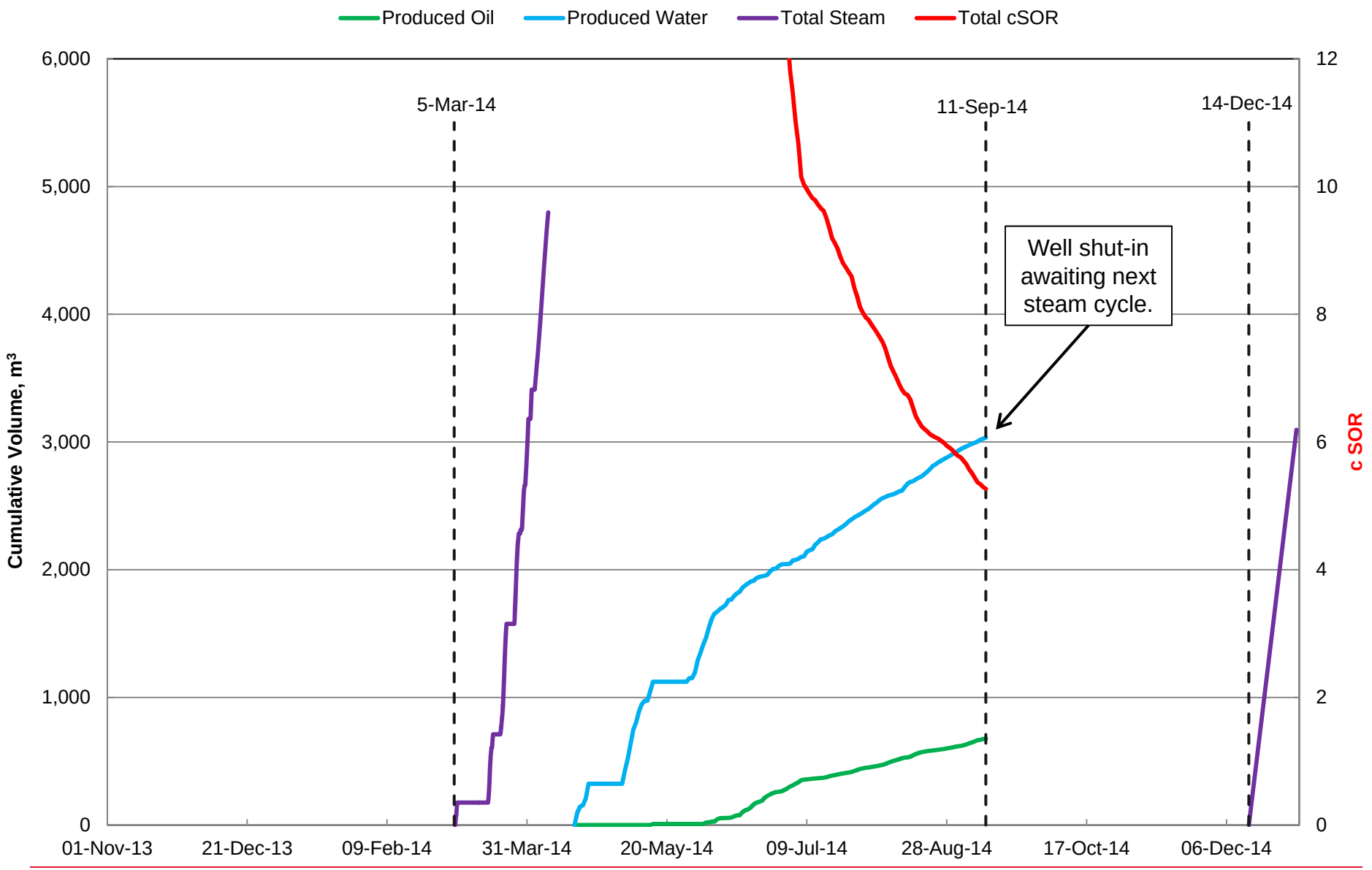
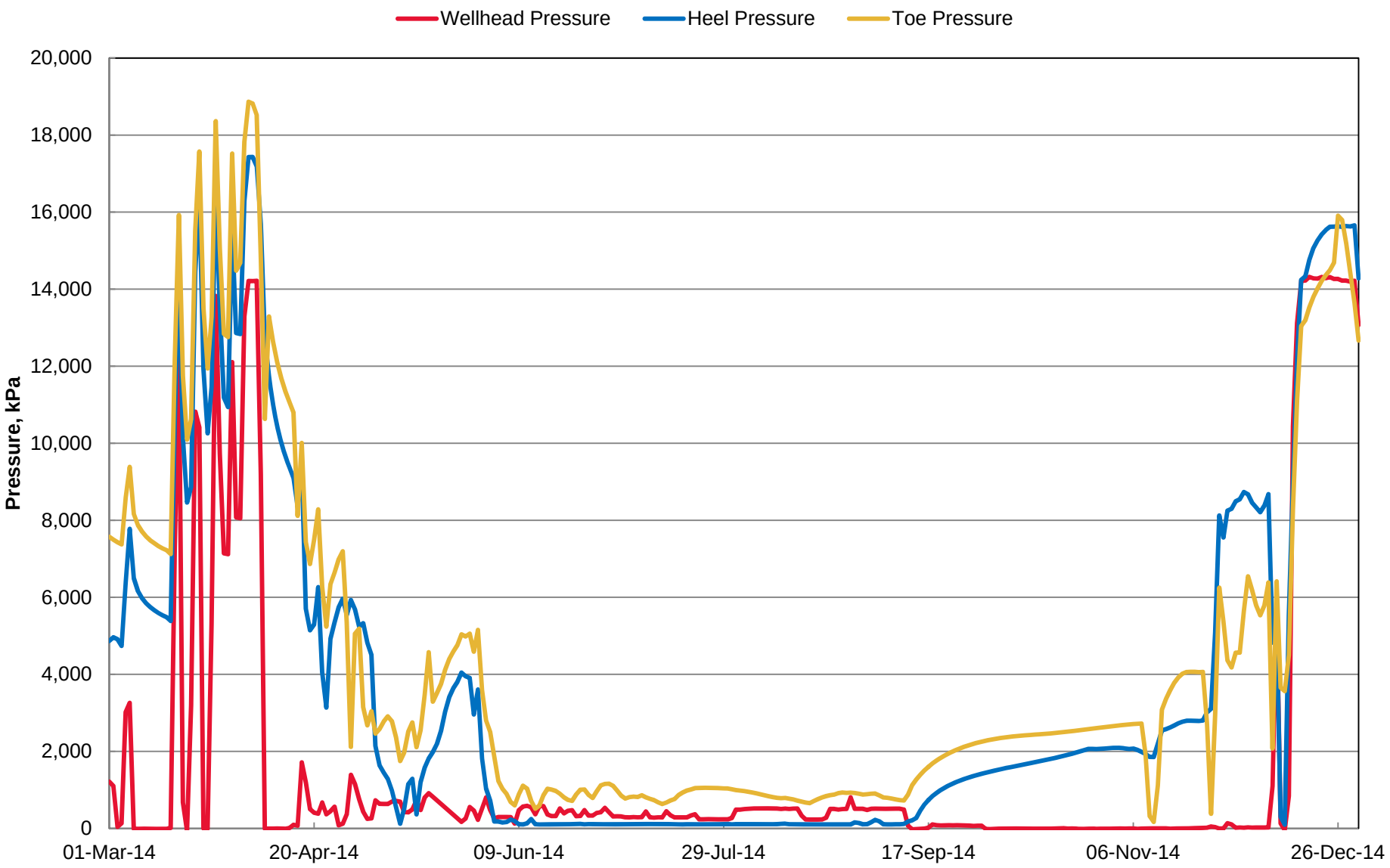


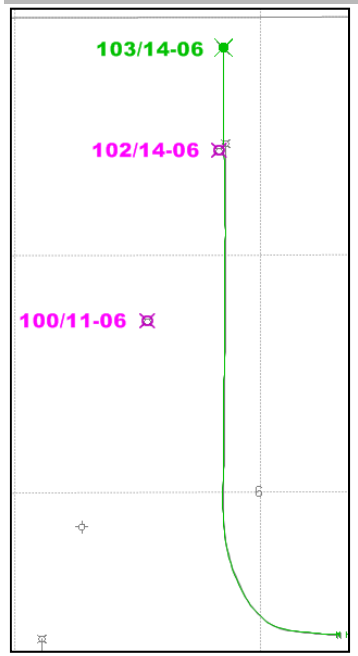
Scheme Performance – Well 103/14-06 Bottomhole Conditions

PennWest



Scheme Performance – Well 103/14-06

PennWest



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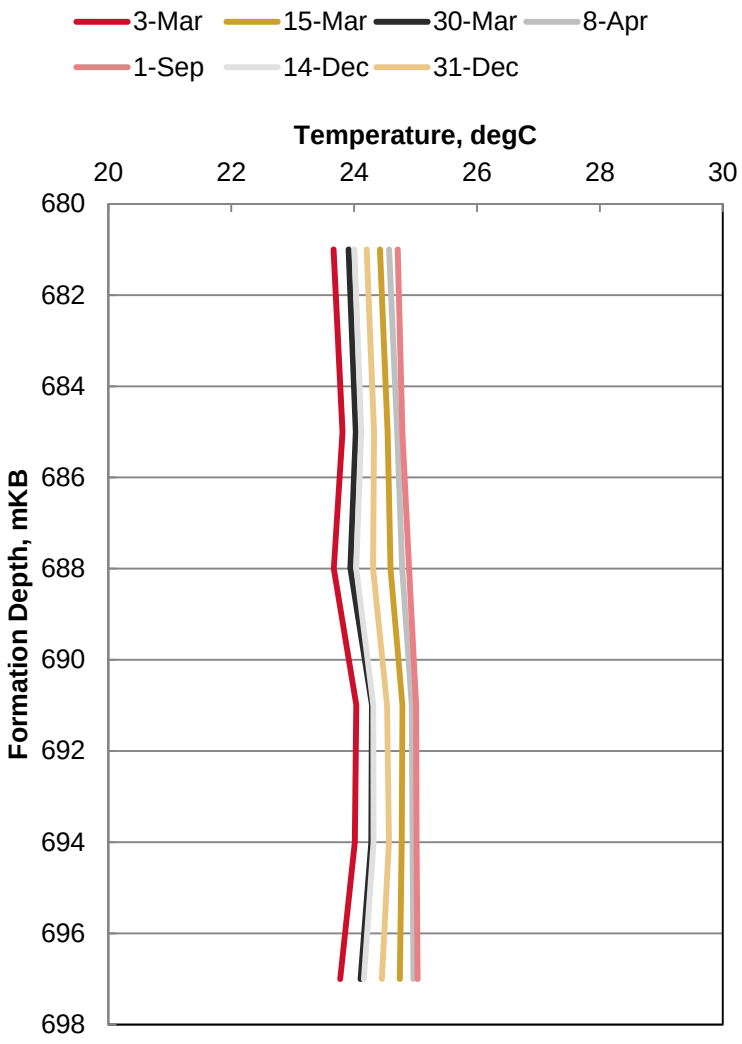

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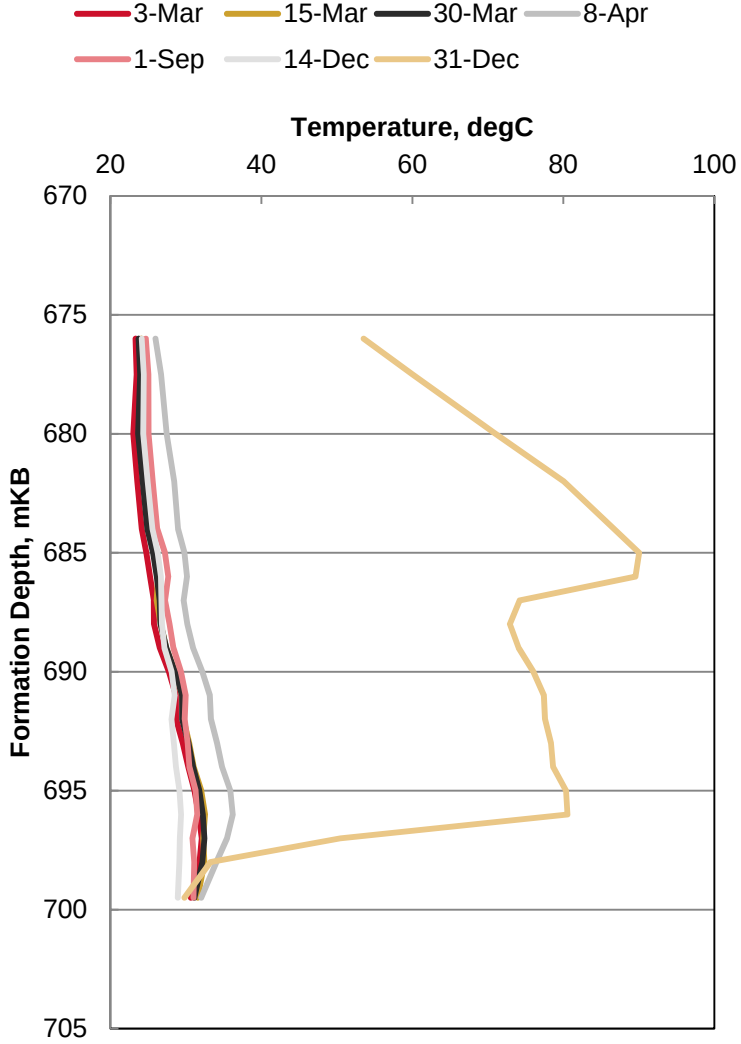

Scheme Performance – Steam Injection

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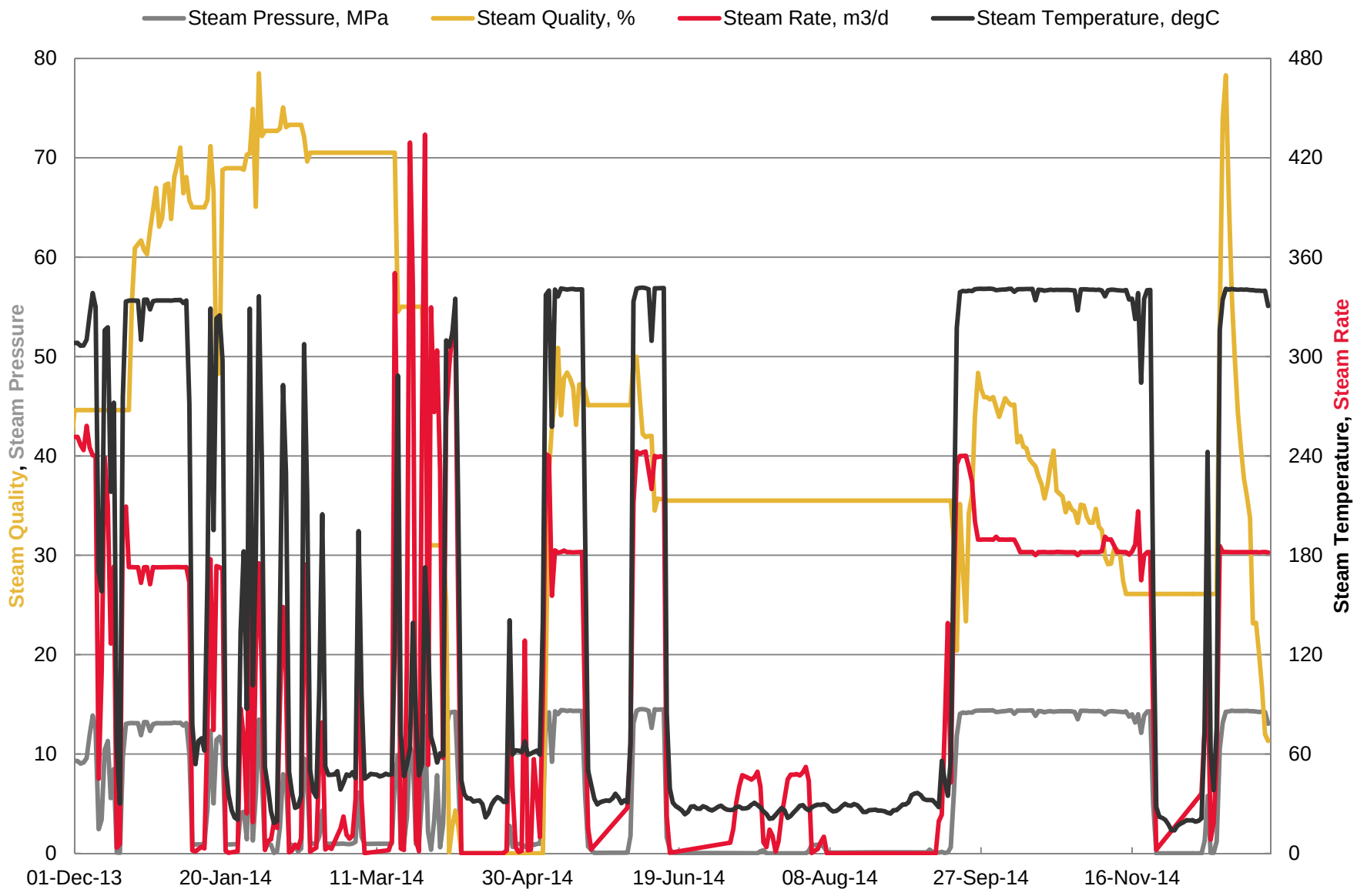

Scheme Performance – Offsetting Primary Wells

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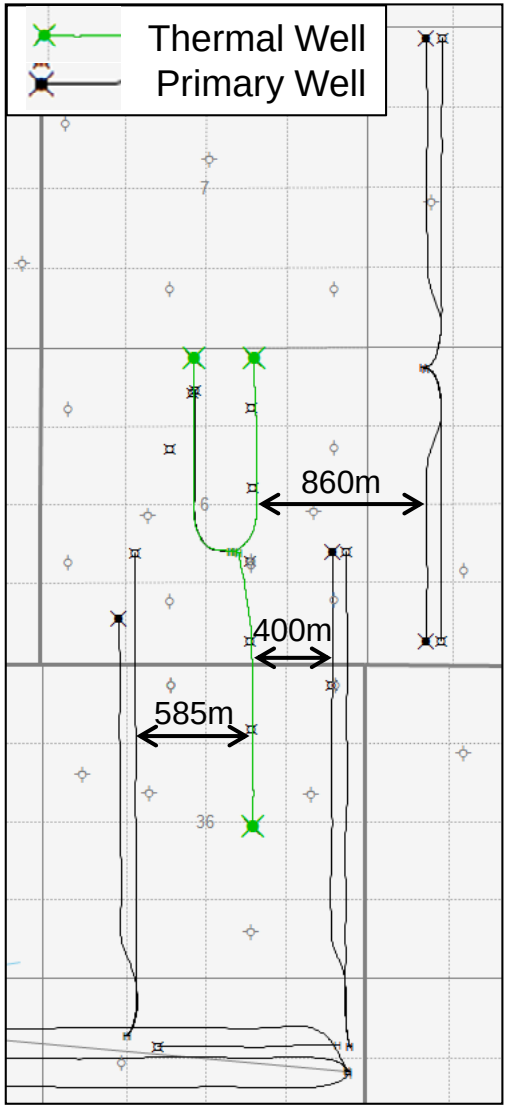

- Offsetting primary wells are thermally compatible
- To date, Penn West has not identified any communication between the thermal wells and the offsetting primary wells
- Temperature of the produced fluids is monitored to identify any potential steam migration, and will be shut in if temperatures show a significant increase

Scheme Performance – Recovery Factor

PennWest

Cycle 1 Production, m^3	2,067
Cycle 2 Production to Date, m^3	1,335
Total Production to Date, m^3	**3,402**
OBIP, m^3	5,441,000
Current Recovery, %	0.1%
Estimated Ultimate Recovery*, %	3%

*Estimated Ultimate Recovery is low due to the large project area defined. Typical primary recovery in this area is 5%.

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PennWest

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8. **Future Plans**

Future Plans

PennWest

- Complete second steam cycle on Well 103/14-06 in Q1 2014
- Begin second steam cycle on Well 100/07-36
- Evaluate second production cycles on all three pilot wells to determine third steam cycle schedule
- With the increased injection volumes, Penn West is still early in the evaluation phase of pilot results and the technology's application in the specific reservoir conditions
- Continuously evaluating project economics in light of current market conditions

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Harmon Valley South HCSS Pilot Surface Review

Surface Agenda

PennWest

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

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2. Measurement and Reporting
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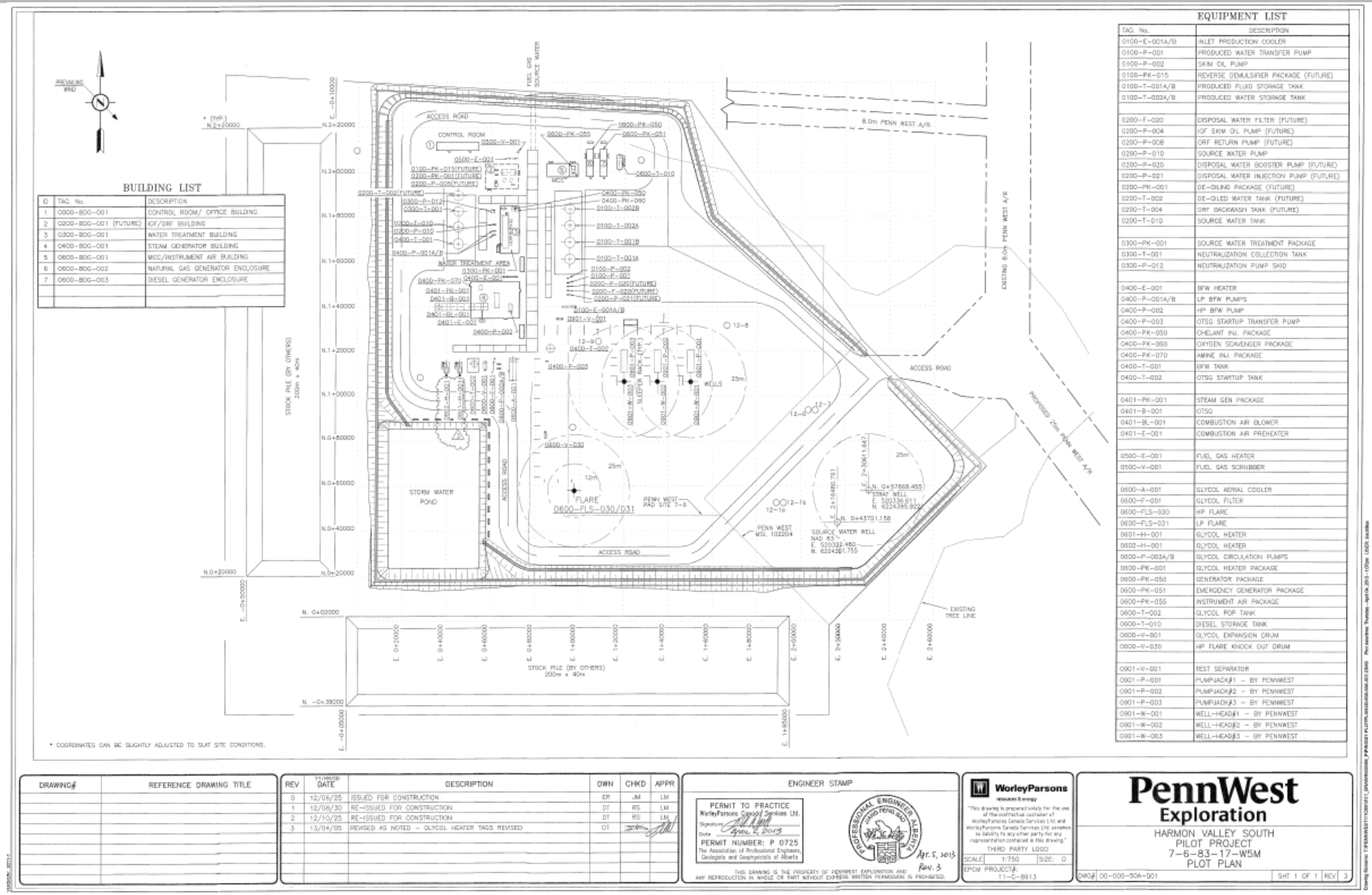
Facilities – Pilot Plot Plan

PennWest



DRAWING#	REFERENCE DRAWING TITLE

REV	DATE (YY/MM/DD)	DESCRIPTION	DWN	CHKD	APPR
0	12/06/25	ISSUED FOR CONSTRUCTION	EP	JM	LM
1	12/08/30	RE-ISSUED FOR CONSTRUCTION	DT	RS	LM
2	12/10/25	RE-ISSUED FOR CONSTRUCTION	DT	RS	LM
3	13/04/05	REVISED AS NOTED – GLYCOL HEATER TAGS REVISED	OT		

ENGINEER STAMP

PERMIT TO PRACTICE
WorleyParsons Canada Services Ltd.
Signature
Date April 5, 2013
PERMIT NUMBER: P 0725
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

PROFESSIONAL ENGINEER ALBERTA
Apr. 5, 2013
Rev. 3

WorleyParsons resources & energy

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THIRD PARTY LOGO

SCALE: 1:750 | SIZE: D

EPCM PROJECT#: 11-C-8913

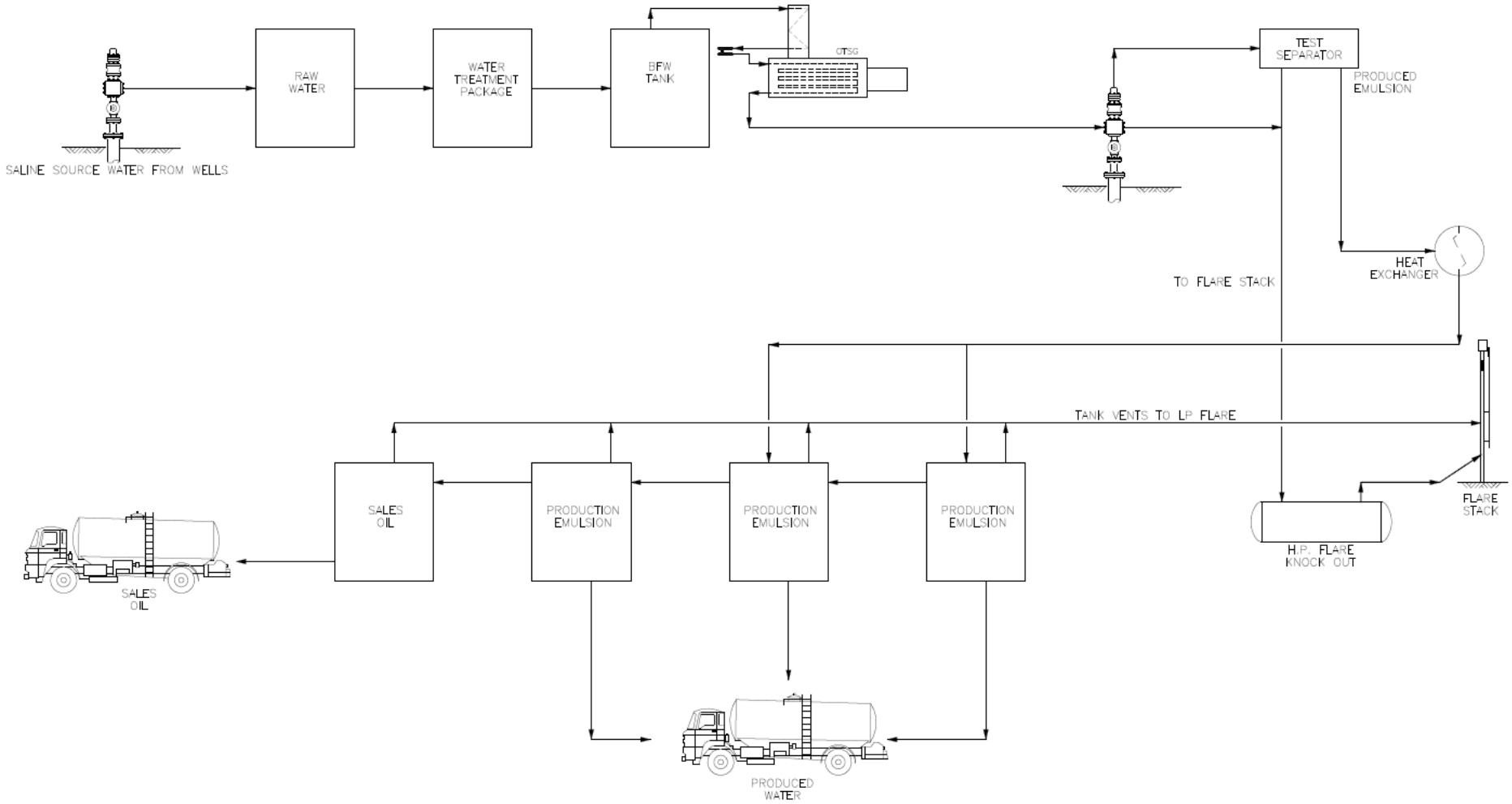
PennWest Exploration

HARMON VALLEY SOUTH
PILOT PROJECT
7-6-83-17-W5M
PLOT PLAN

DWG# 00-000-50A-001 | SHT 1 OF 1 | REV 3

Facilities – Process Flow Diagram

PennWest



Facilities - Modifications

PennWest

- 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

PennWest

- 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

PennWest

- 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

Facility Performance

PennWest

- Other Equipment:
  - Genset Packages: installed diesel and natural gas generators. Downtime for various reasons, such as overcurrent trips, cooked wires, detonation problems, fan failure, VFD faults.
  - Glycol Heaters: Downtime caused by variety of reasons, such as overloads, coolant leaks, cooked VFD, VFD faults.
  - The fuel gas lines were mostly installed without insulation or heat tracing – moisture in lines caused variety of problems and equipment trips.

Facility Performance

PennWest

- Radar level transmitters in produced fluids tanks failed to provide correct tank level feedback. Tank level gauges installed instead.
- Significant work required to swing well from steaming to production service. In future, use spectacle blinds instead of removable spools in places where possible.
- The flare knock-out drum was not fitted with separate liquid transfer pump. The vacuum truck is used as a solution. Operating costs should be considered when looking into decisions aimed at capital savings.

Facility Performance – Power Consumption

PennWest

- Harmon Valley South Thermal Pilot operates using an natural gas generator with a diesel generator as back-up.

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 %
Jul-13	22.3	0	0	0	0%
Aug-13	206.4	0	0	0	0%
Sep-13	186.5	0	0	0	0%
Oct-13	239.9	0	0	0	0%
Nov-13	304.7	0	18.1	0	0%
Dec-13	639.5	0	6.2	0	0%
Jan-14	389.6	0	6.2	0	0%
Feb-14	277.3	0	6.2	0	0%
Mar-14	280.6	0	6.2	0	0%
Apr-14	210.9	0	5	0	0%
May-14	261.2	0	6.9	0.1	0%
Jun-14	293.7	0	11.5	0.3	0%
Jul-14	73.5	0	6.9	0.3	0%
Aug-14	92.4	0	6.7	0.2	0%
Sep-14	256.2	0	3.6	0.2	0%
Oct-14	527.2	0	10.6	0	0%
Nov-14	419.7	0	18.1	0	0%
Dec-14	435.7	0	17.1	0.1	0%

Surface Agenda

PennWest

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

Measurement and Reporting

PennWest

- 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

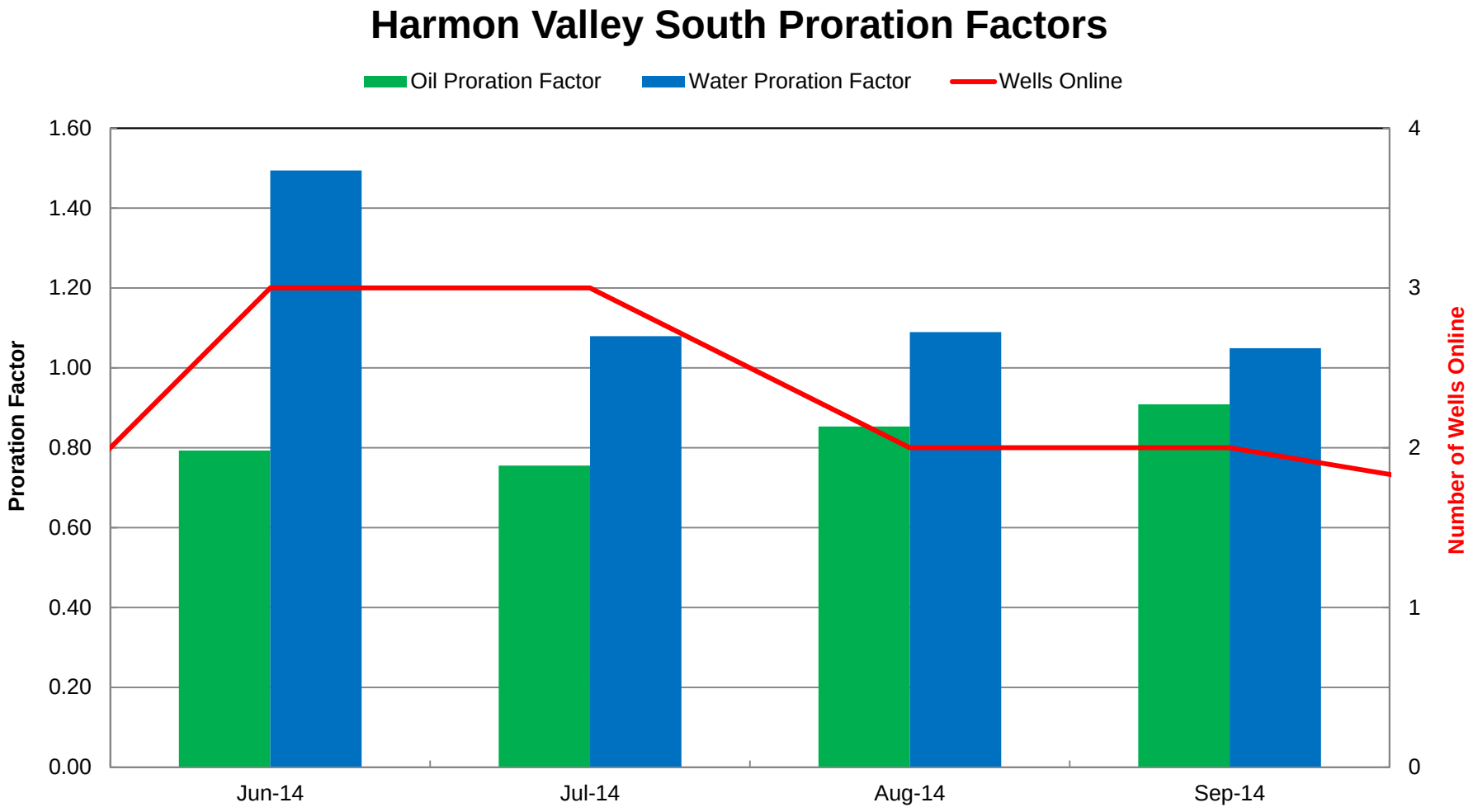
PennWest

- 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

Measurement and Reporting - Proration Factors

PennWest

- Multiple wells producing Jun-14 through Sep-14



Measurement and Reporting – Water Balance

PennWest

INJECTION FACILITY AB IF 0128299

Month	TOTAL IN m^3	TOTAL OUT m^3	INVENTORY ADJUSTMENT m^3	BALANCE m^3	BALANCE %
Nov-13	2,808	2,463	315	-29	1.0%
Dec-13	5,420	5,428	-8	0	0.0%
Jan-14	2,749	2,807	26	85	3.1%
Feb-14	717	908	-51	140	19.5%
Mar-14	3,231	3,157	71	-3	0.1%
Apr-14	1,601	1,598	3	0	0.0%
May-14	2,969	2,849	-43	-164	5.5%
Jun-14	2,515	2,544	-104	-74	3.0%
Jul-14	0	0	0	0	0.0%
Aug-14	43	0	41	-2	4.8%
Sep-14	3,077	2,992	85	0	0.0%
Oct-14	6,081	6,117	-36	0	0.0%
Nov-14	4,368	4,368	0	0	0.0%
Dec-14	3,566	3,512	54	0	0.0%

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PennWest

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Water Use

PennWest

- 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

	Brackish Water, m^3	
	1F1/16-36-082-18W5	100/14-25-082-18W5
Nov-13	461	931
Dec-13	4,272	1,139
Jan-14	2,578	171
Feb-14	592	125
Mar-14	1,554	1,677
Apr-14	63	1,527
May-14	1,347	1,622
Jun-14	413	2,102
Jul-14	0	0
Aug-14	23	0
Sep-14	1,887	1,105
Oct-14	6,063	18
Nov-14	4,313	55
Dec-14	2,637	928

Surface Agenda

PennWest

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Water Treatment

PennWest

- 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
- Separate heated storage for chemicals currently being constructed
- Harmon Valley South Pilot facility does not recycle produced water due to make up water requirements of less than 500 000 m^3/year

Surface Agenda

PennWest

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Water and Waste Disposal

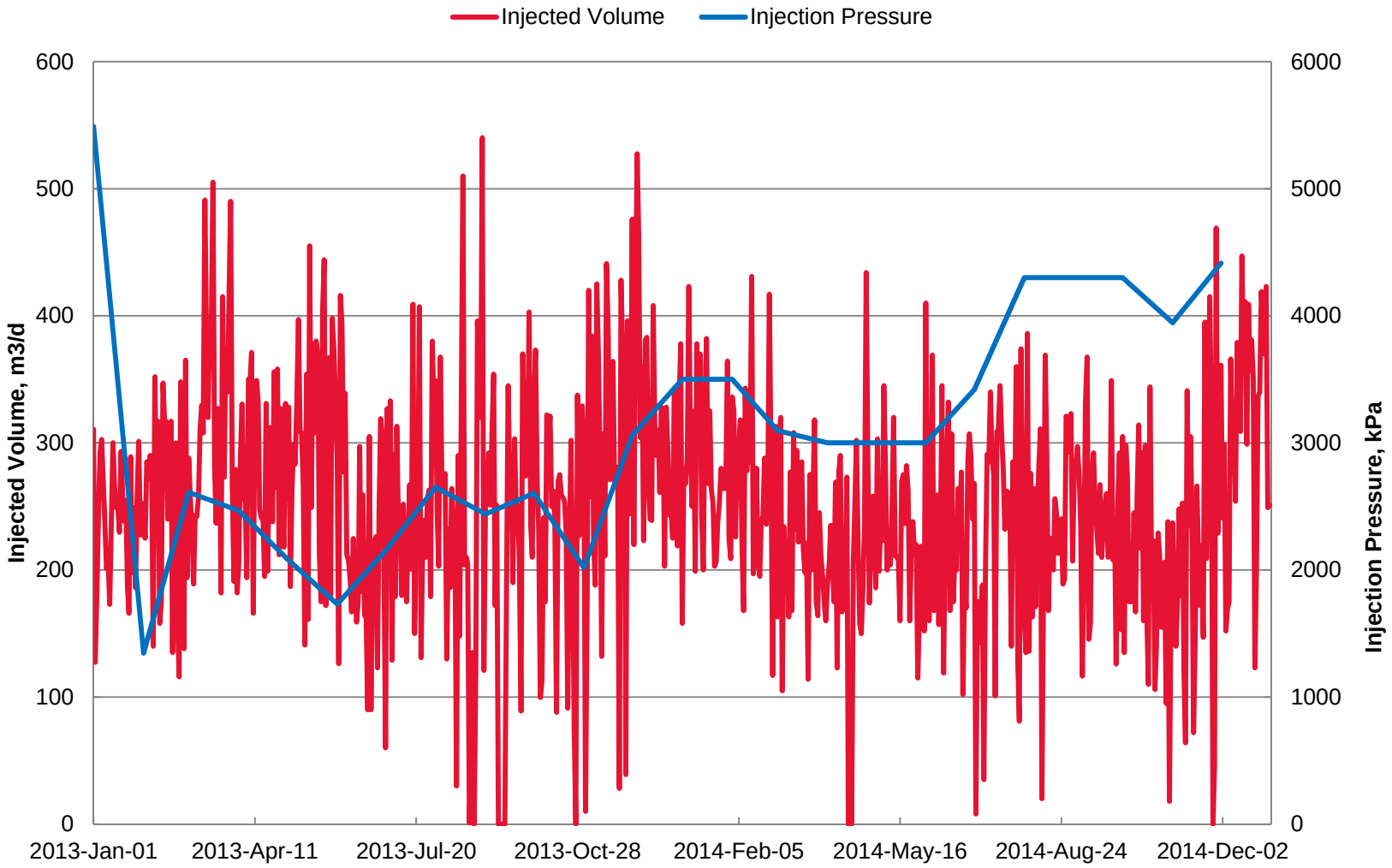
PennWest

- 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

Water Disposal

PennWest

100/14-18-082-17W5 Disposal Well



Includes all disposal water injected at 100/14-18-082-17W5

Surface Agenda

PennWest

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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-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 tonne

SO_2 Production

PennWest

- EPEA Approval for Harmon Valley South 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	0.4	0.3
Sep-13	0.3	0.2
Oct-13	0.3	0.3
Nov-13	0.5	0.3
Dec-13	0.5	0.4
Jan-14	0.1	0.1
Feb-14	0.4	0.3
Mar-14	0.4	0.4
Apr-14	0.2	0.2
May-14	2.8	1.9
Jun-14	0.4	0.2
Jul-14	0.6	0.4
Aug-14	0.1	0.1
Sep-14	0.2	0.1
Oct-14	0.3	0.2
Nov-14	0.5	0.4
Dec-14	0.5	0.5

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Environmental

PennWest

- 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

PennWest

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

Surface Agenda

PennWest

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Non-Compliance – Voluntary Self-Declarations

PennWest

- Jan 2013: High Risk Enforcement due to application for Directive 056 Facility License prior to Directive 042 MARP Approval

- April 2014: Exceeded steam injection volume to 103/14-06-083-17W5 during steam cycle 1
  - Injected 3,569 m^3 above 14.5MPa due to faulty cumulative steam calculated tag

Surface Agenda

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Future Plans

PennWest

- Evaluating project success with increased injection volumes
- Evaluating project economics in light of current market conditions

Questions?

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