Performance Presentation for In-Situ Oilsands

Experimental Scheme Approval No. 11825
November 28th, 2016

AER Directive 054 - 2016 Performance Presentation

Section 3.1.1

Subsurface Issues Related to Resource Evaluation and Recovery

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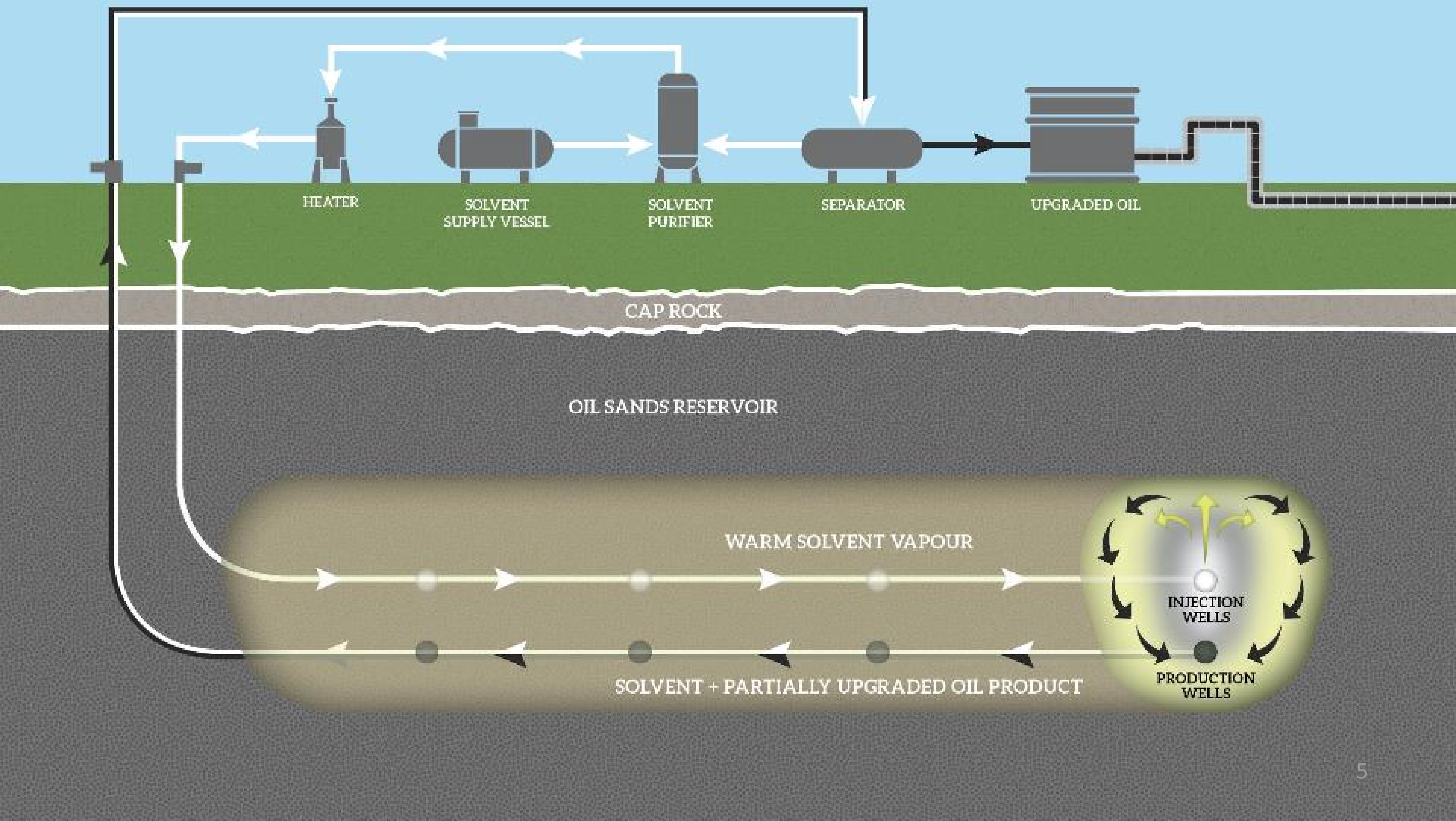
Background

Nsolv is an in-situ technology that uses warm solvent to extract bitumen from oil sands efficiently and sustainably:

- Up to 75% reduction in GHGs compared to SAGD
- In-situ upgrading → downstream GHG benefits
  - Currently observing upgrade from 8 to 14 API
- Zero process water usage

How it works


HEATER
SOLVENT SUPPLY VESSEL
SOLVENT PURIFIER
SEPARATOR
UPGRADED OIL
CAP ROCK
OIL SANDS RESERVOIR
WARM SOLVENT VAPOUR
INJECTION WELLS
PRODUCTION WELLS
SOLVENT + PARTIALLY UPGRADED OIL PRODUCT

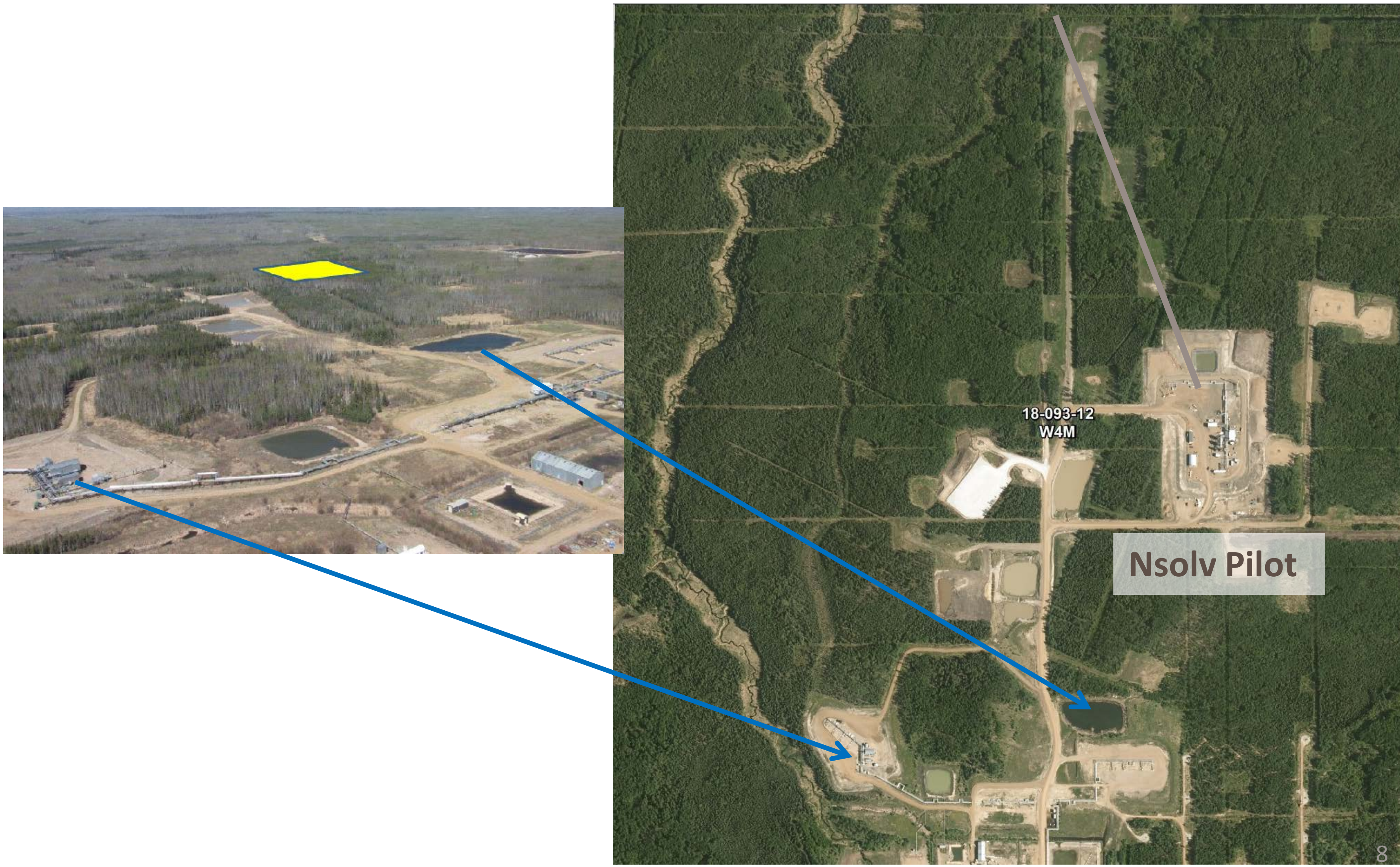
Background – BEST Pilot Plant

- **B**itumen **E**xtraction **S**olvent **T**echnology
- Purpose: demonstrate commercial viability of the Nsolv process in a field setting
- 1 x 300 m HZ well pair
- 7 x vertical observation wells
- 238.5 m^3/d (1500 bpd) solvent delivery capability
- 79.5 m^3/d (500 bpd) oil processing capability

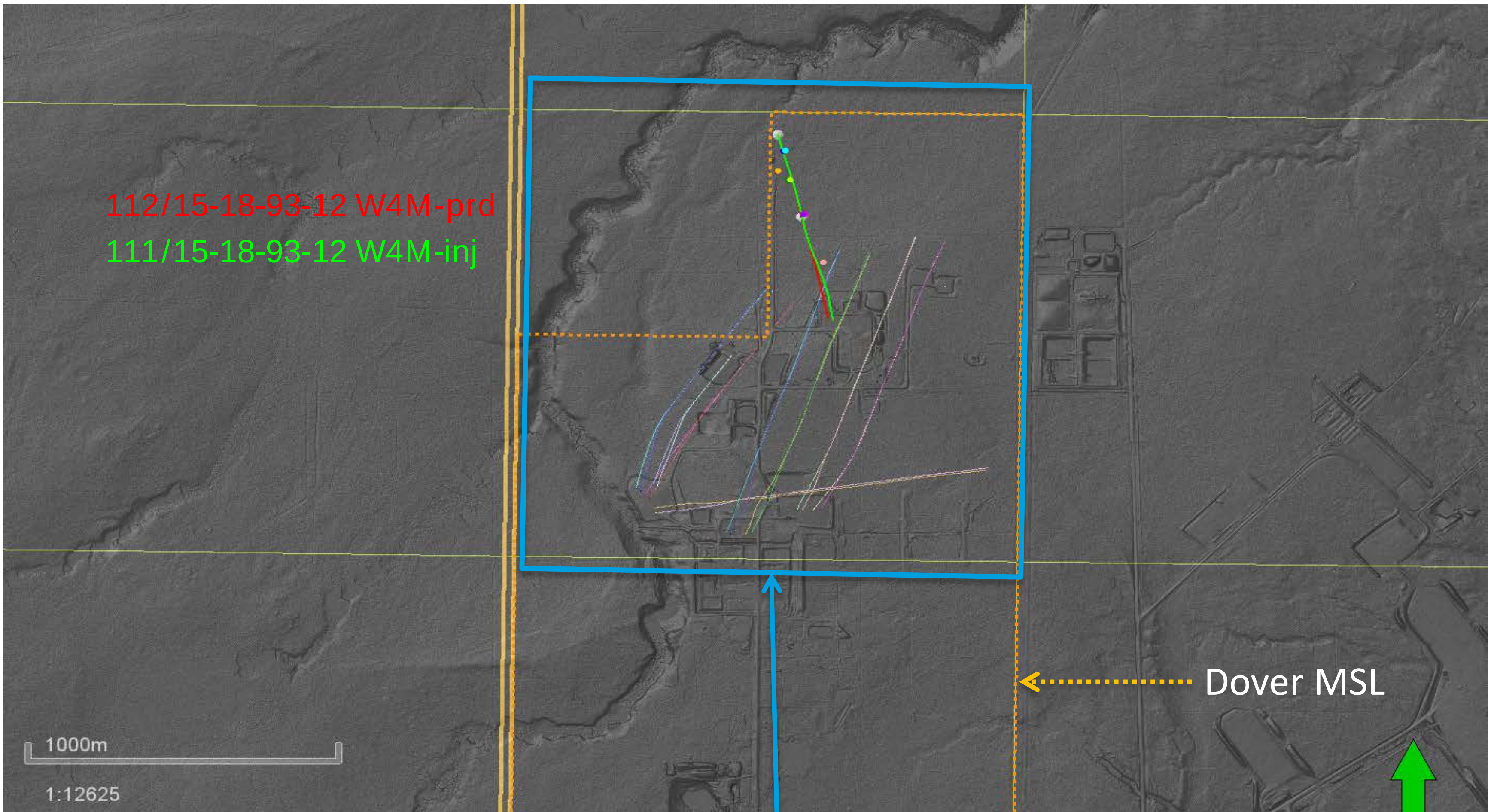
Background – BEST Pilot Plant

- Ability to use either propane or butane
  - In order to minimize any potential for solvent losses to the bitumen reservoir, the solvent chamber is kept in balance with the native reservoir pressure
  - The ideal operating temperatures are between 35-75 °C as this provides an adequate rise in the bitumen temperature to significantly reduce the bitumen viscosity
  - Choice of solvent is therefore based upon the solvent whose vapour pressure between 35 to 75 °C is balanced with the native reservoir pressure
  - Butane was chosen since at 60 °C its vapour pressure is ~600 kPag

Background – Project Location



Project Location



Section 18, Twn. 93 Rng. 12W4

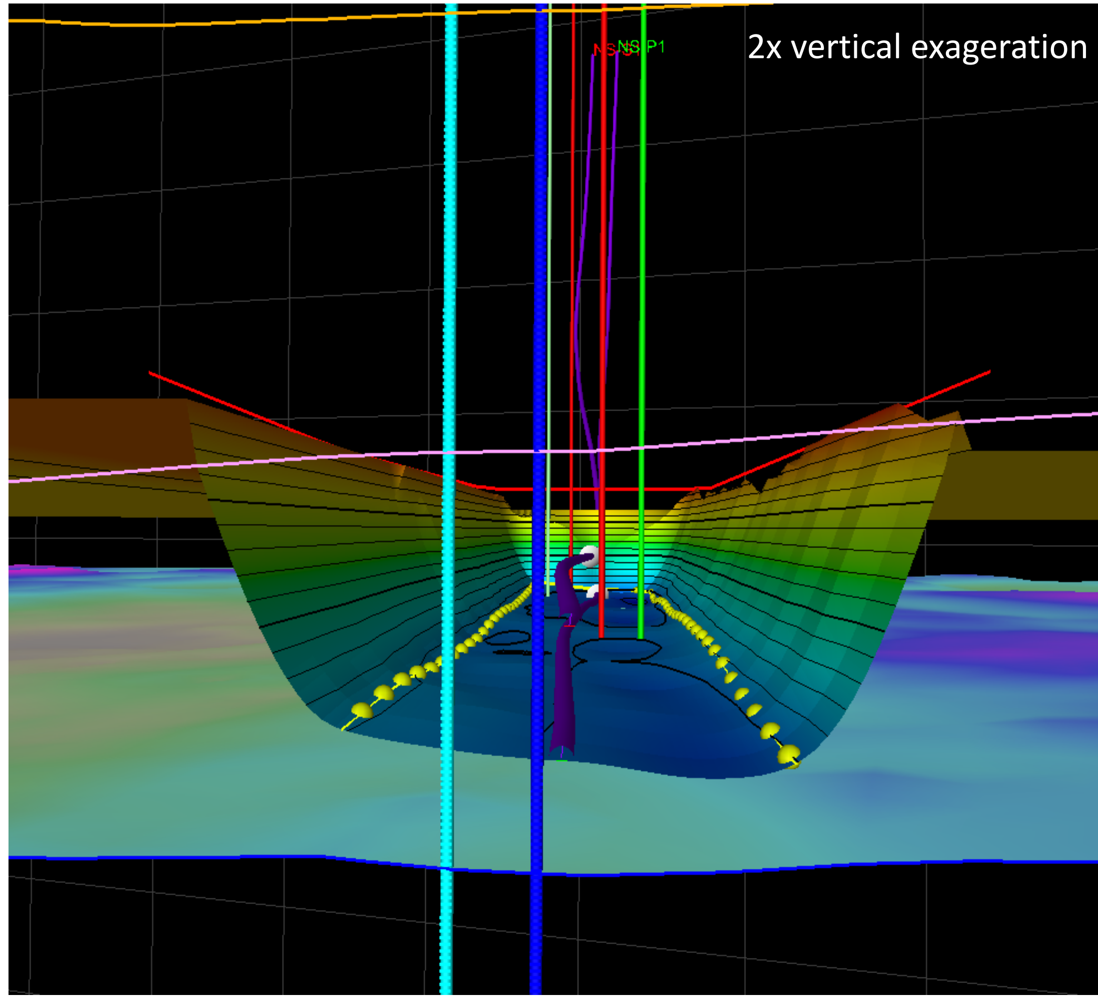
BEST Pilot Plant – Commissioned Summer 2013

Volumetrics (Based on ~35m drainage radius)

<u>Volume Calculation</u>

- Drainage Area = 24,313m2
- Pay Thickness = 13m above producer
- So=75%, Porosity=33.4%
- 79,175m3 Exploitable PIIP
- Recoverable Bitumen
    - 10° drainage angle (~24% reduction)
    - 75% chemical yield
    - 45,130m3 (57% recoverable)
    - 15,242 m3 bitumen recovered as of Aug 30th, 2016

    - 34% of recoverable
    - 19% of exploitable PIIP

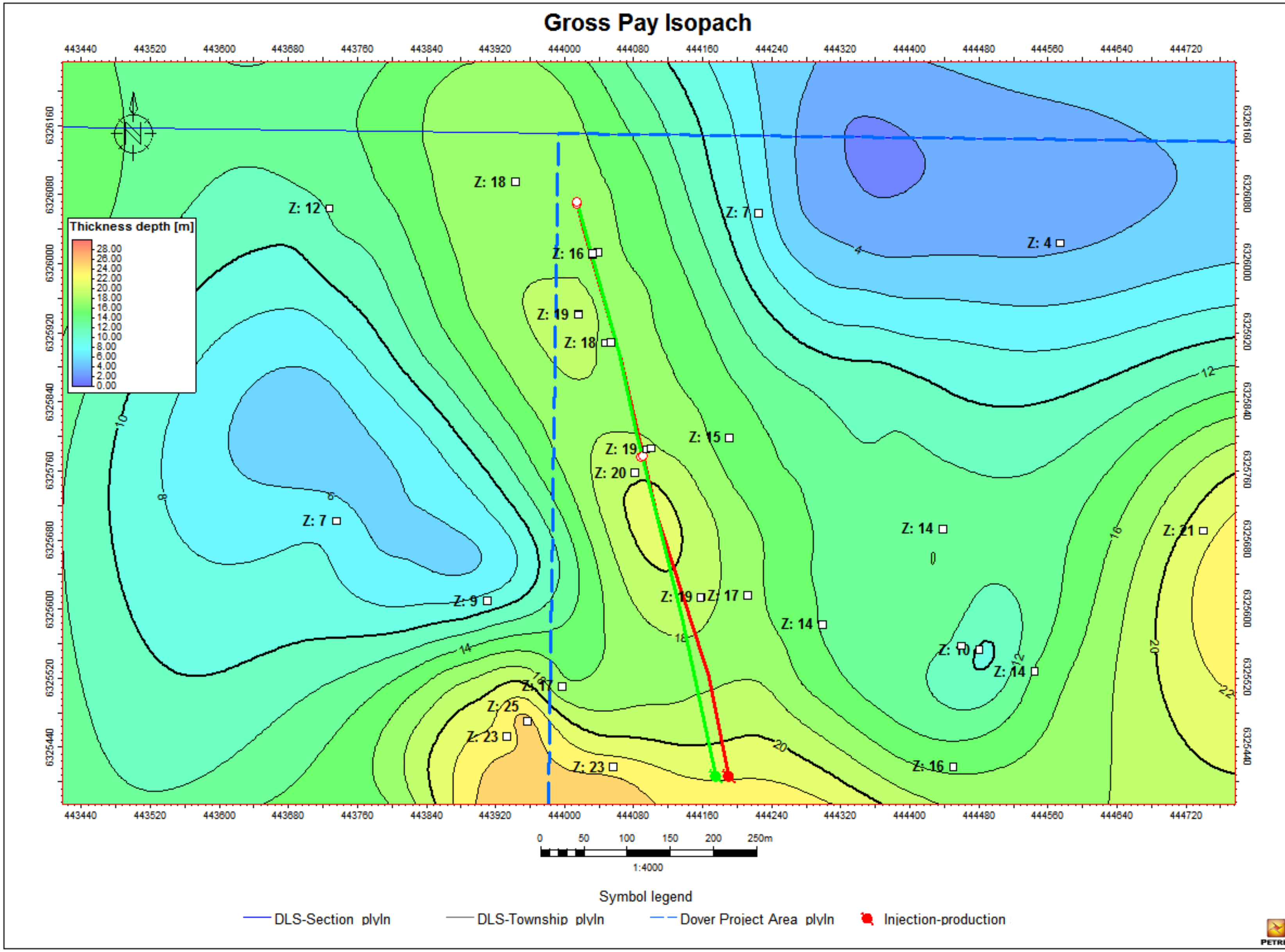


PIIP=Area* Pay thickness above producer* Oil Saturation* Porosity

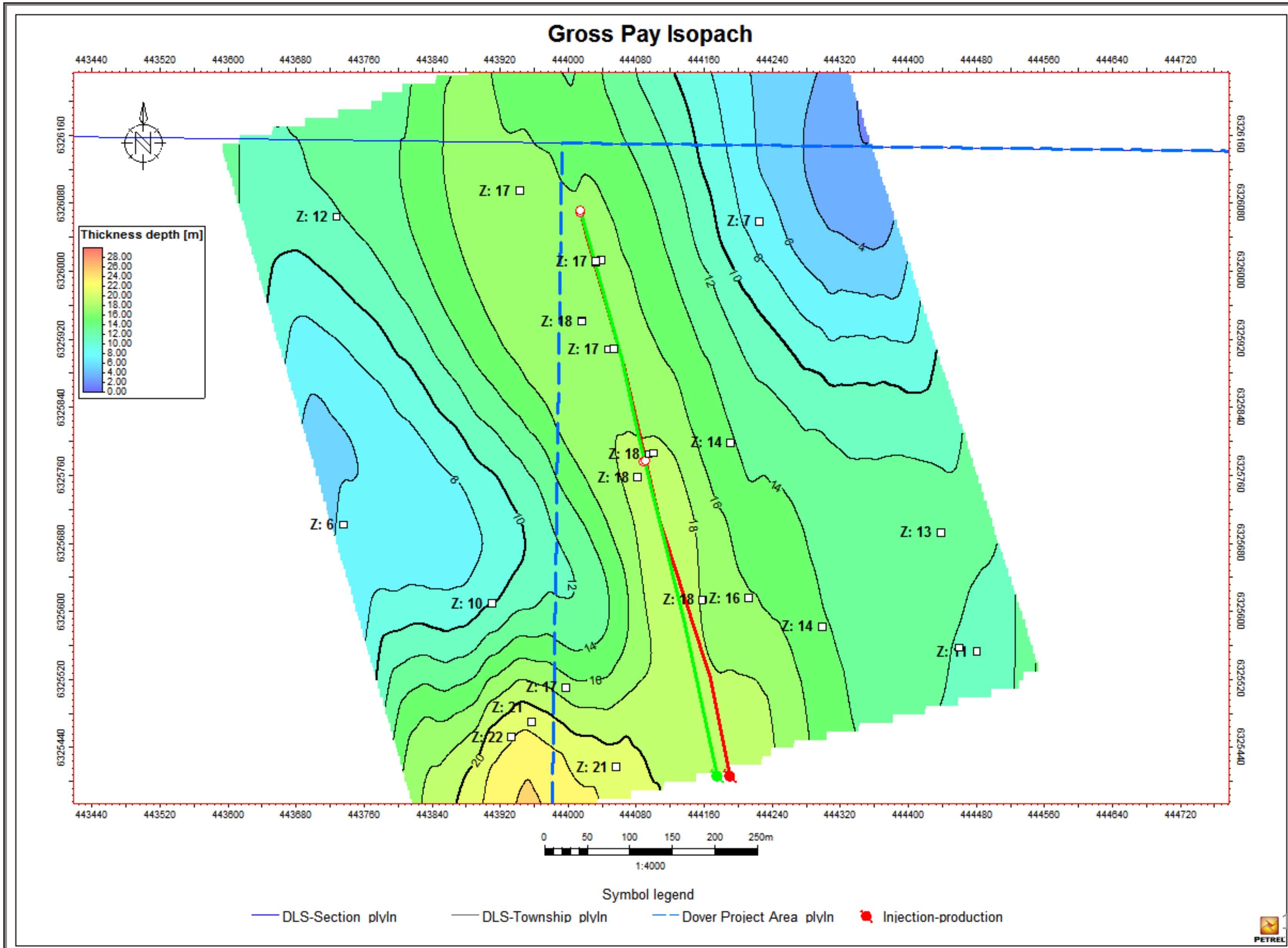
Average Reservoir Parameters

Porosity	33.4%
Effective Porosity	29%
Oil Saturation	75%
Horizontal Perm Petrel	6500mD, (3670 breccia)
Vertical Perm Petrel	5370mD, (2400 breccia)
Horizontal Perm Core Data	6817mD
Vertical Perm Core Data	5300mD (arithmetic ave)
Exploitable Pay	13m
Net Pay	18m
Depth to top of Pay	123.5m
Native Reservoir Pressure (Top of Pay)	600kPag
Native Reservoir Temperature	7°C

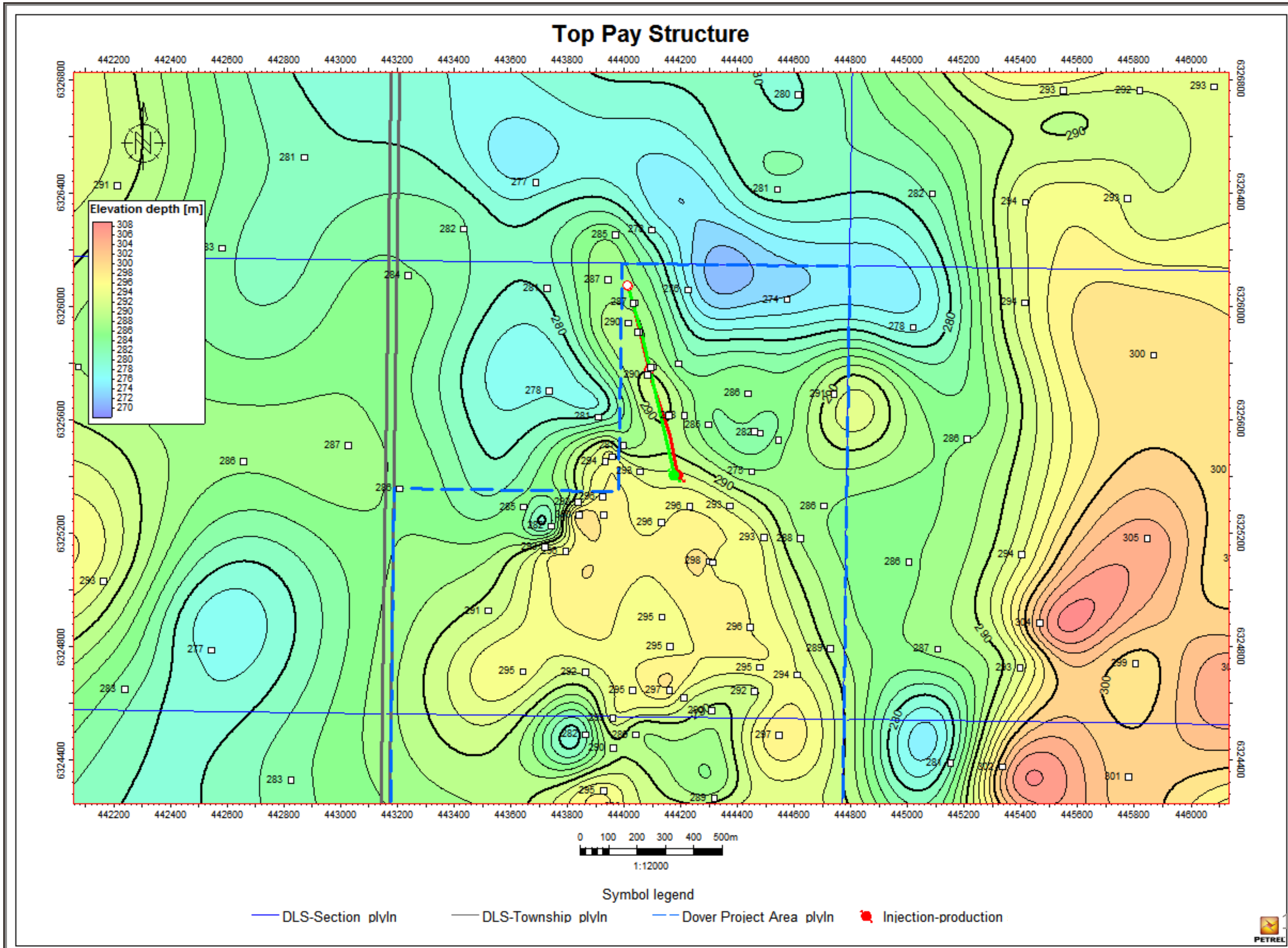
Geology – Gross Pay Interval



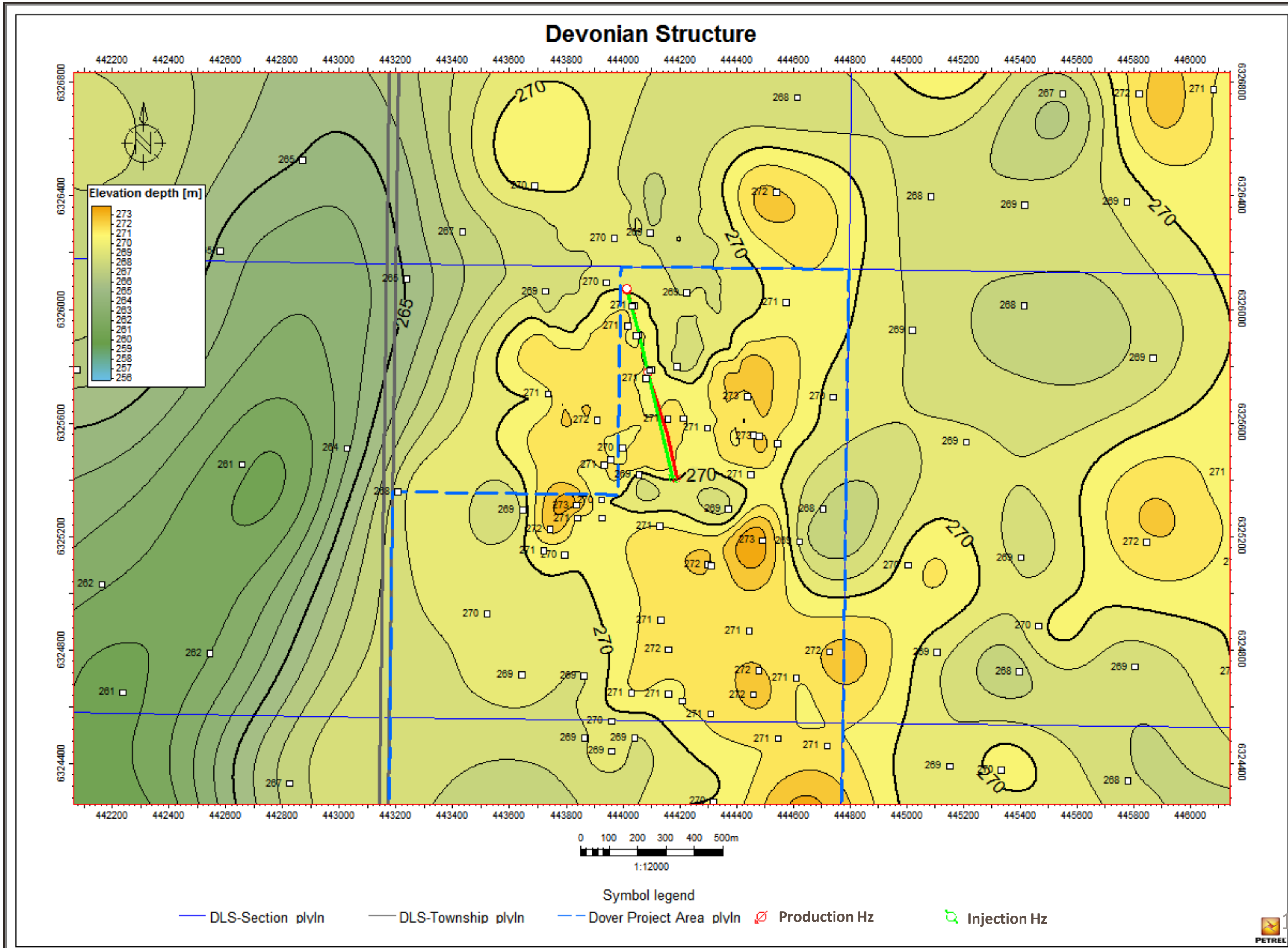
Geology – Net Bitumen Pay



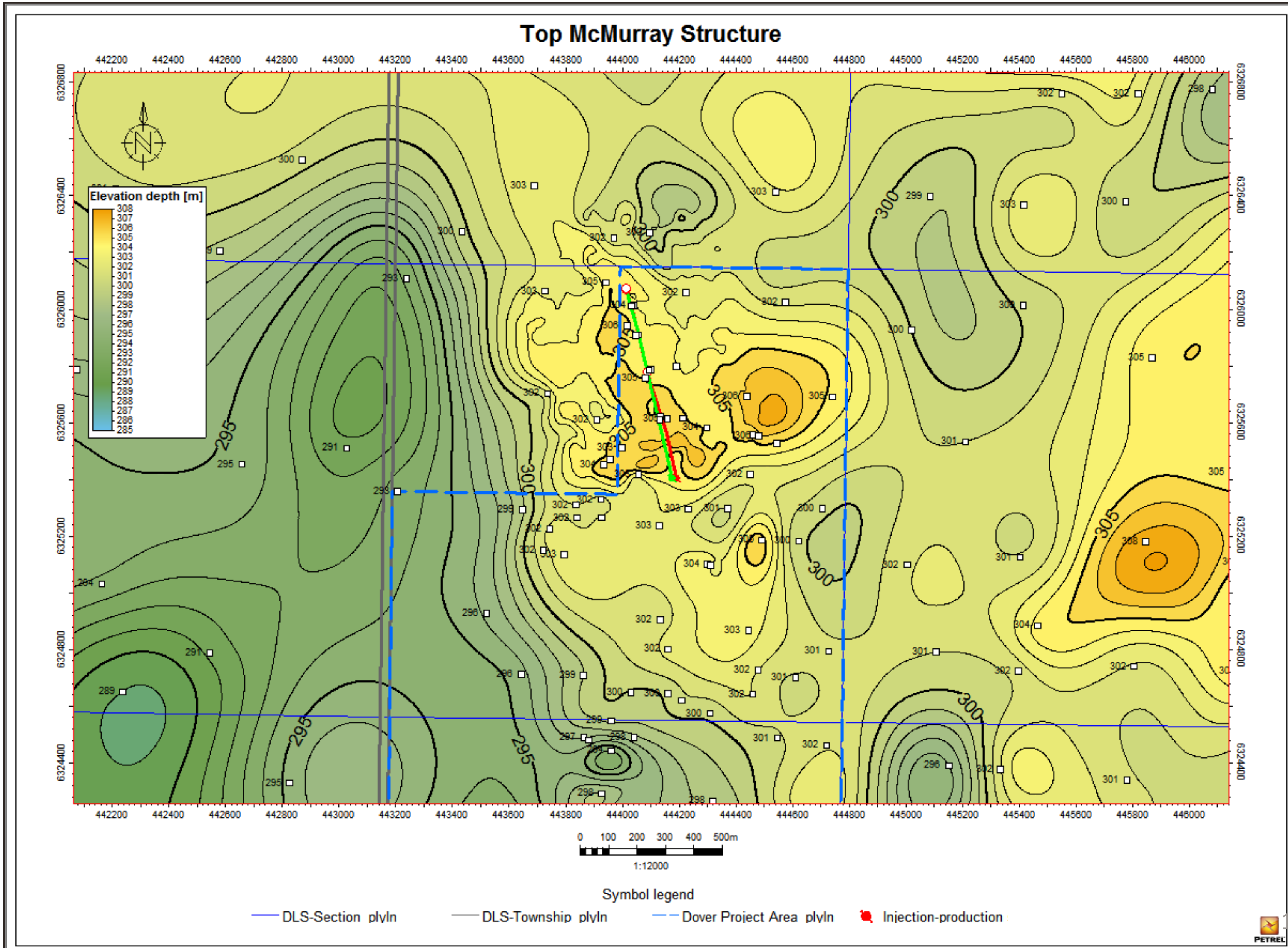
Geology – Top Pay Structure



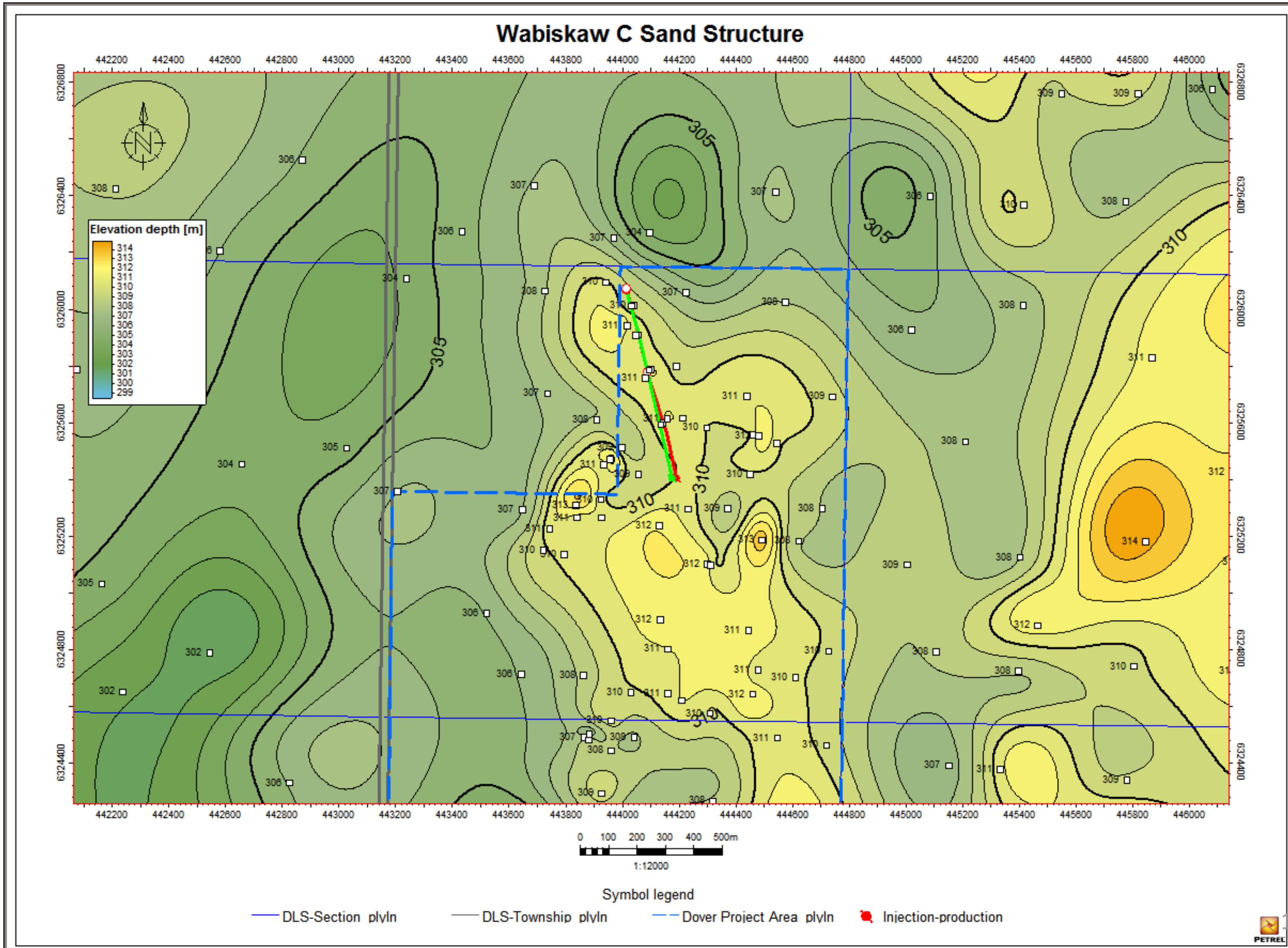
Geology – Devonian Structure



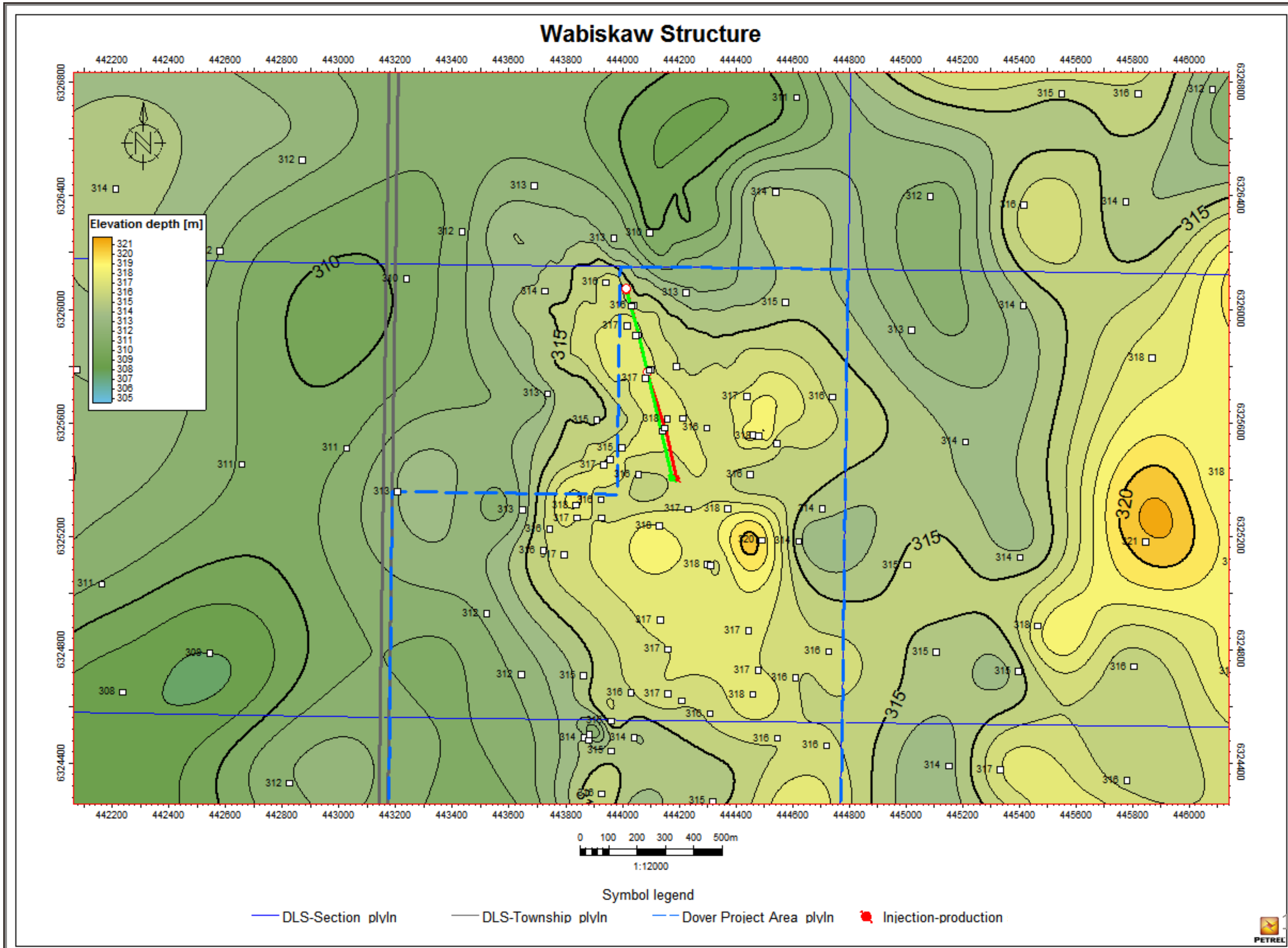
Geology – McMurray Structure



Geology – Wab C Sand Structure

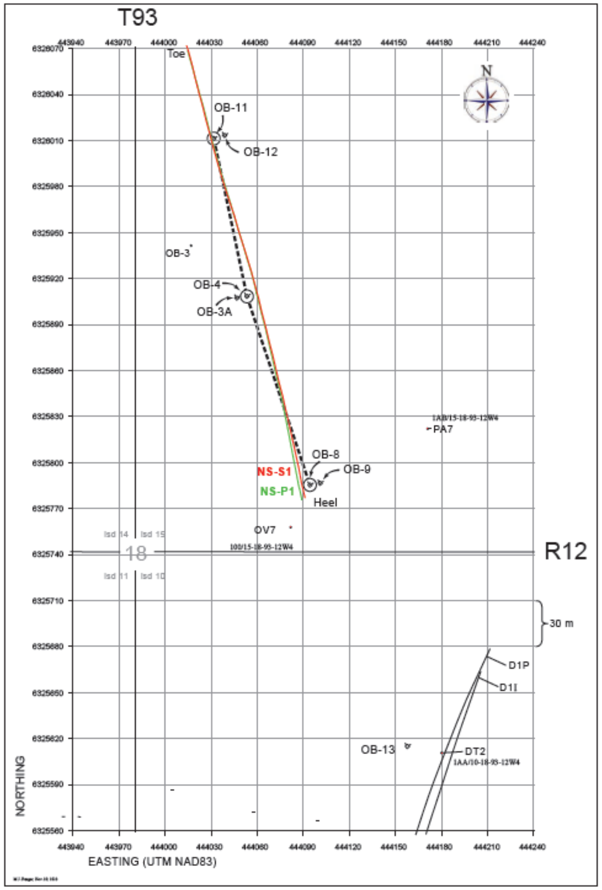


Geology – Wabiskaw Structure



Geology – Logs

OB-08
Offset 6.7m



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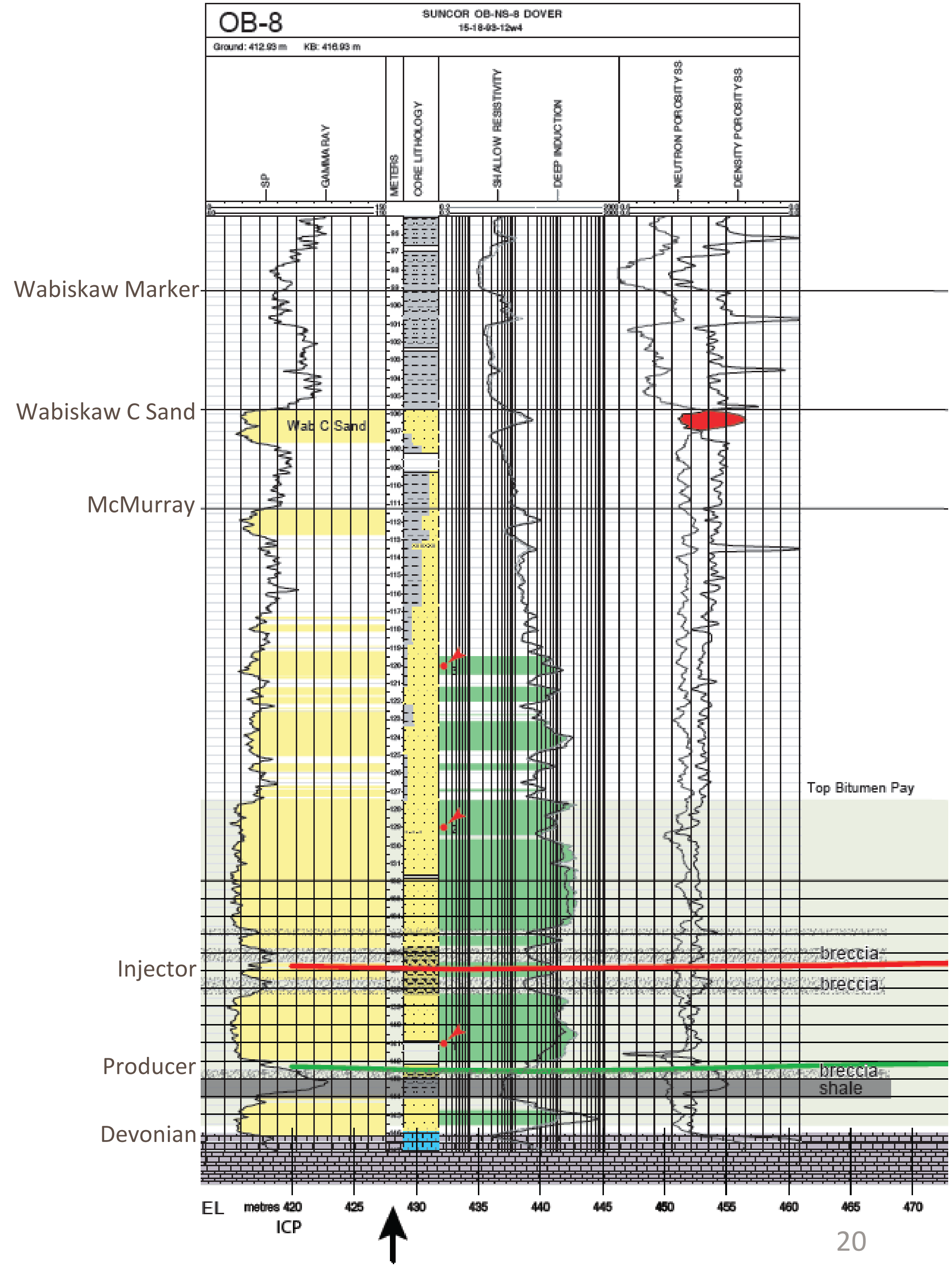
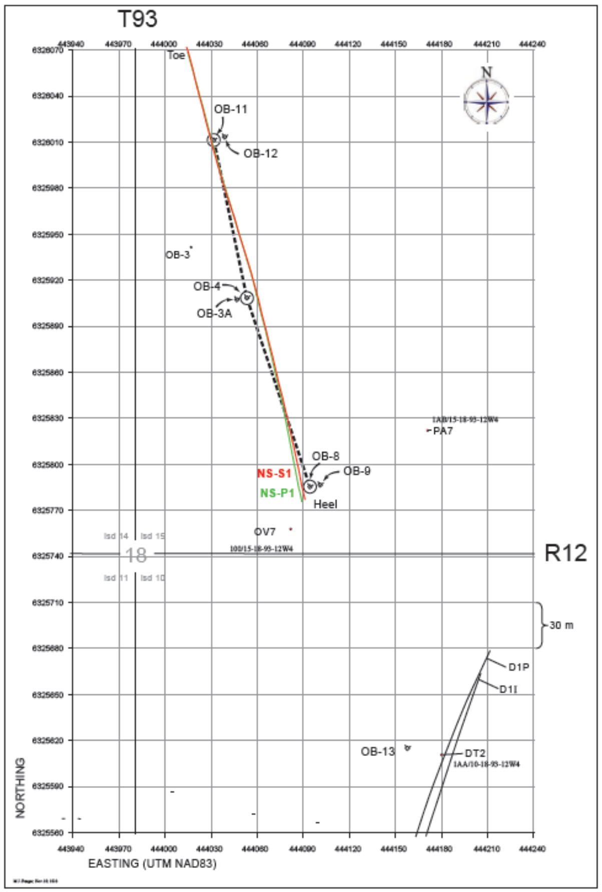
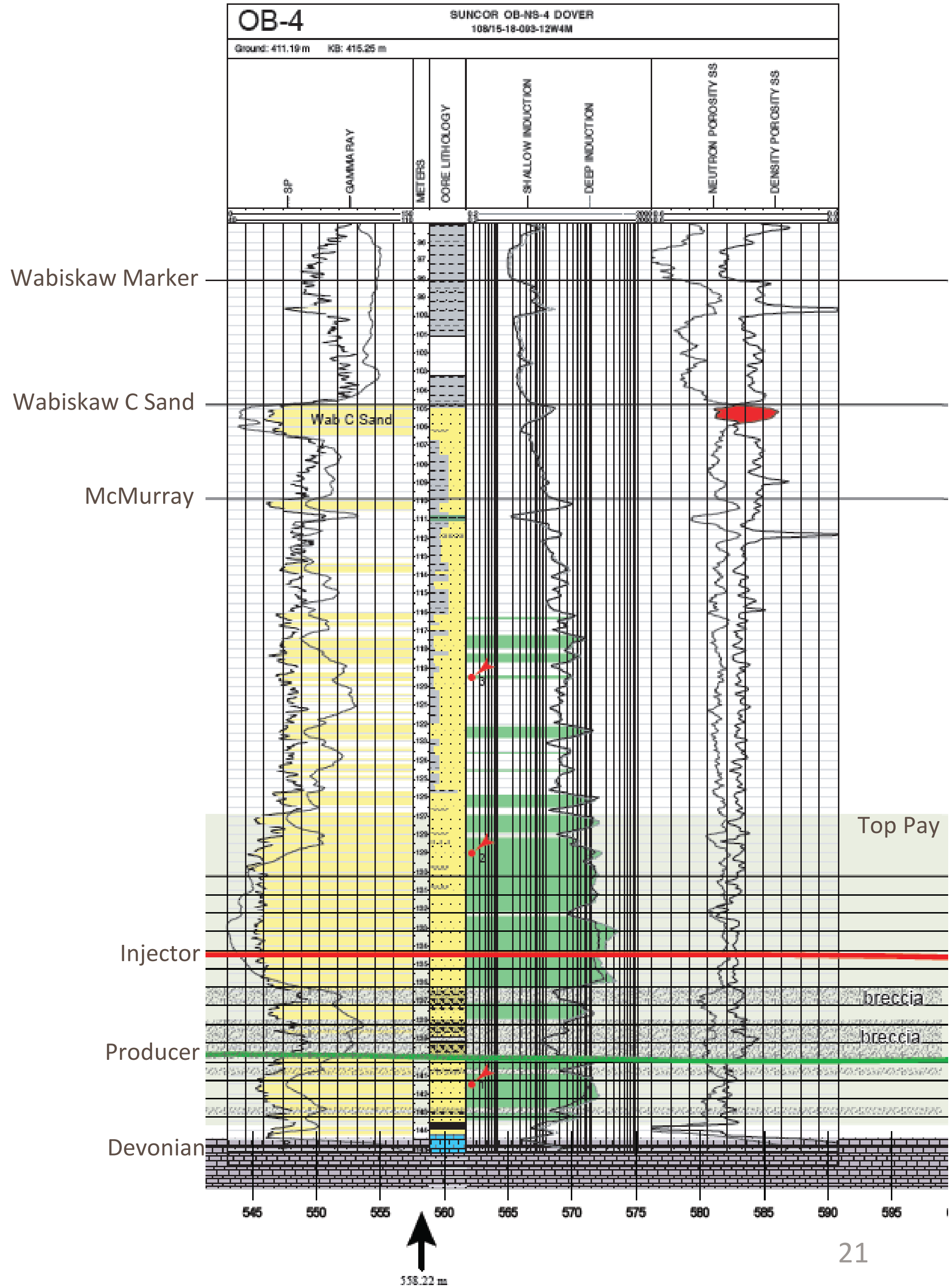


Geology – Logs

OB-04
Offset 3.6m





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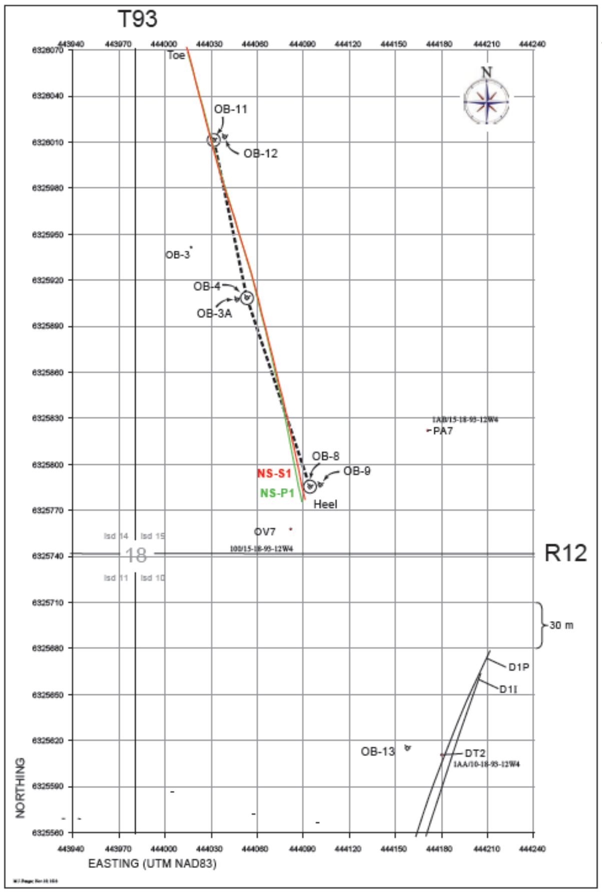
Geology – Logs

OB-11
Offset 4.3m



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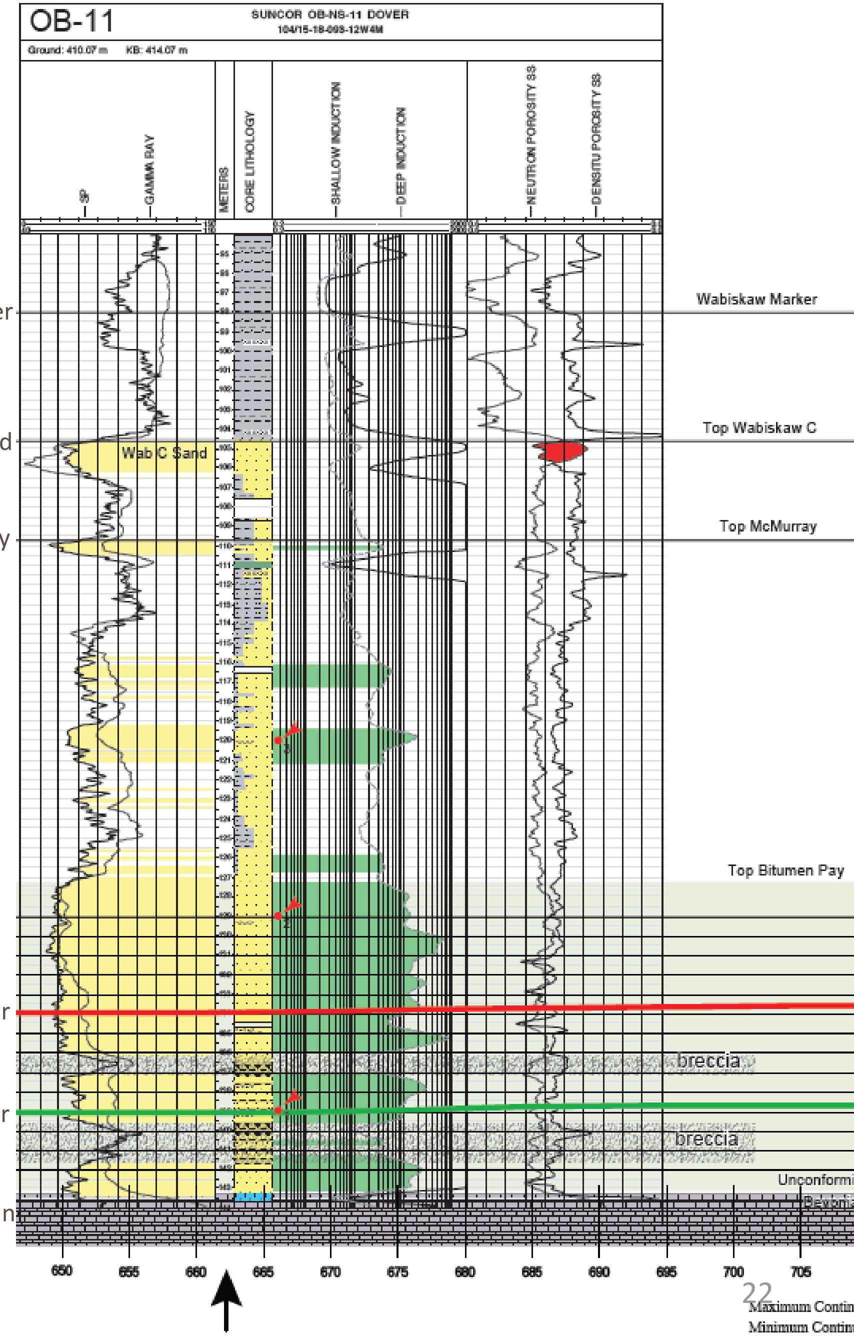
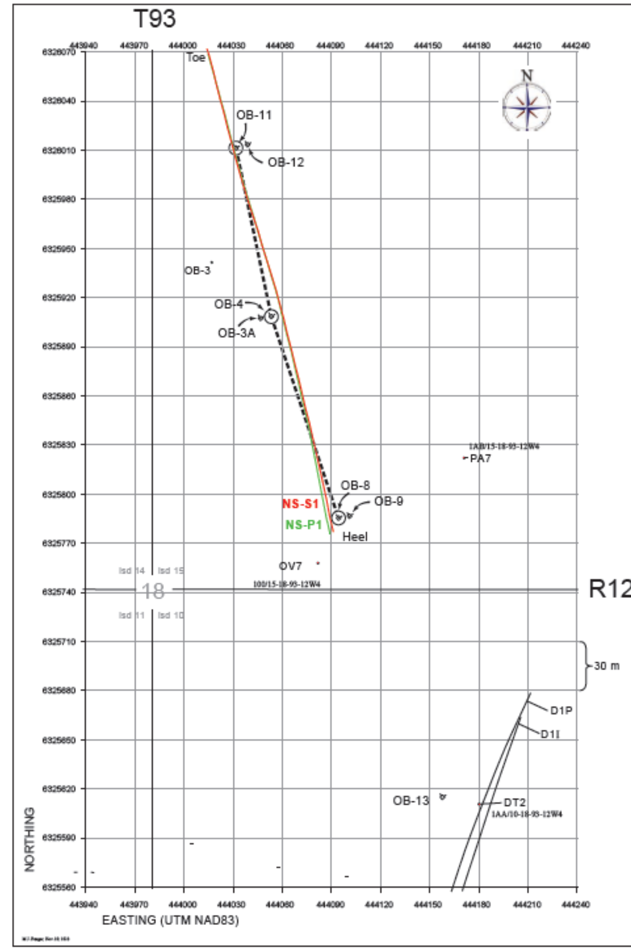


Geology

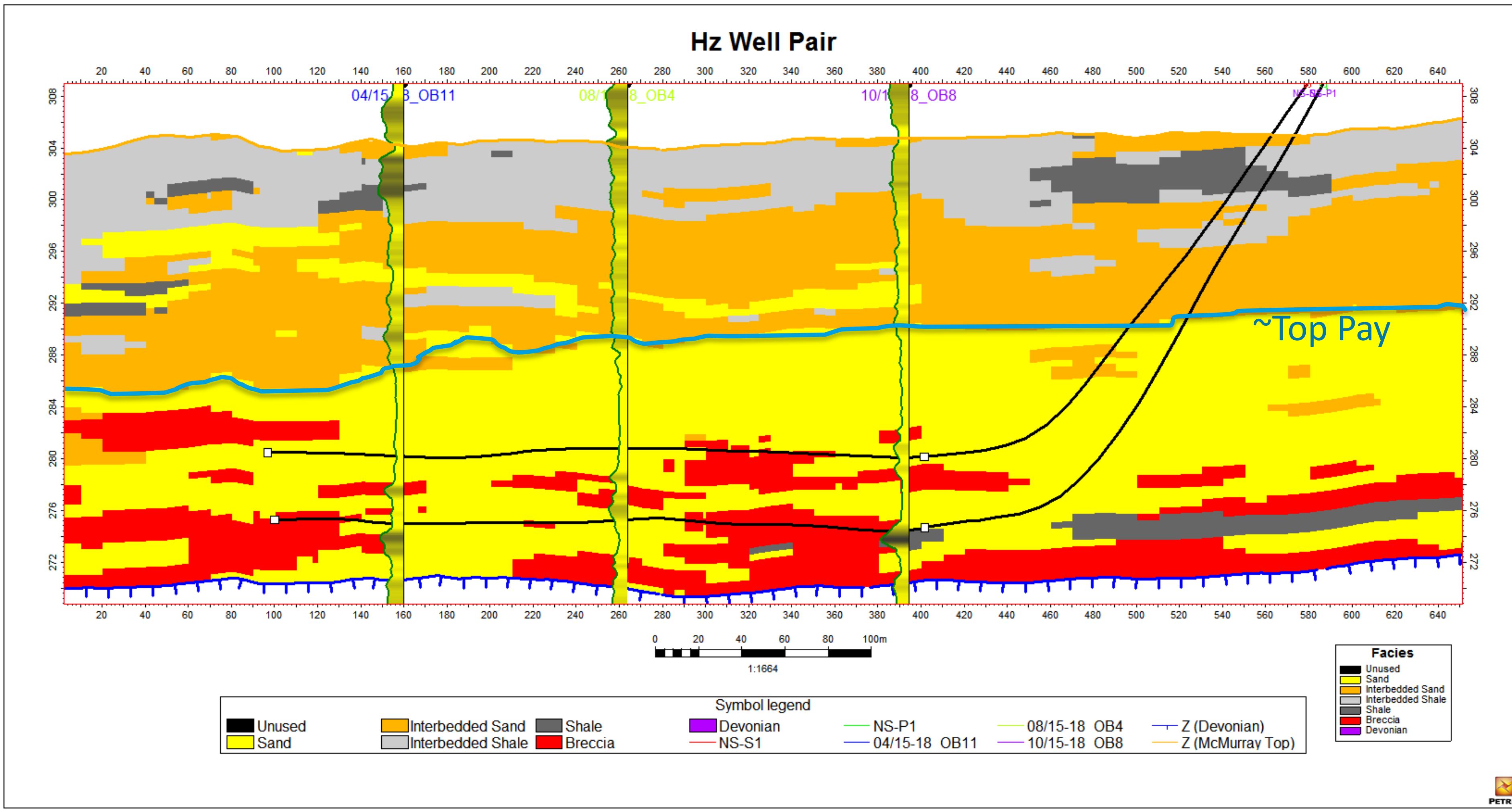
Cored Wells:

- OB 13
- OB 08
- OB 04
- OB 11

- Routine analysis
- Bitumen characterization
- N + S + metal contents



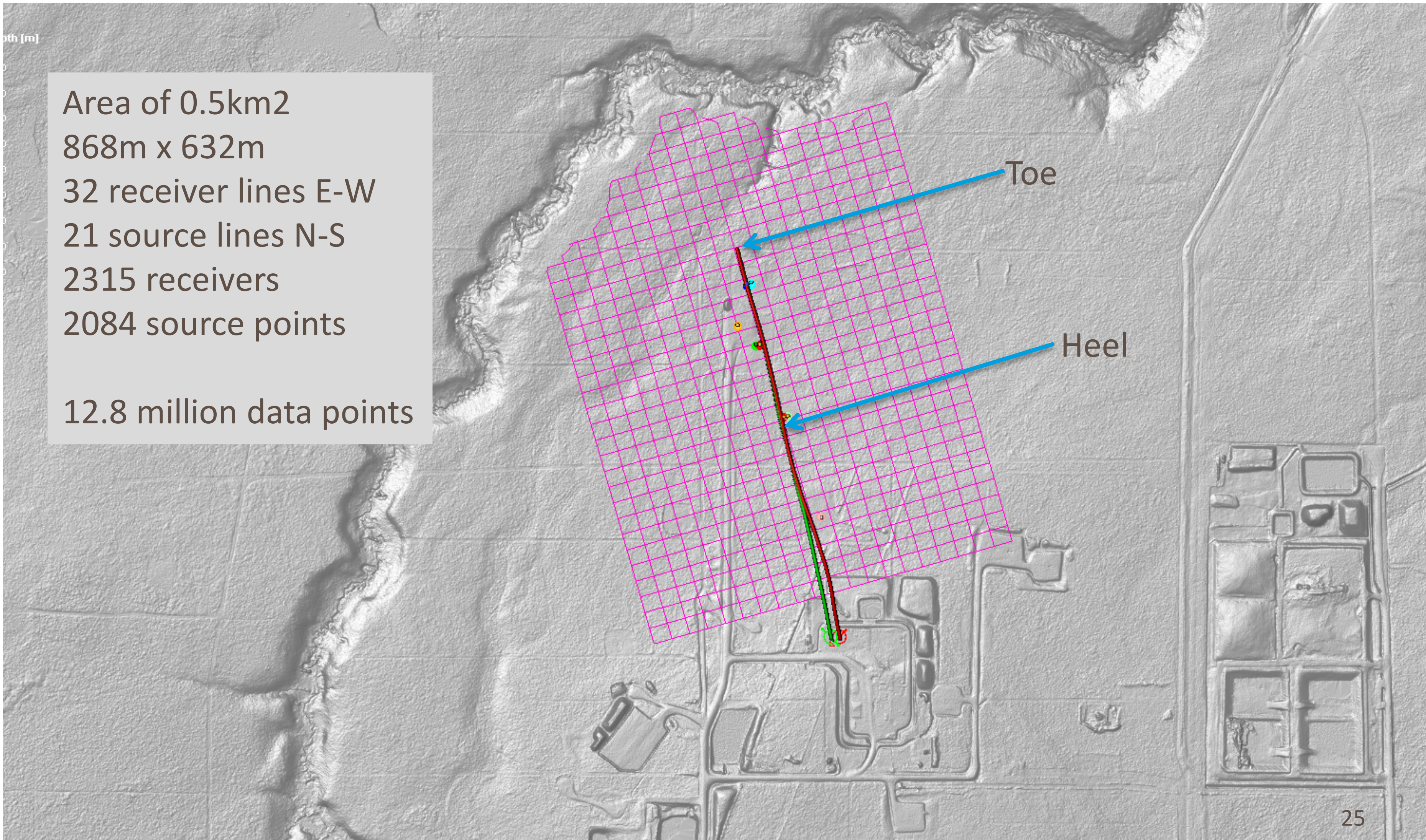
Hz Well Cross Section



3D Seismic March 15th, 2015
Reshot March 28th, 2016

Area of 0.5km2
868m x 632m
32 receiver lines E-W
21 source lines N-S
2315 receivers
2084 source points

12.8 million data points



Operating Pressure

As per AER Bulletin 2014-03

MOP=0.8 x caprock fracture closure gradient x depth to base of caprock

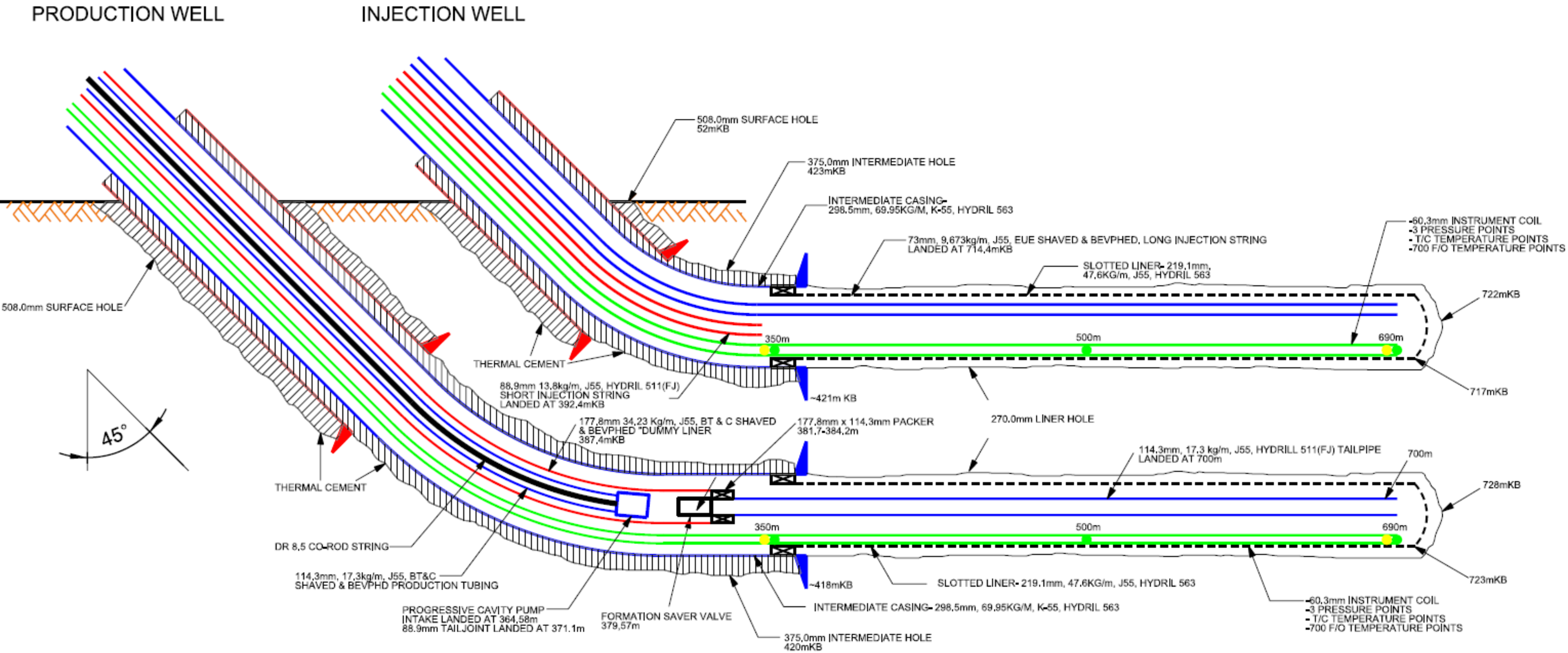
Caprock fracture gradient = 21 kPa/m*
Shallowest Wabiskaw D shale is in well OB-3 (102/15-18-093-12W4) @105m MD

MOP = 0.8 x 21 kPag/m x 105m = 1,764 kPag

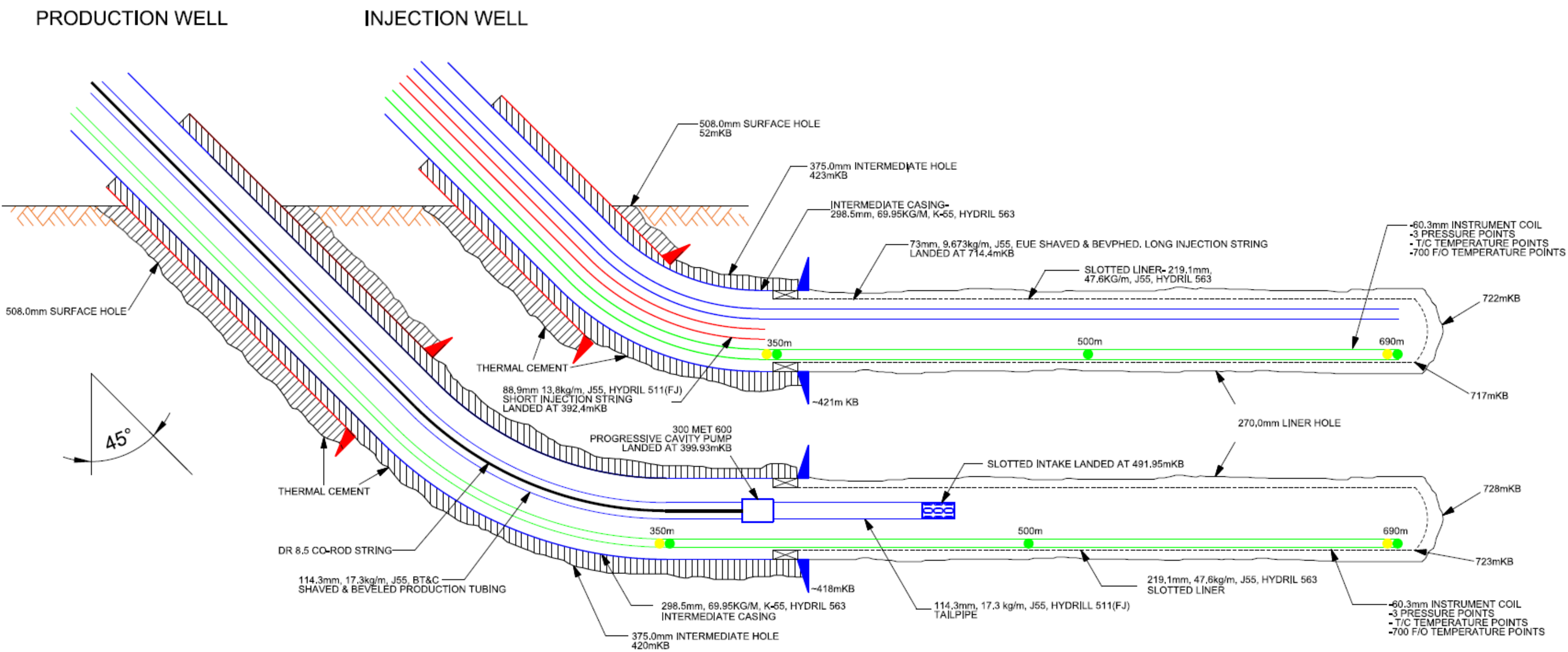
Our current operating window is 570-600 kPag or ~ 34% of MOP as per AER bulletin 2014-03.

*From Suncor MacKay River mini frac analysis

Completions – MTM PCP

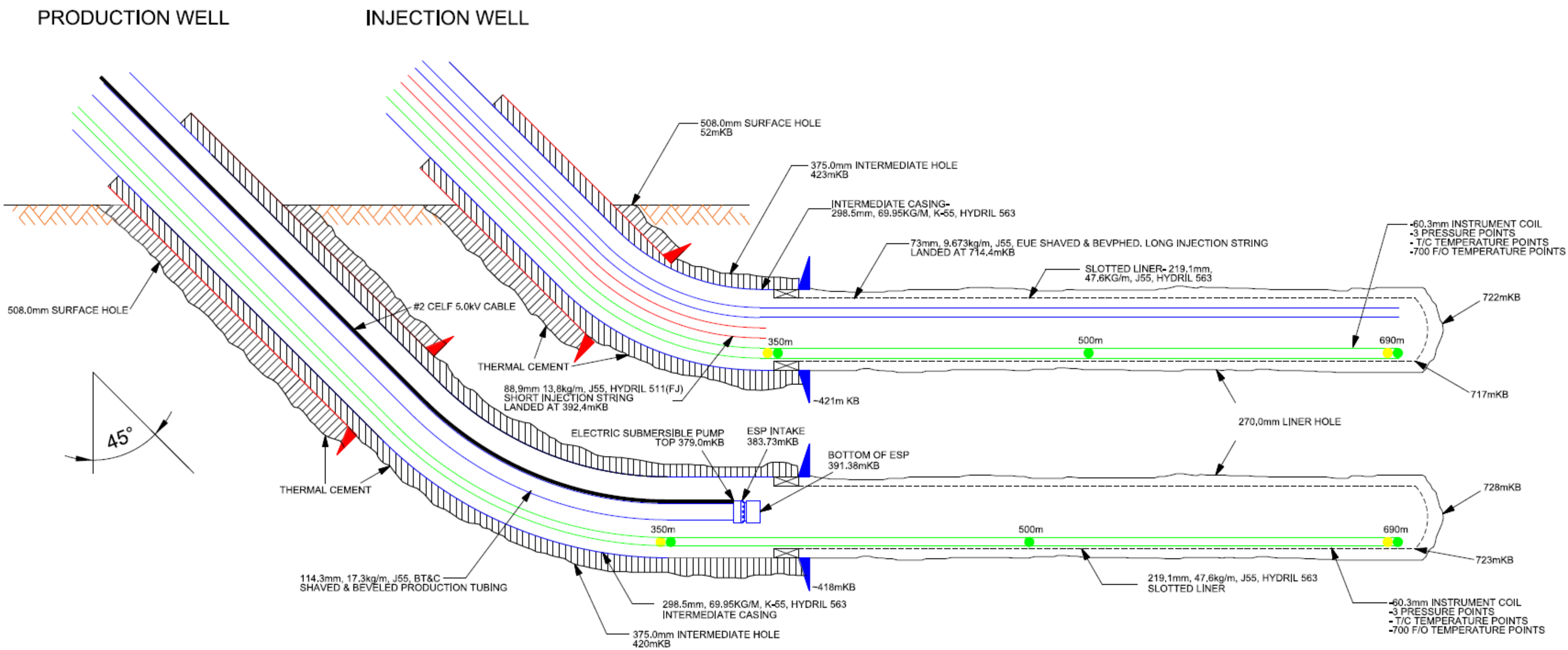


Completions – MTM PCP (2)



Removal of dummy liner/packer/FSV assembly and shortening of tailpipe was intended to have 2 effects – minimizing pressure losses within the wellbore and adjusting the withdrawal point away from the toe, towards a less productive area closer to the heel. Overall performance improvements were difficult to quantify as the replacement PCP run life was short and the well was subsequently re-completed with an ESP (see subsequent slide)

Completions – ESP



Artificial lift

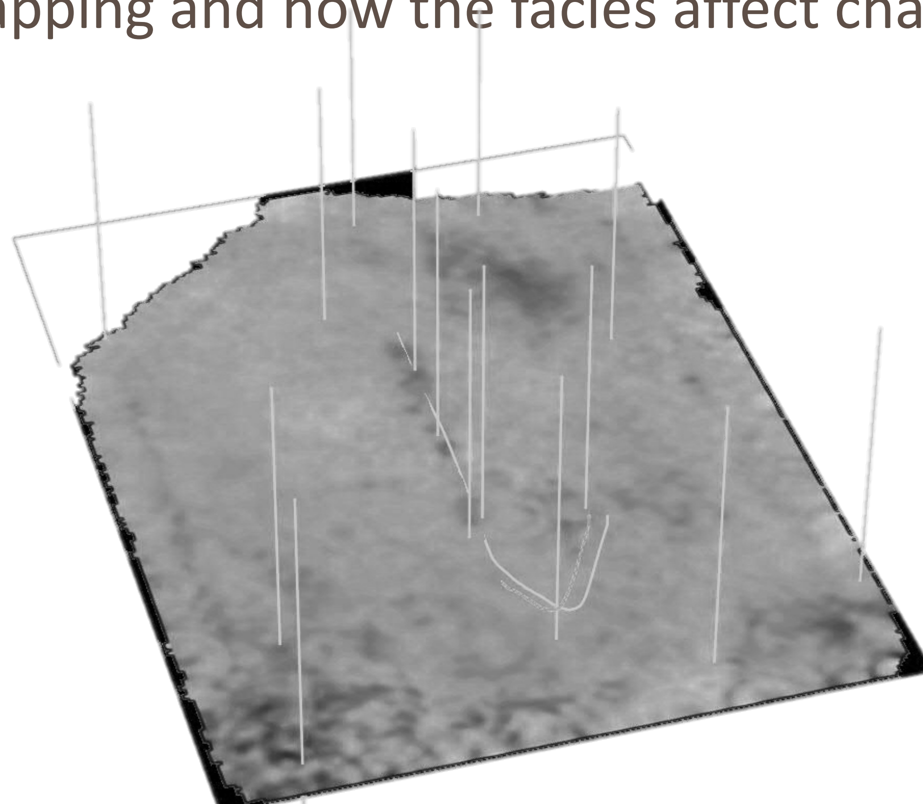
- Production well was equipped with metal PCP pump (Project start – 1 Apr 2015):
  - Capacity: 300 m3/ day / 100 RPM @ 100% efficiency
  - Rated lift: 600 m of water column
  - Pump efficiency: degraded over time down to 10%, exacerbated by low viscosity fluid
- PCP was changed to an ESP (15 Apr 2015 – September 2015), increasing lift capacity.
  - Capacity: 400 m3/ day
- ESP failure in September 2015. ESP was replaced and has been operating from September 2015 to present

Instrumentation

- Each HZ well is equipped with the same instrumentation package:
  - Heel and toe thermocouple
  - Heel, mid and toe bubble tubes
    - Ethane used for bubble tube gas instead of methane – reduction in potential introduction of non-condensable gas into the reservoir which could hinder oil flux rates
  - Fiber optic temperature sensor (700 m)
- Production well monitoring at the pump intake for P&T
- Observation wells equipped with:
  - 26 point thermocouple bundle
  - 2-3 piezometers per well

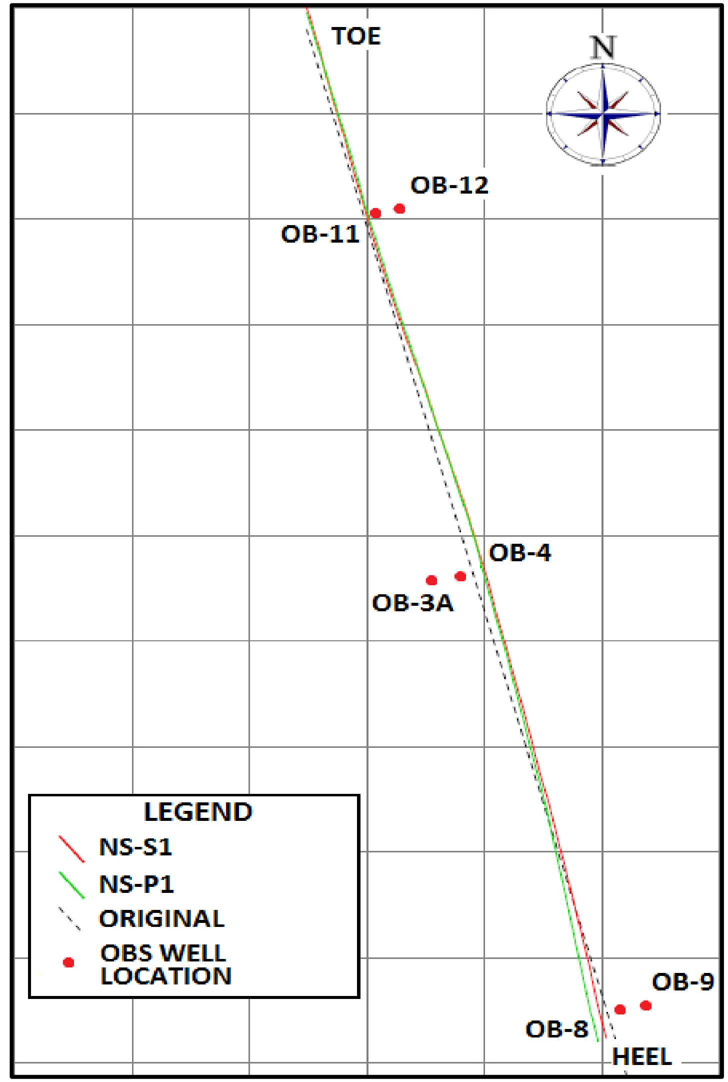
Seismic Objectives

- To map the extent of the Nsolv vapour chamber using an integrated quantitative interpretation workflow.
- Facies mapping and how the facies affect chamber growth.



Seismic & Well Data

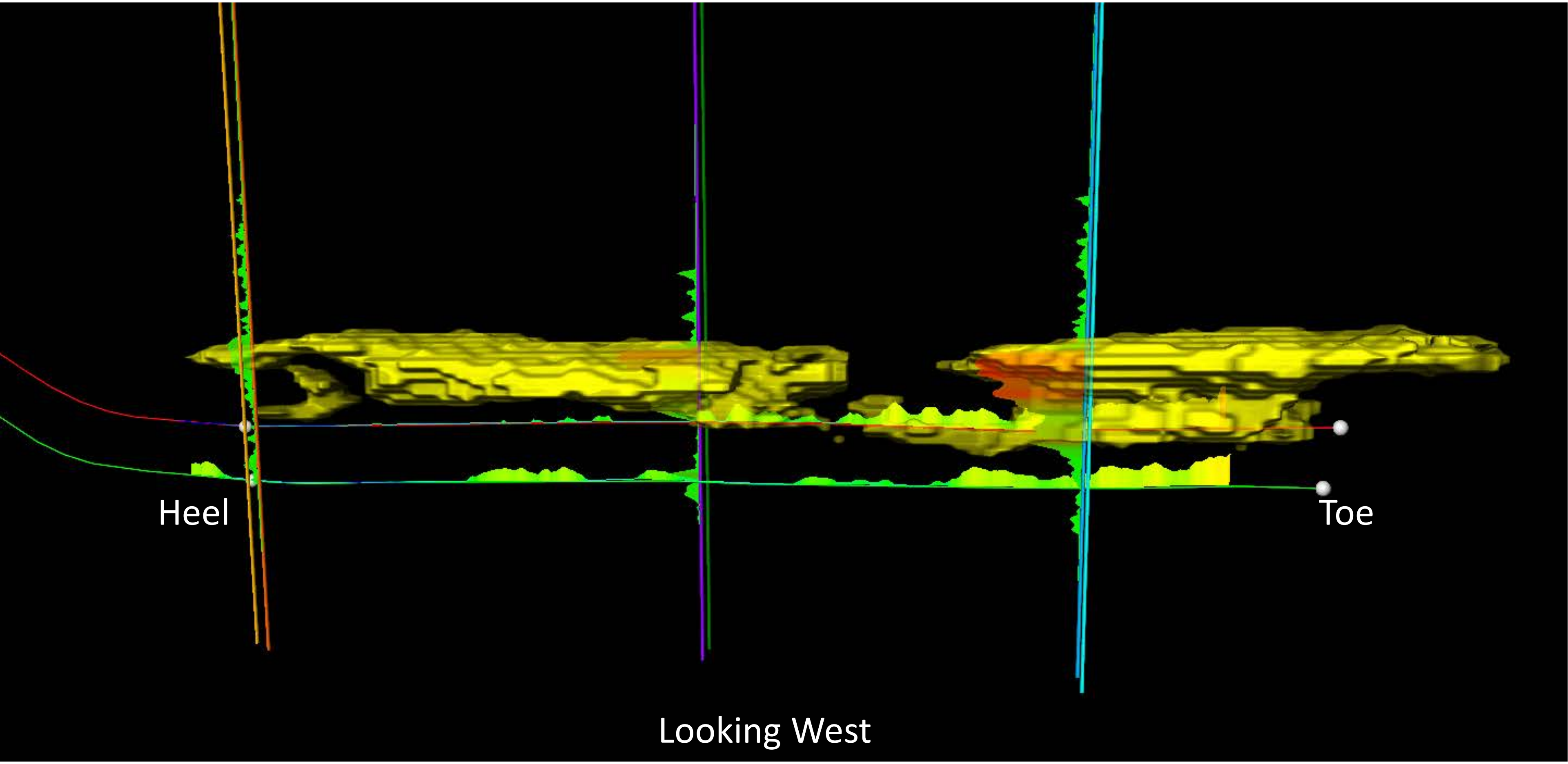
- Time-lapse (2015 and 2016 monitors), multi-component (3C) seismic surveys (Mackay 3D).
  - 2015 survey acquired on March 15th
  - 2016 survey acquired on March 28th.
- AVO complaint pre-stack time migrated and 4D processed
  - PP (Compression)
  - PS (Compression & Shear)
- 6 observation wells with thermocouples, 3 of them with RST (Reservoir Saturation Tool) logs.
- Temperature falloff data for injector and producer wells
- 29 vertical wells, 15 wells have sonic & density, no shear logs available in the survey.
- 5 dipole sonic wells outside the survey (within 1 km) were used to estimate shear information.



2016 Seismic Chamber

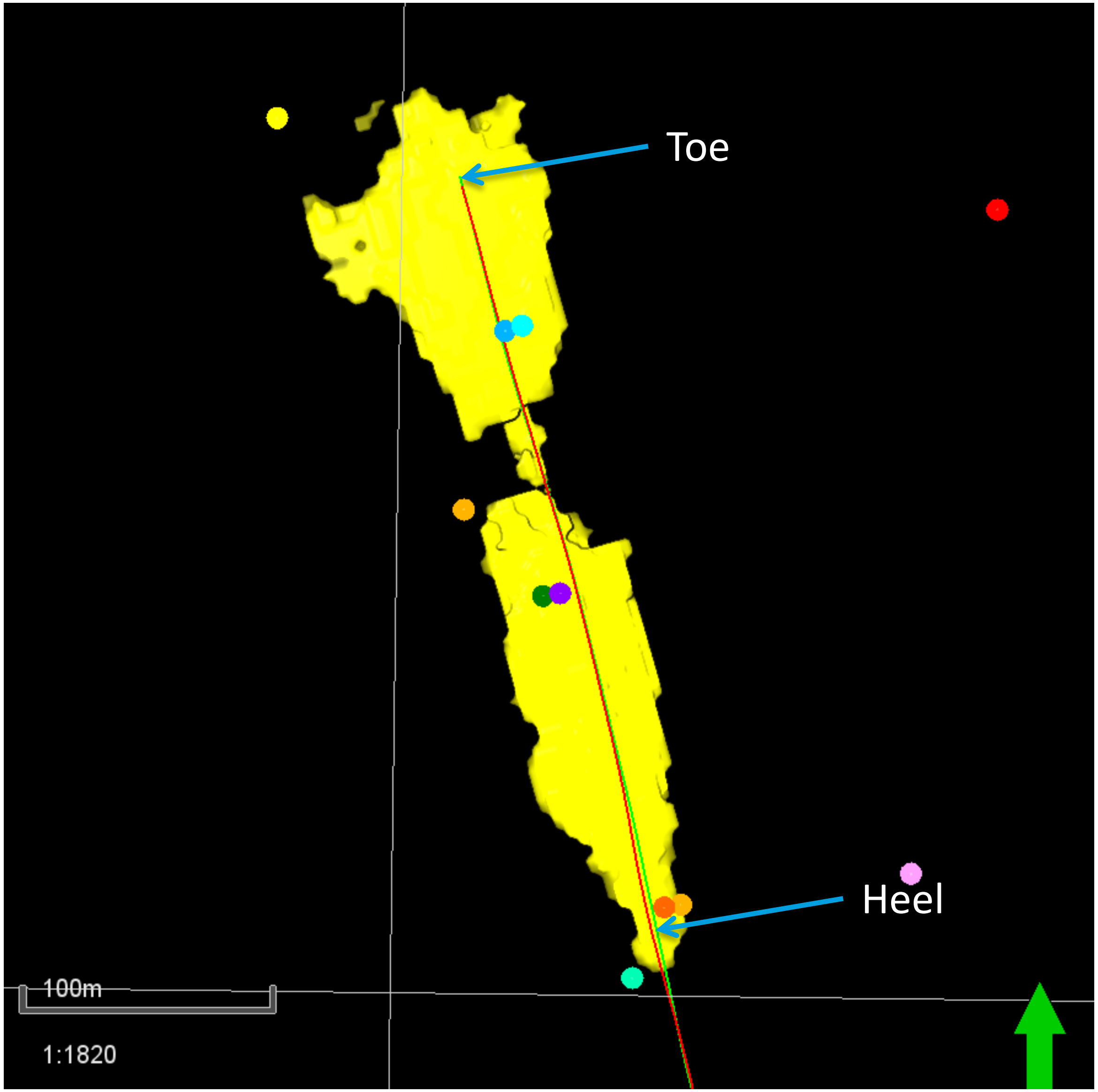
64k Geobody >25% Gas Sat.

The 64k m3 geobody is the best match to the production data as well as the existing RST and thermocouple data.



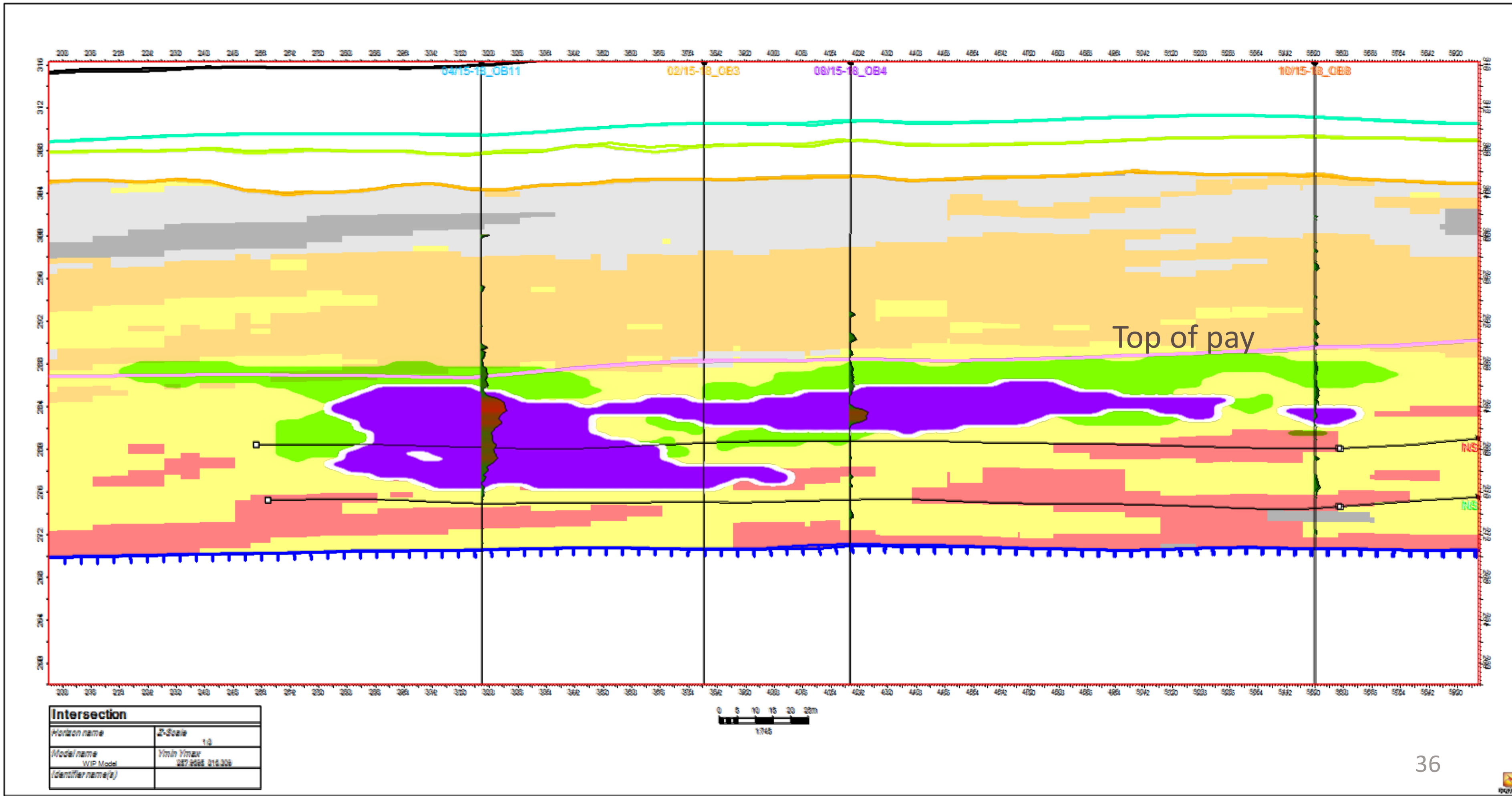
Plan View of Chamber

- Plan view of the solvent chamber showing lateral growth of up to 70+m near the toe
- Average growth rates of ~2.8 cm/d determined from seismic cross sections and OBS well measurements



2015 vs 2016 Chamber

- Vertical chamber growth intersecting top of pay in most areas
- Axial growth at toe beyond where we have DTS data
- Chamber migration at heel (OB8 temperature fluctuations)



Scheme Performance – Timeline

Pre-heating → Warm-up → Displace → Dilution & Cooling → Solv Inj & Drain → Production

2013							2014							2015			2016		
Mar	Apr	May	...	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	...	Dec	Jan	...	Dec	Jan	...	Aug
Pre-heating		Warm-up			Displacement			Dilution	Solv Inj & Drain		Production Phase								

Scheme Performance – Startup Phases

- Pre-heating:
  - Pre-heating occurred prior to the facility being fully constructed with electrical heaters in each well
  - Heating of injector well started later than the production well due to delivery timing of the heating strings

Scheme Performance – Startup Phases

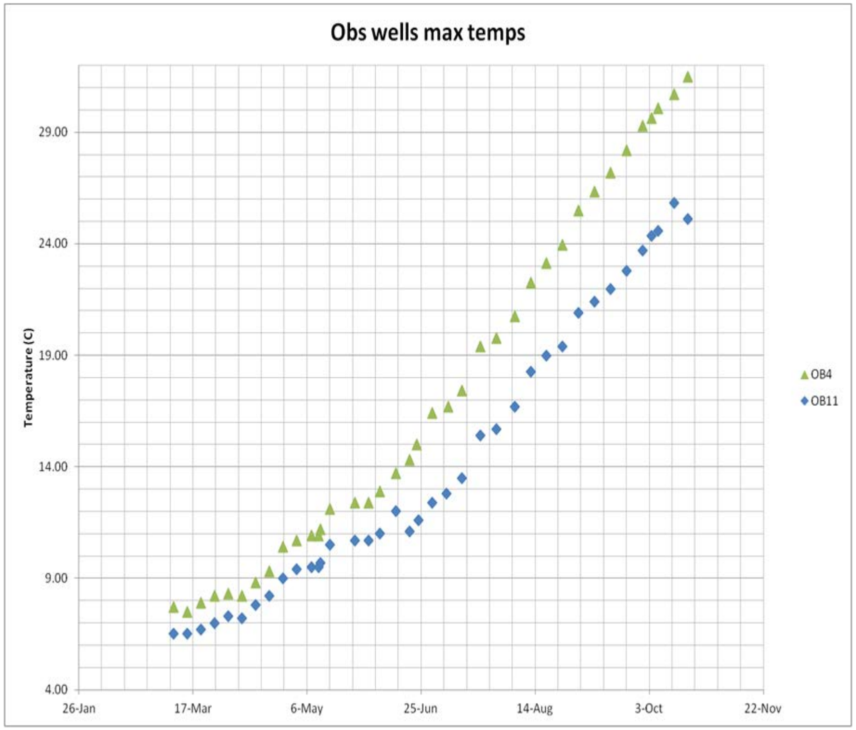
- Warm-up:
  - Conductive heating of the reservoir to raise centerline temperature to 55°C
  - Electric heater pulled from the production well and run into the injection well for dual heaters
  - Electric heaters in the Injector, hot diesel circulation in the Producer with downhole pump
  - Circulation in the injection well instead of electrical heating in this phase was initially envisioned, however electrical heating performance to date was good enough to justify eliminating this expense and using existing equipment on hand

Scheme Performance – Startup Phases

- Displacement:
  - Induce inter-well fluid communication with increasing differential pressure between the wells
  - Targeting minimum 50% conformance
- Dilution & Cool-down:
  - Reduction of sub-surface temperatures for solvent injection (allow for condensing action to occur)
  - Reduction of startup fluids viscosity to facilitate drainage

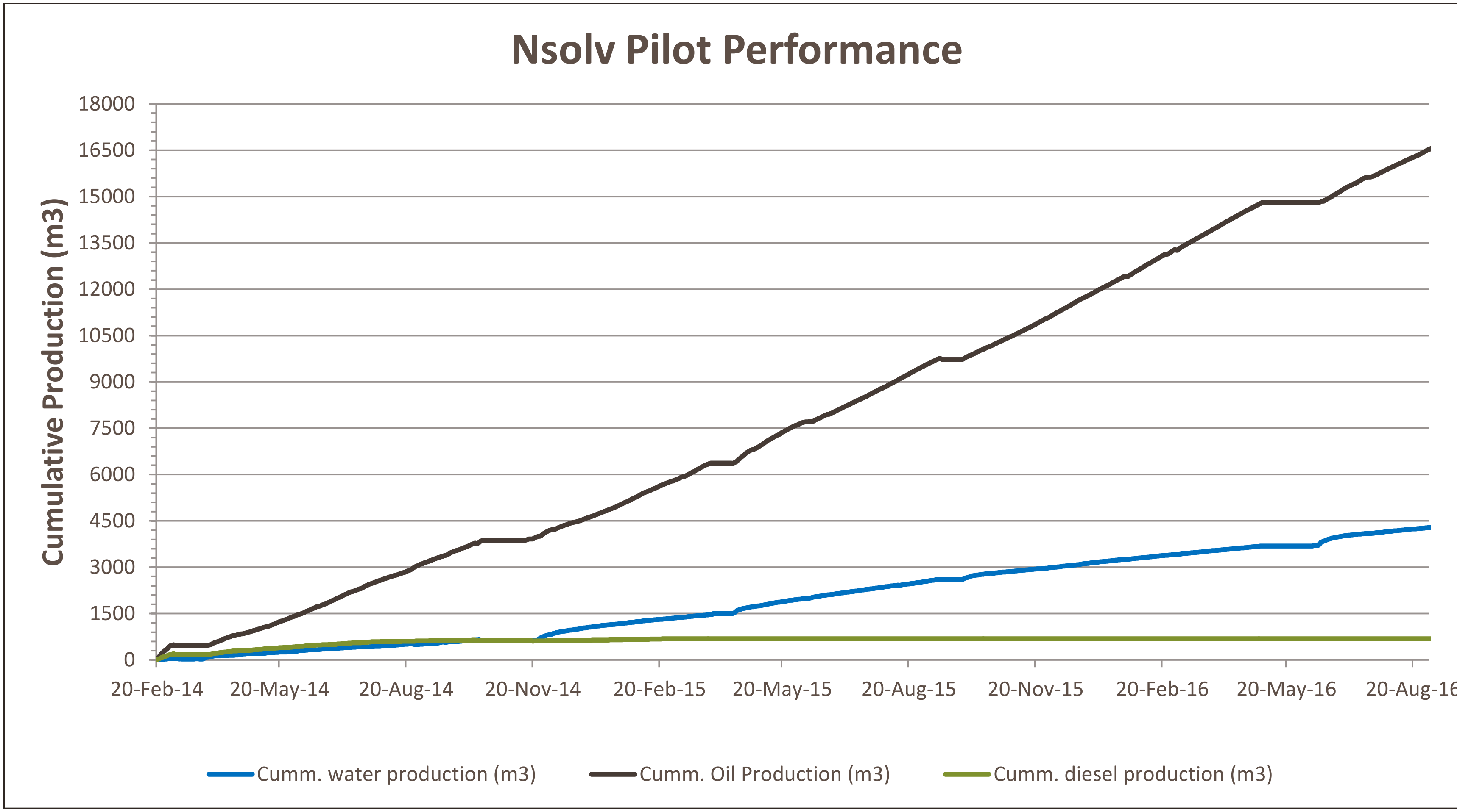
Scheme Performance – Startup Phases

Warmup



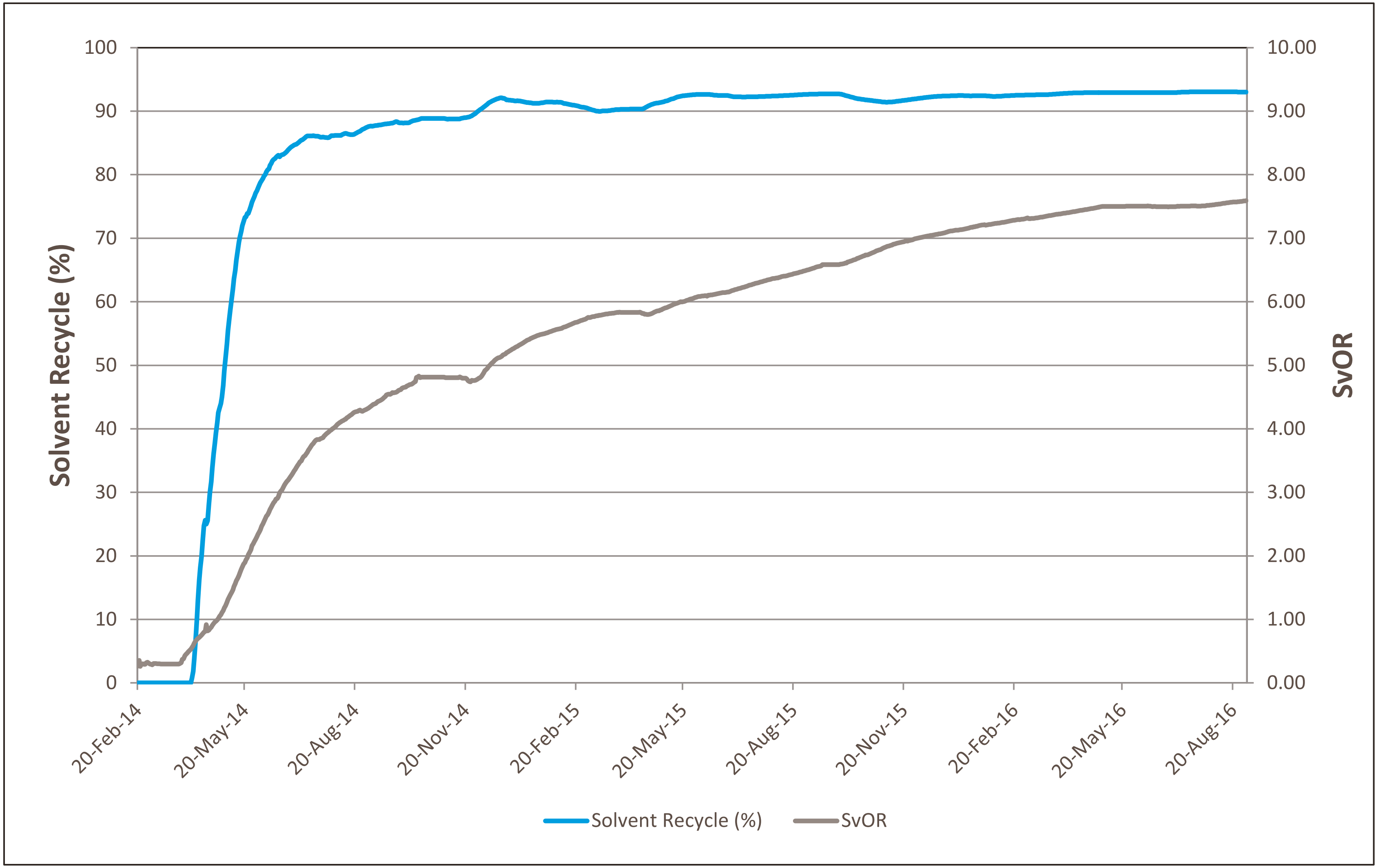
Displacement

Scheme Performance – Cumulative Fluid Volumes



- 100% diesel recovery achieved in February 2015
- 34% recoverable bitumen recovered 19% of exploitable PIIP bitumen recovered (Refer to Slide 11 (Volumetrics) for calculation details)

Scheme Performance – Solvent Balance



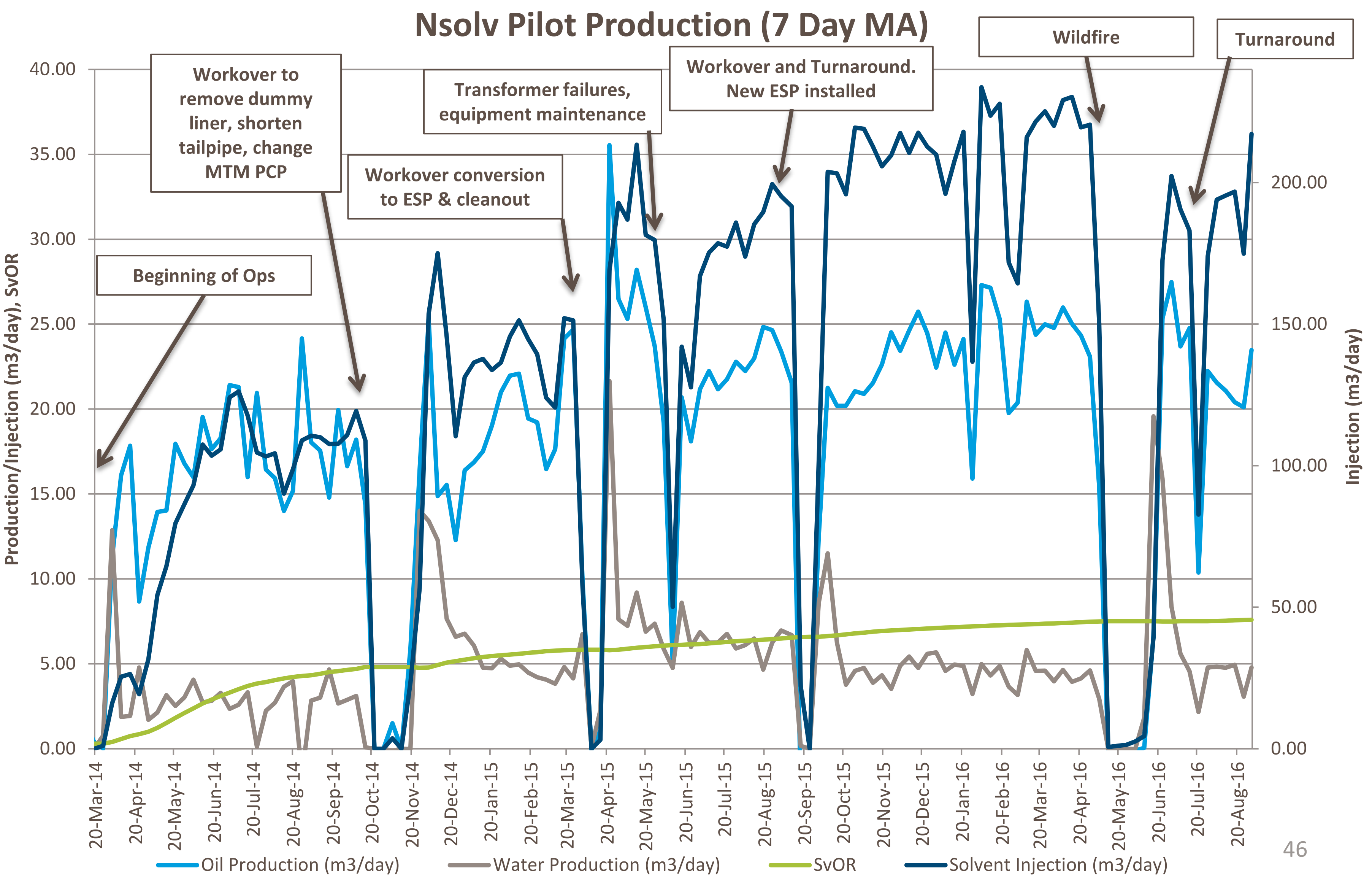
Scheme Performance – Solvent Balance

- Design Solvent Oil Ratio (SvOR) of 5:1 or less
- Currently around 8:1 cum. SvOR at the BEST pilot – there are several reasons why it is higher than originally anticipated:
  - Heat losses: 5:1 ratio was idealized and did not account for heat losses to the overburden and underburden
  - Conformance: Additional heat is currently being lost heating regions of non-conformance – increasing conformance should lead to a reduction in SvOR as those areas start to contribute to bitumen production

Scheme Performance – Solvent Balance

- Gas Coning: Evidence of some solvent vapour being drawn directly into the producer without condensing and liberating oil, thus increasing SvOR
- Reduced pay thickness: Original pay height was expected to be 18.5 m however the average pay thickness was reduced to 12.8 m when the wellpair was raised up to avoid a shale plug encountered while drilling OB 08.

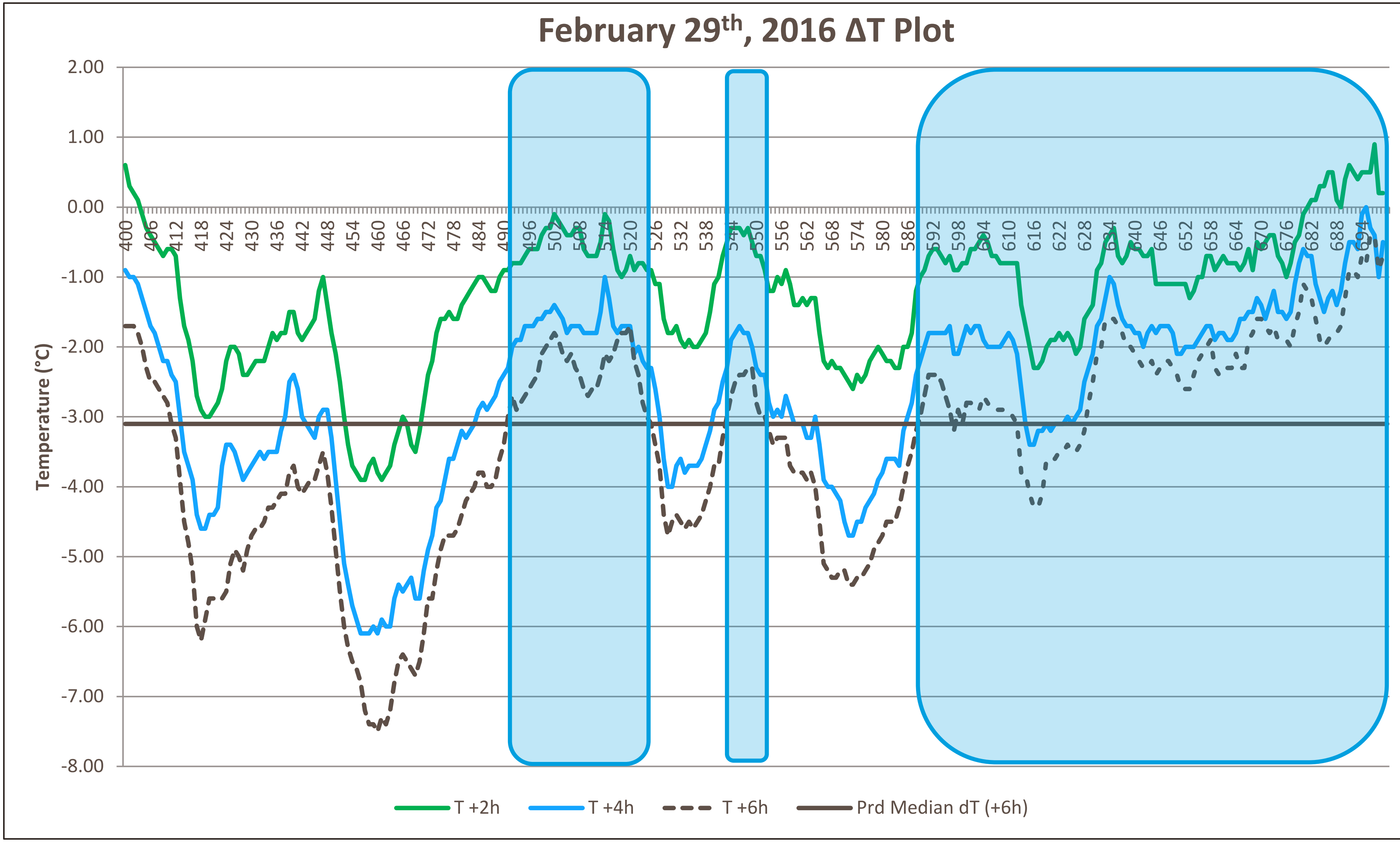
Scheme Performance – Fluid Rates



Scheme Performance – Well Pair Conformance

- Well pair conformance monitored by:
  - DTS data
  - temperature fall-off data
  - Seismic data
- Conformance is approximately 60% or 180m of the 300m wells.
  - This was overestimated in 2015

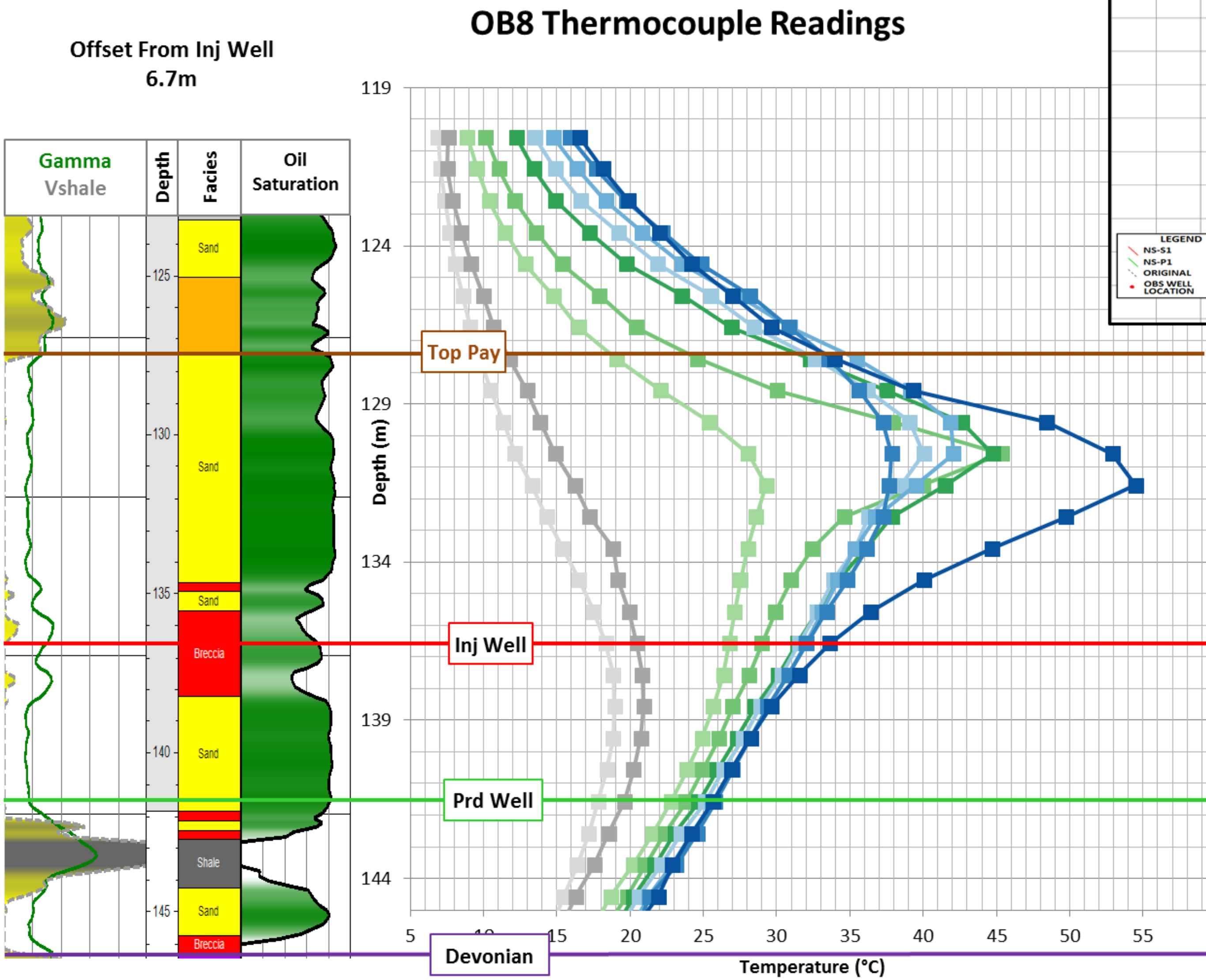
Scheme Performance – Well Pair Conformance

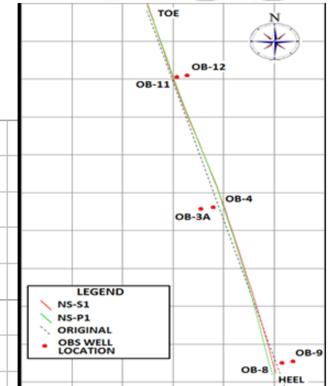


Scheme Performance – Chamber Growth

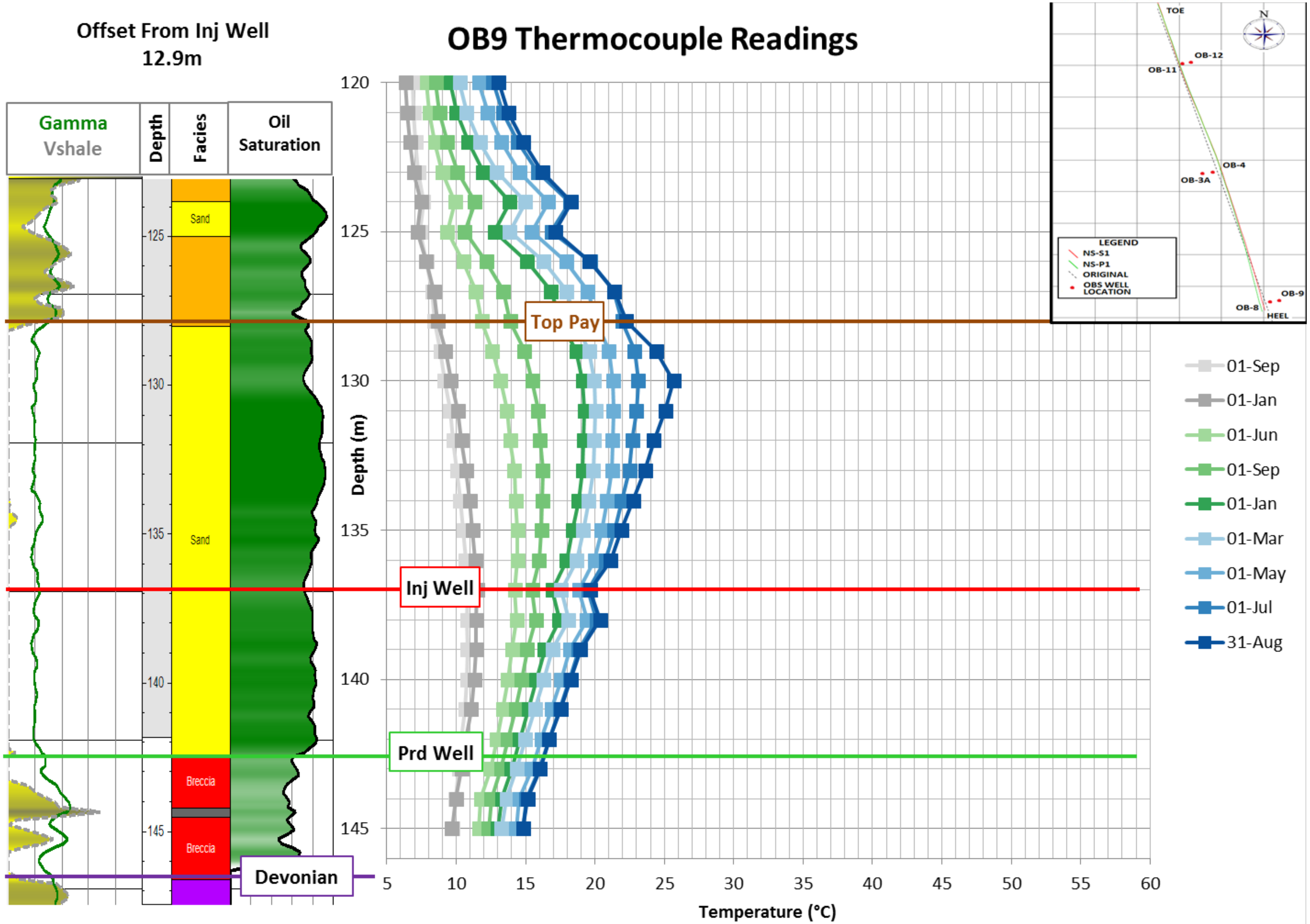
- Overall chamber growth monitored by thermocouples, RST logs at observation wells, and seismic data.
- Solvent chamber has intersected all observation wells except OB9 (15m offset) at the heel.
  - Top of pay reached
  - Growth rates of ~2.8cm/d on average
  - Chamber width has reached 40-60m in most areas

Scheme Performance – Chamber Growth

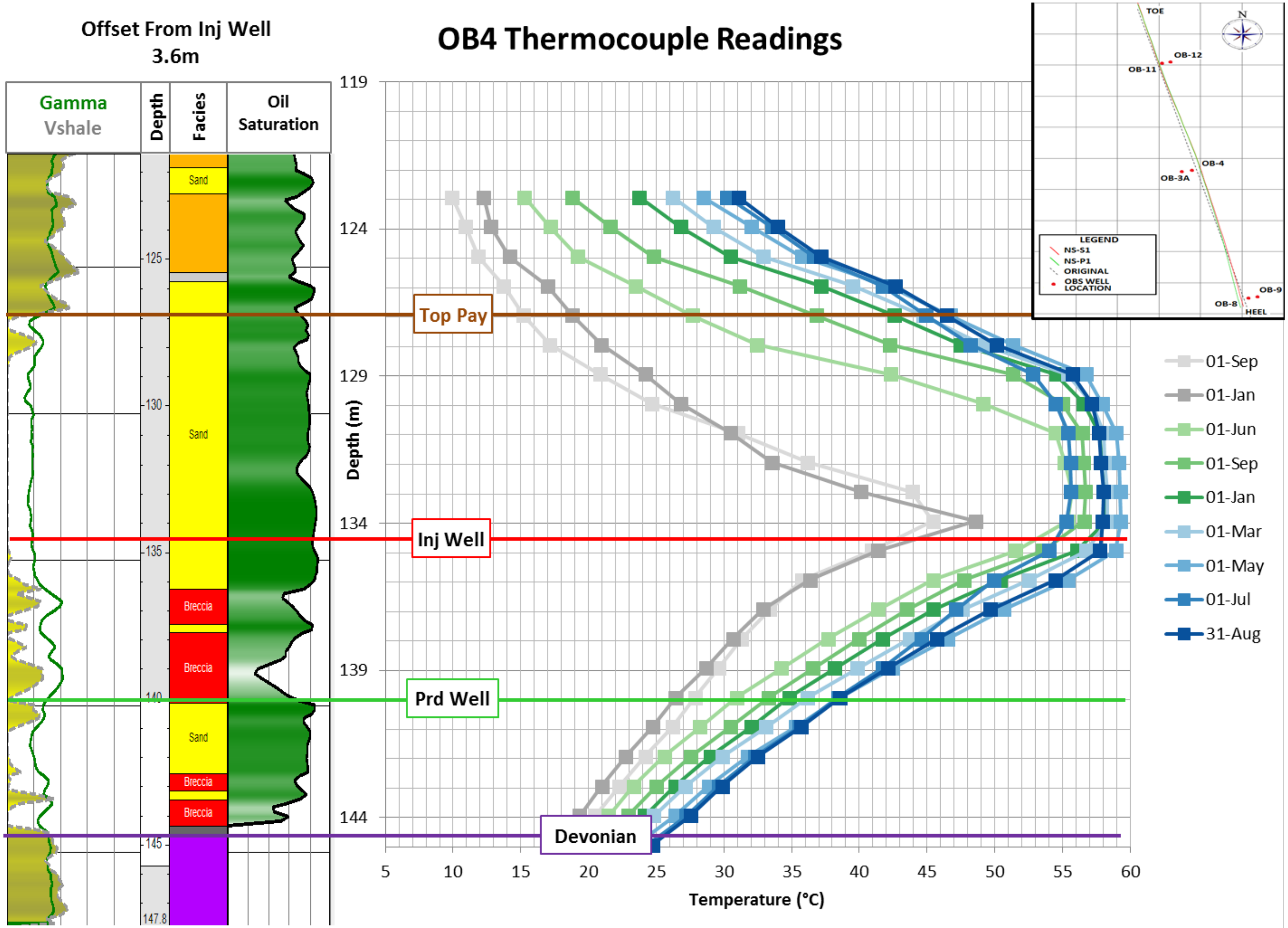




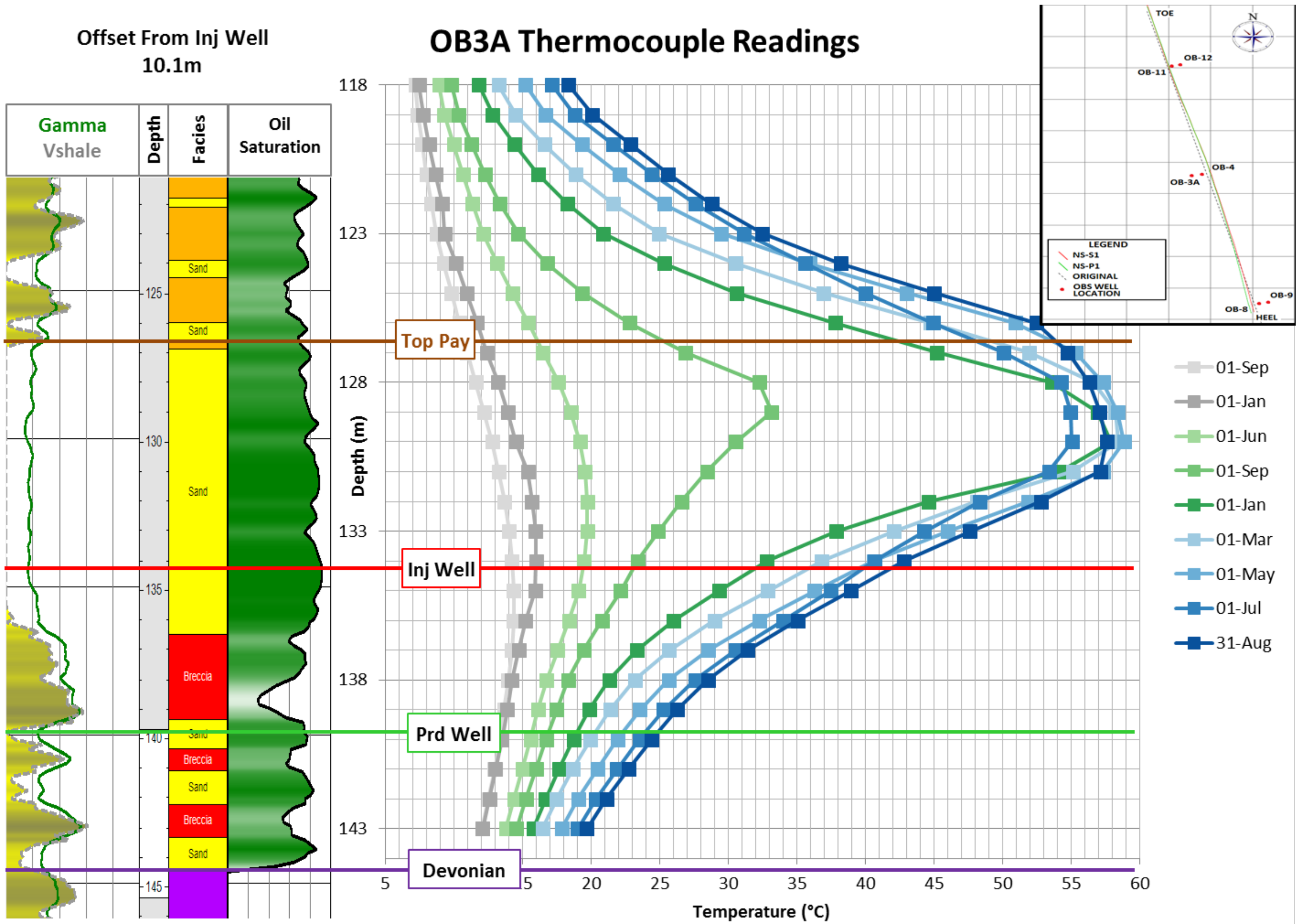
Scheme Performance – Chamber Growth



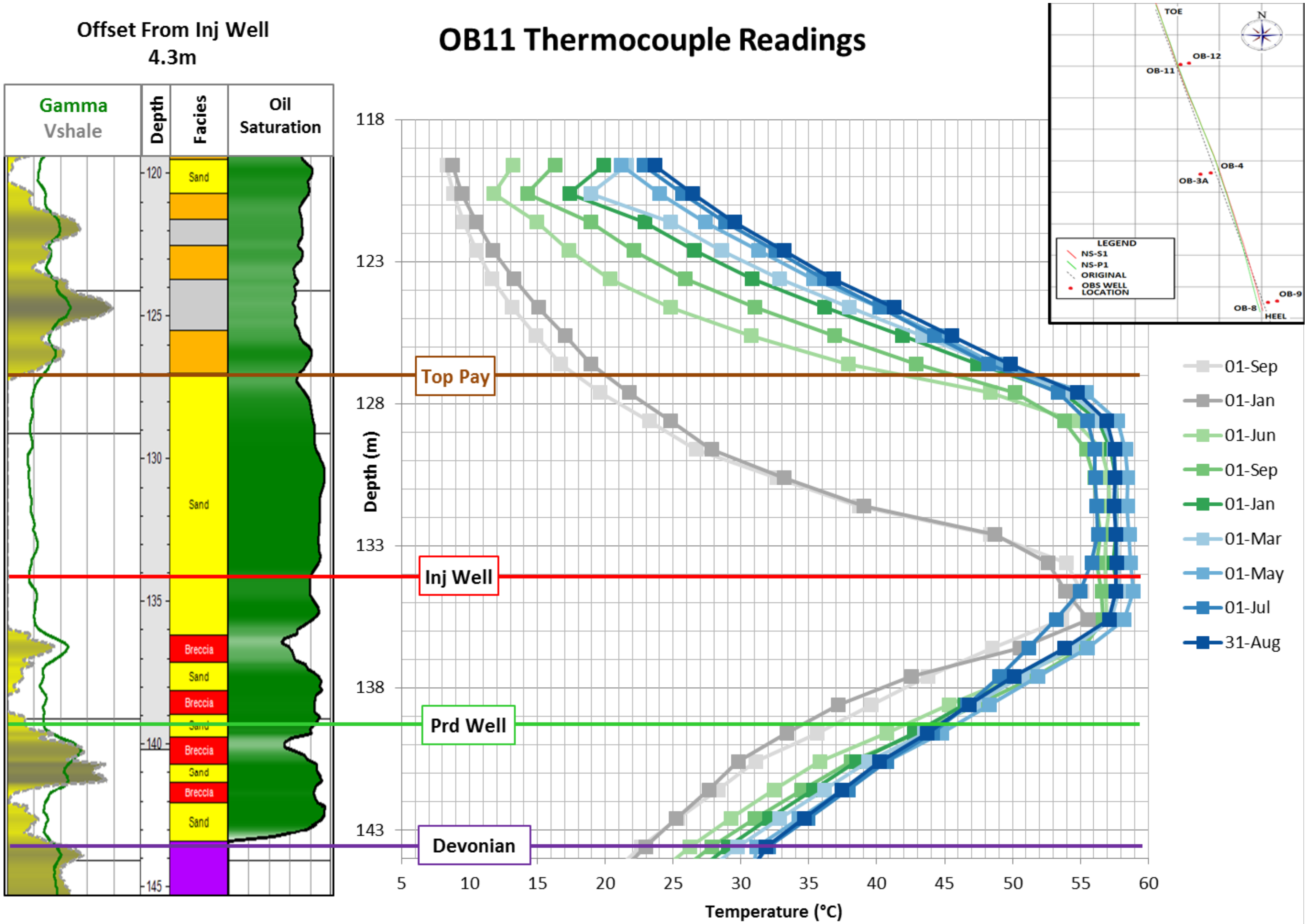
Scheme Performance – Chamber Growth



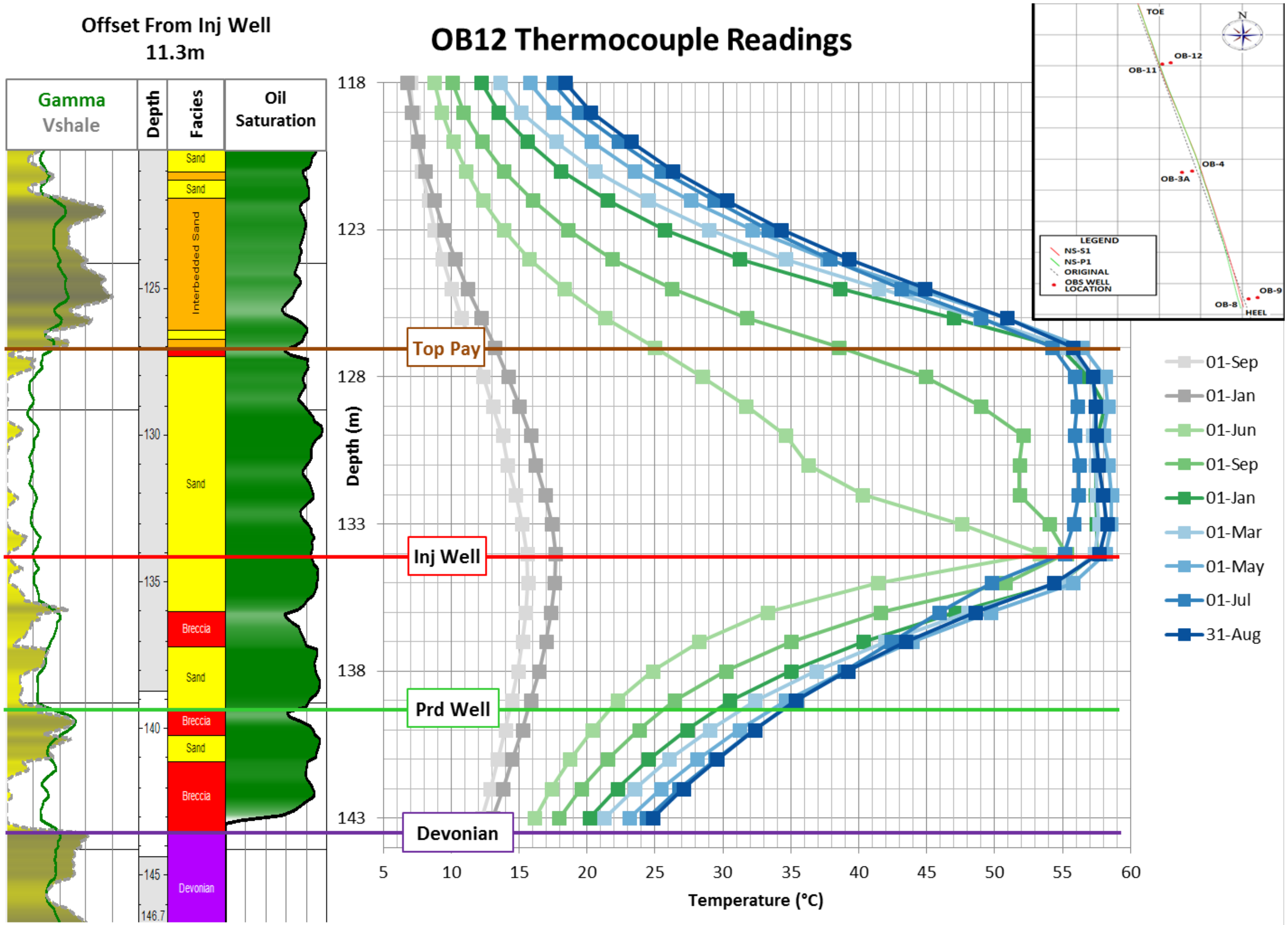
Scheme Performance – Chamber Growth



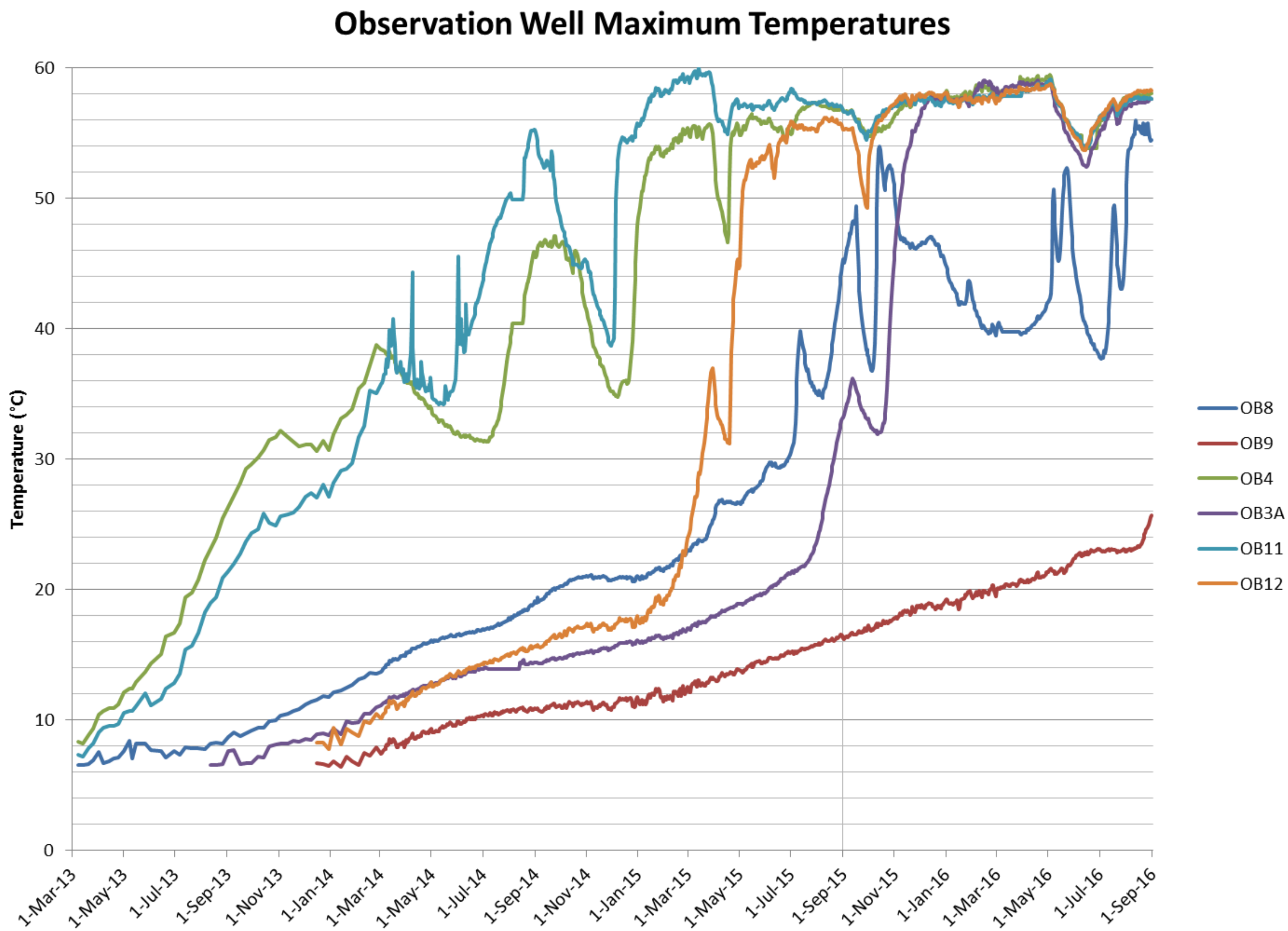
Scheme Performance – Chamber Growth



Scheme Performance – Chamber Growth

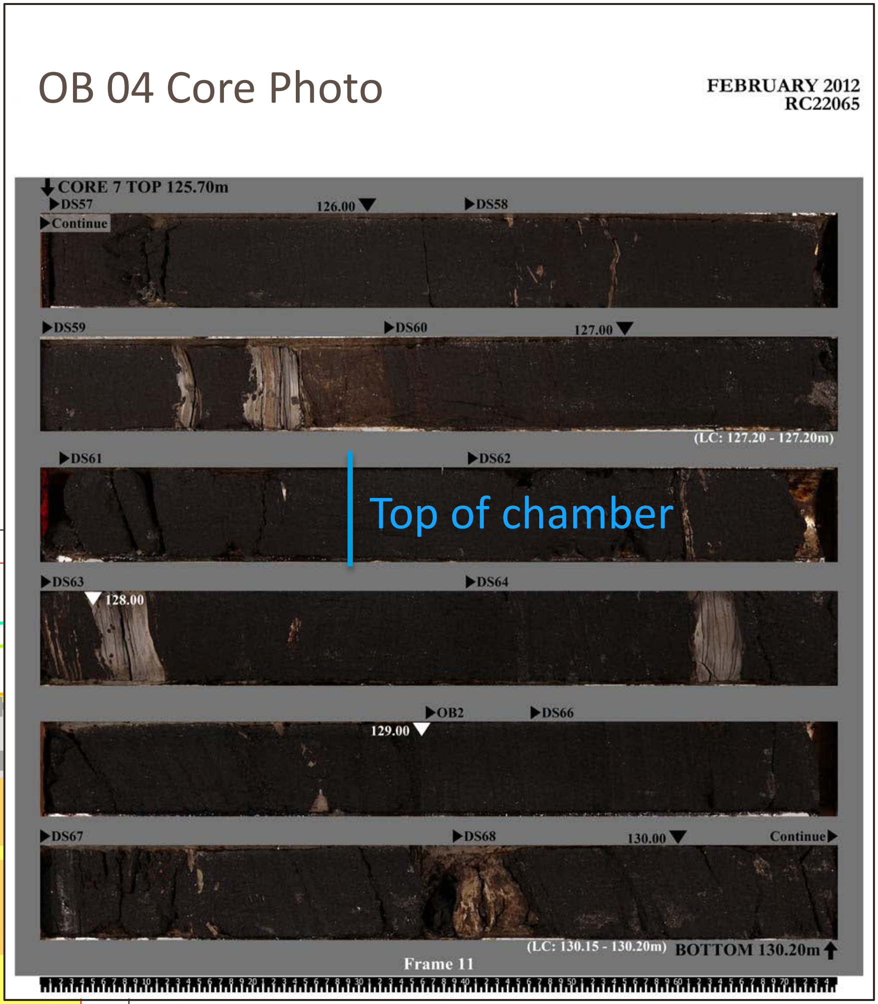


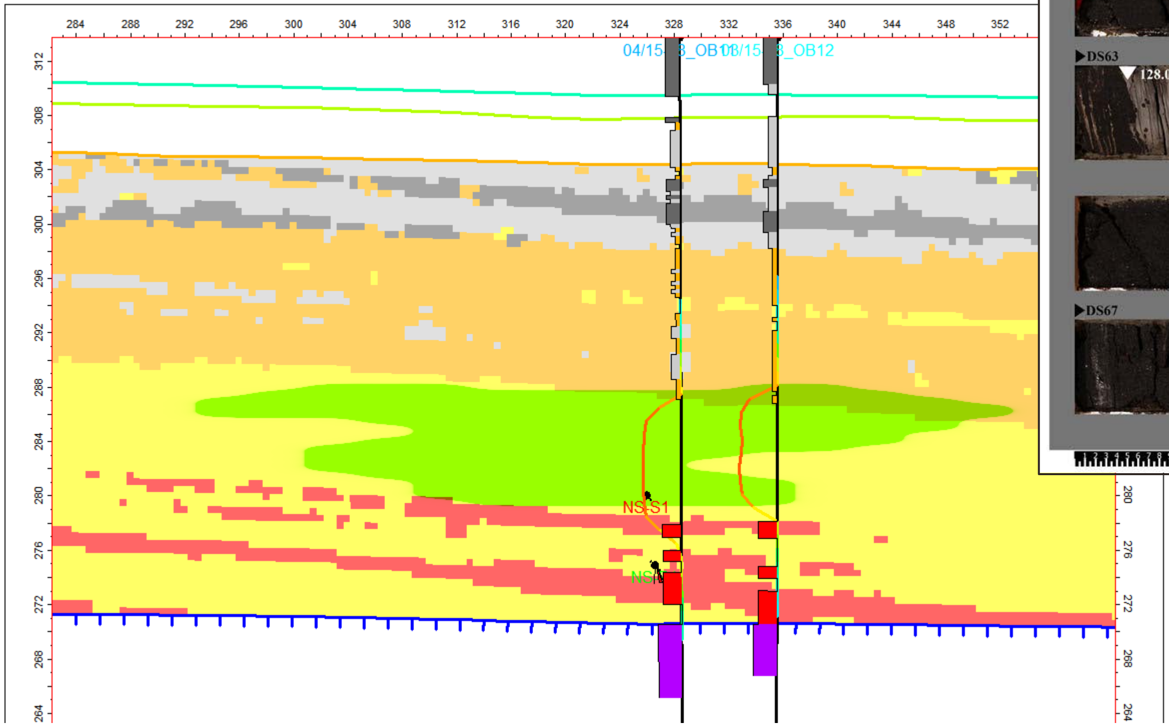
Scheme Performance – Chamber Growth



Chamber Growth Around Baffles

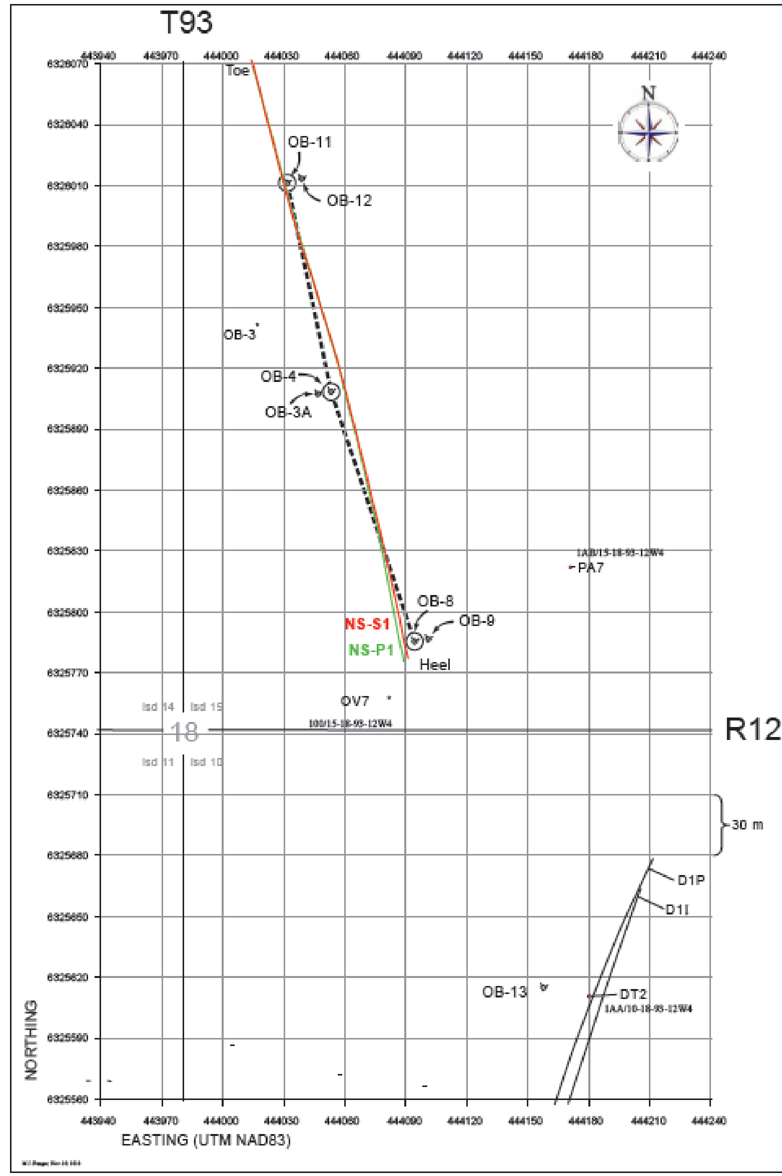
- Seismic results and thermocouple data show that we are above top of pay picked for OB12 (no core photos).
- RST logs show solvent chamber has reached 127.5m at OB4 which is above a few significant IHS beds.





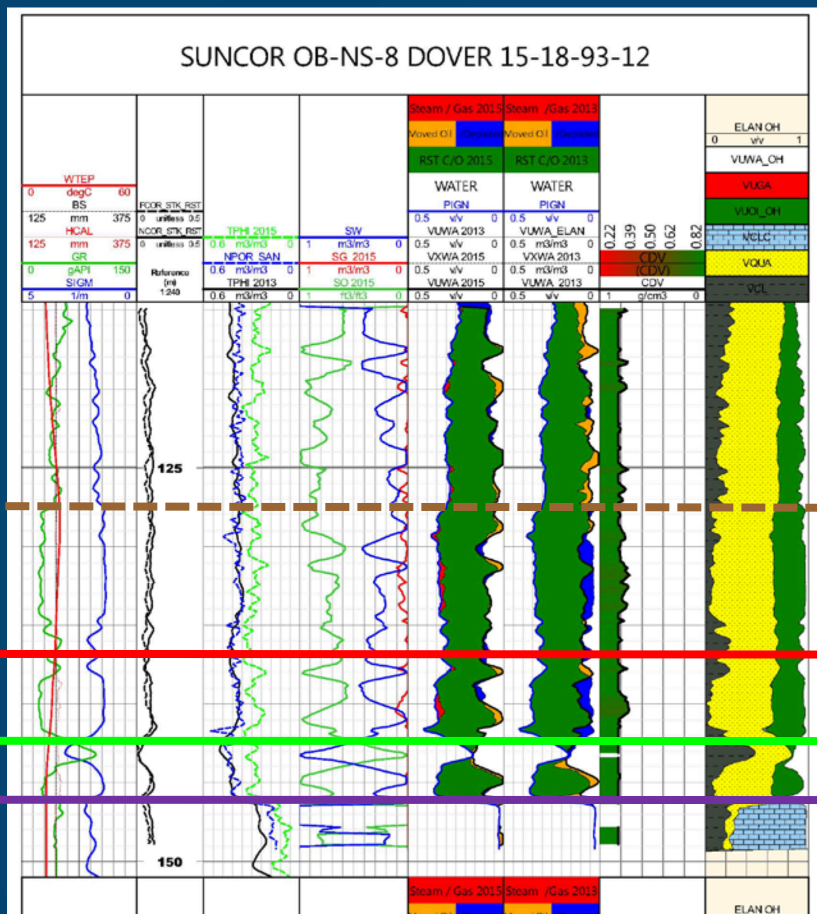
Reservoir Saturation Tool Results (RST Logs)

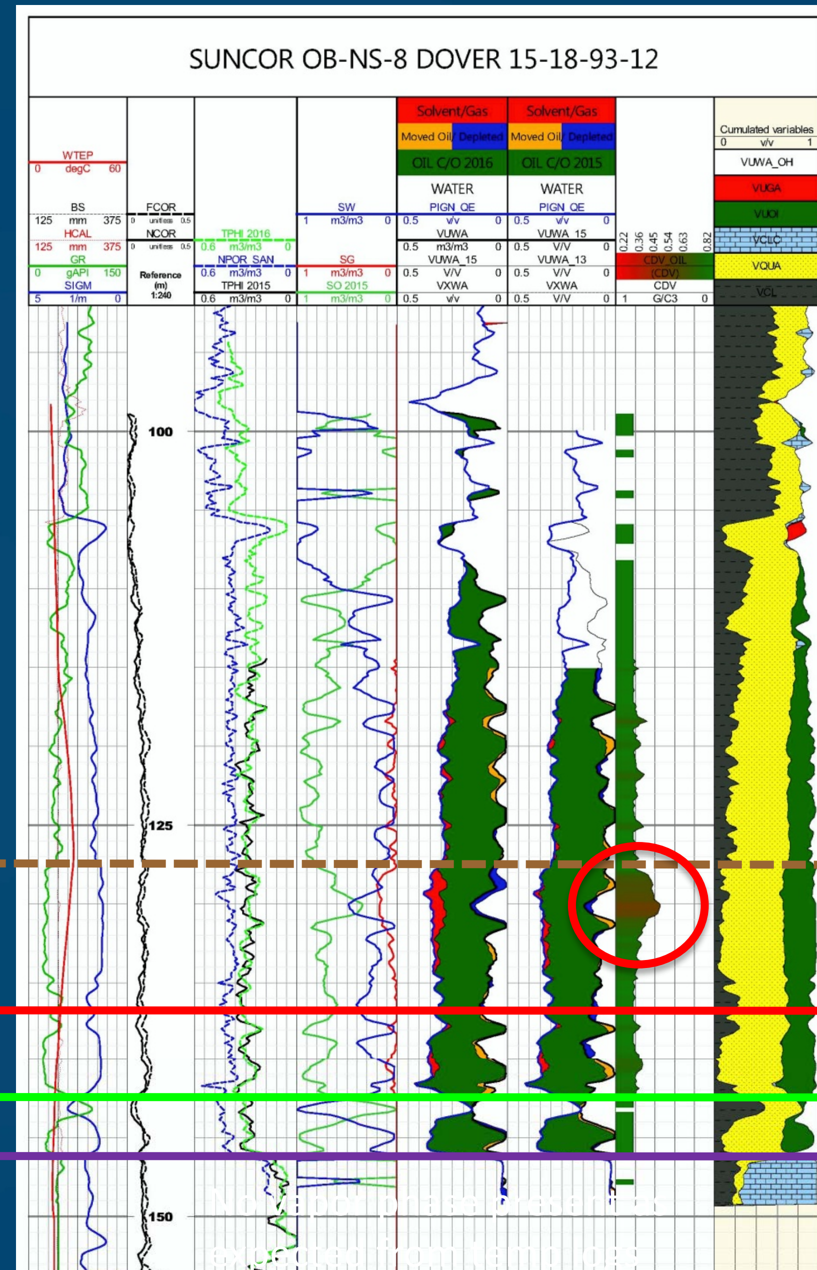
RST logs ran on OB-11, OB-4, and OB-8 on March 18-19th of 2015 and again on Mar 25th, 2016.



<u>OB-08 Heel</u>

Approximately 3m interval of increased gas saturation developing just below top of pay.





Top of Pay

Injector

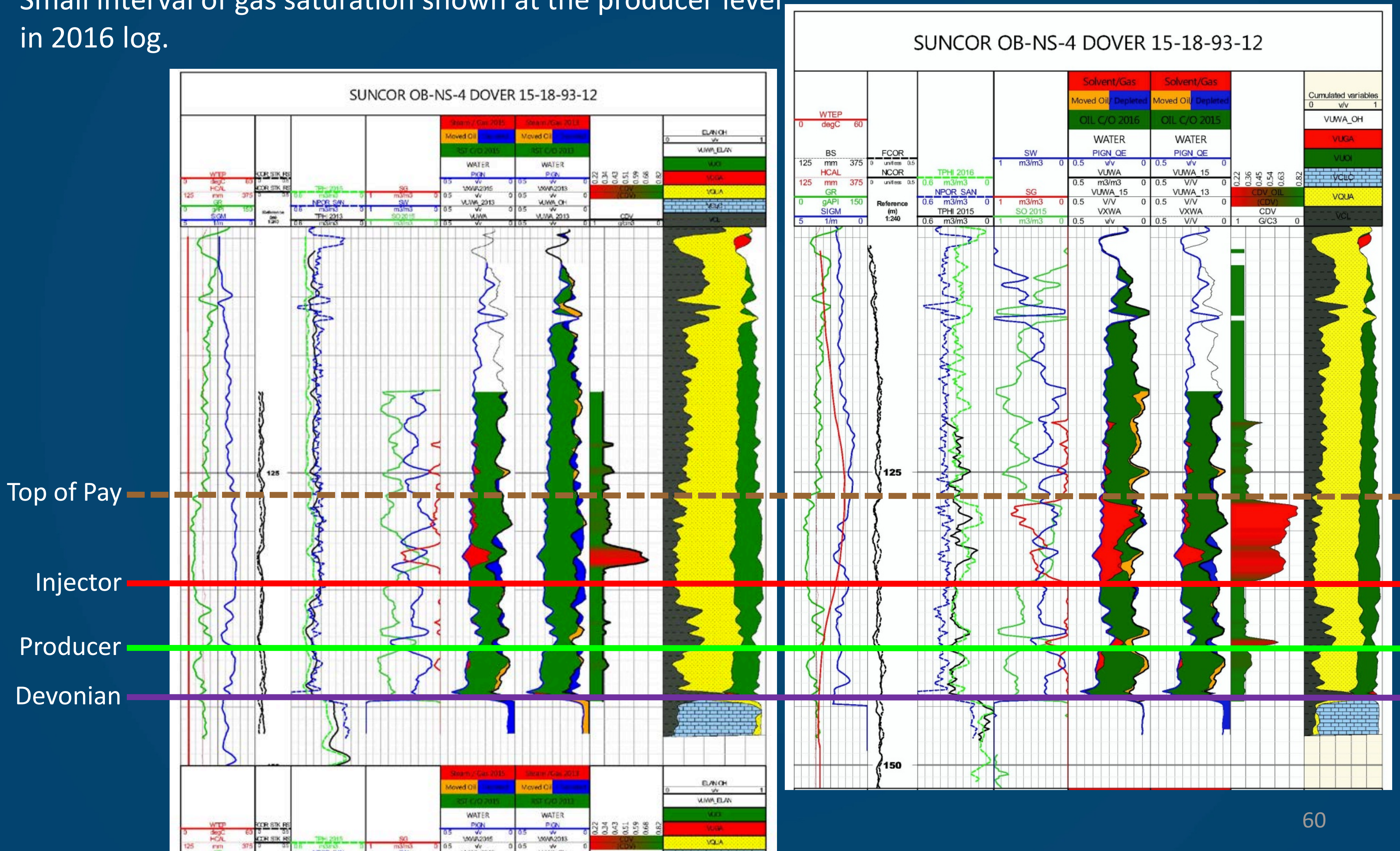
Producer

Devonian

OB-04 Mid

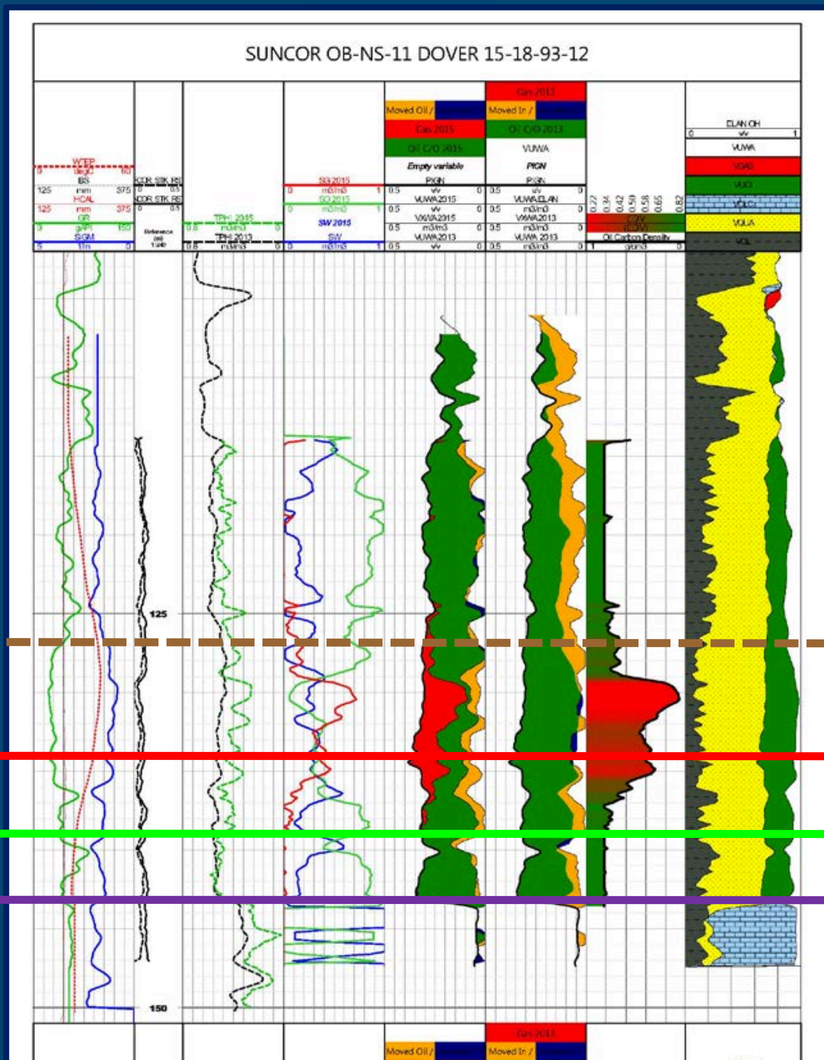
Chamber has grown significantly since last year. ~4m up and 1m down. It has also reached the top of the reservoir at this location.

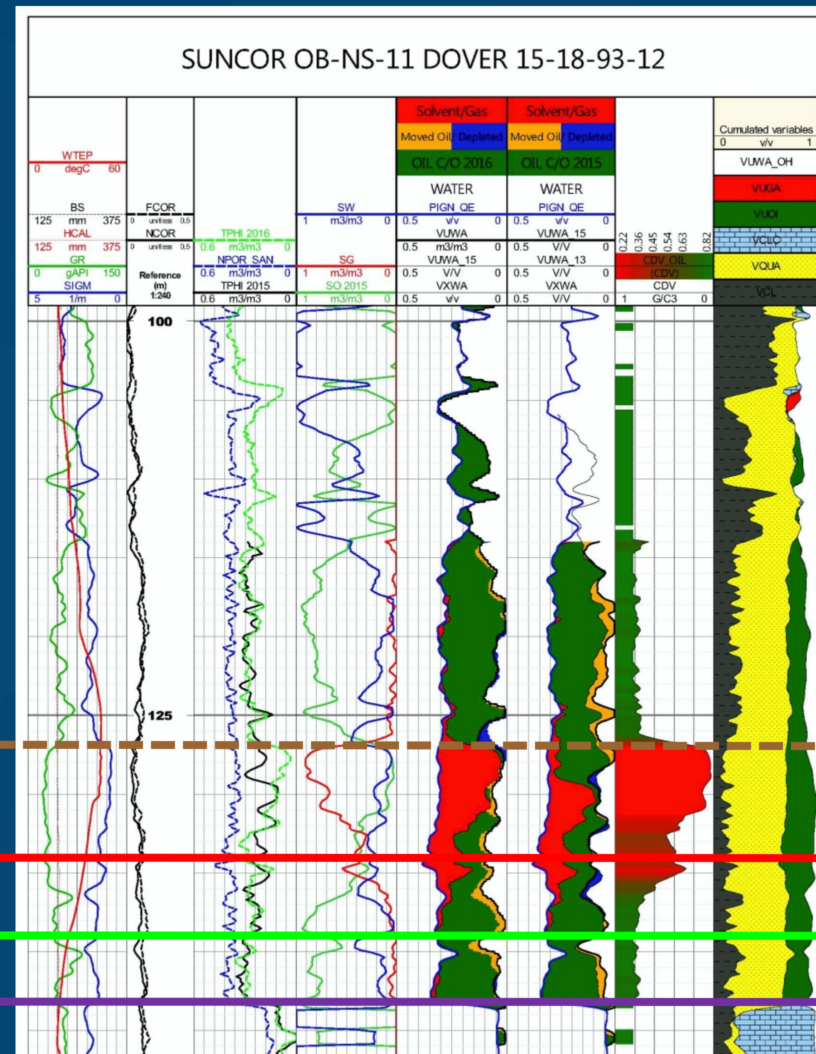
Small interval of gas saturation shown at the producer level in 2016 log.



<u>OB-11 Toe</u>

2016 RST log shows chamber growth vertically to the top of the reservoir as well as conformance between injector and producer in this area.





Top of Pay

Injector

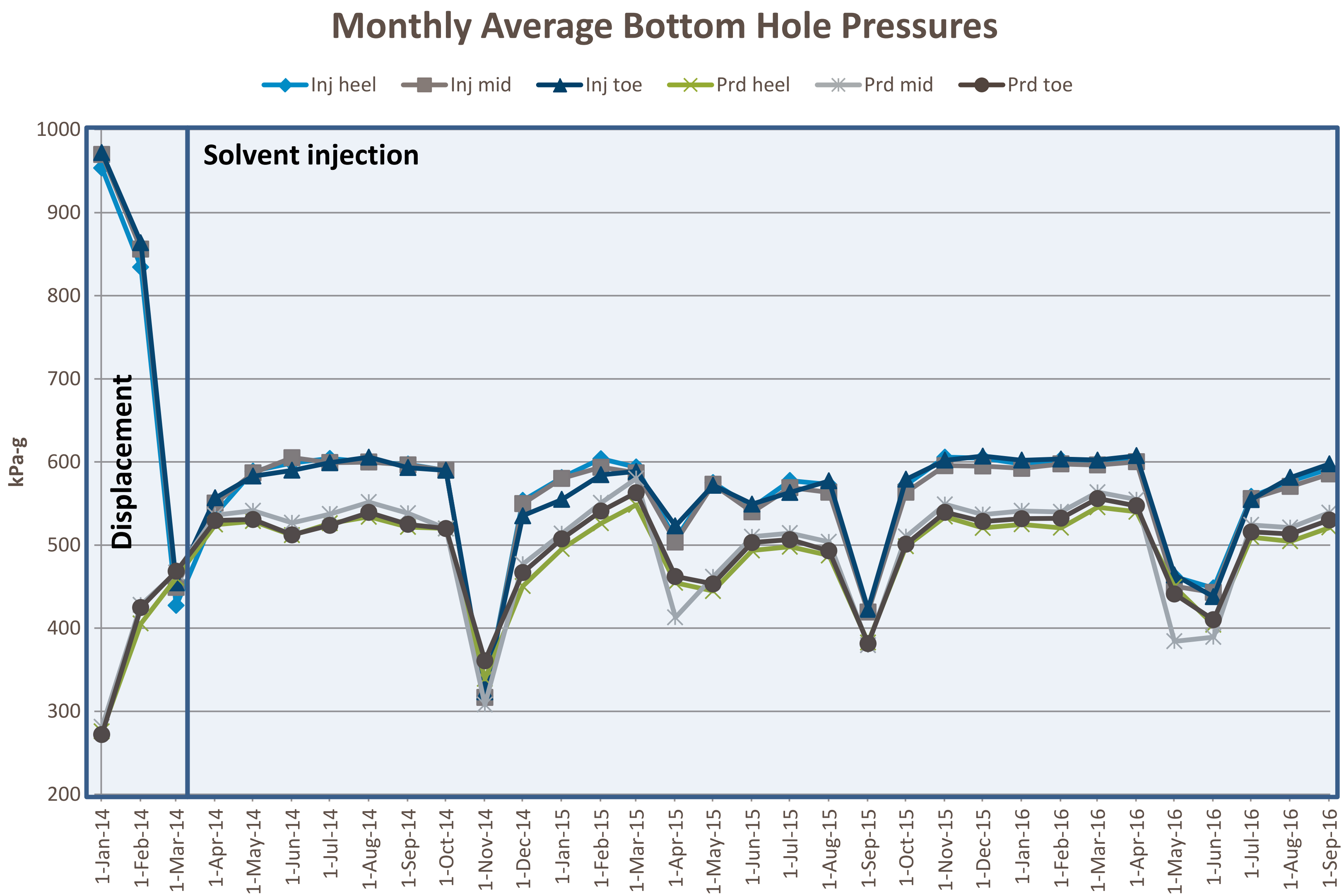
Producer

Devonian

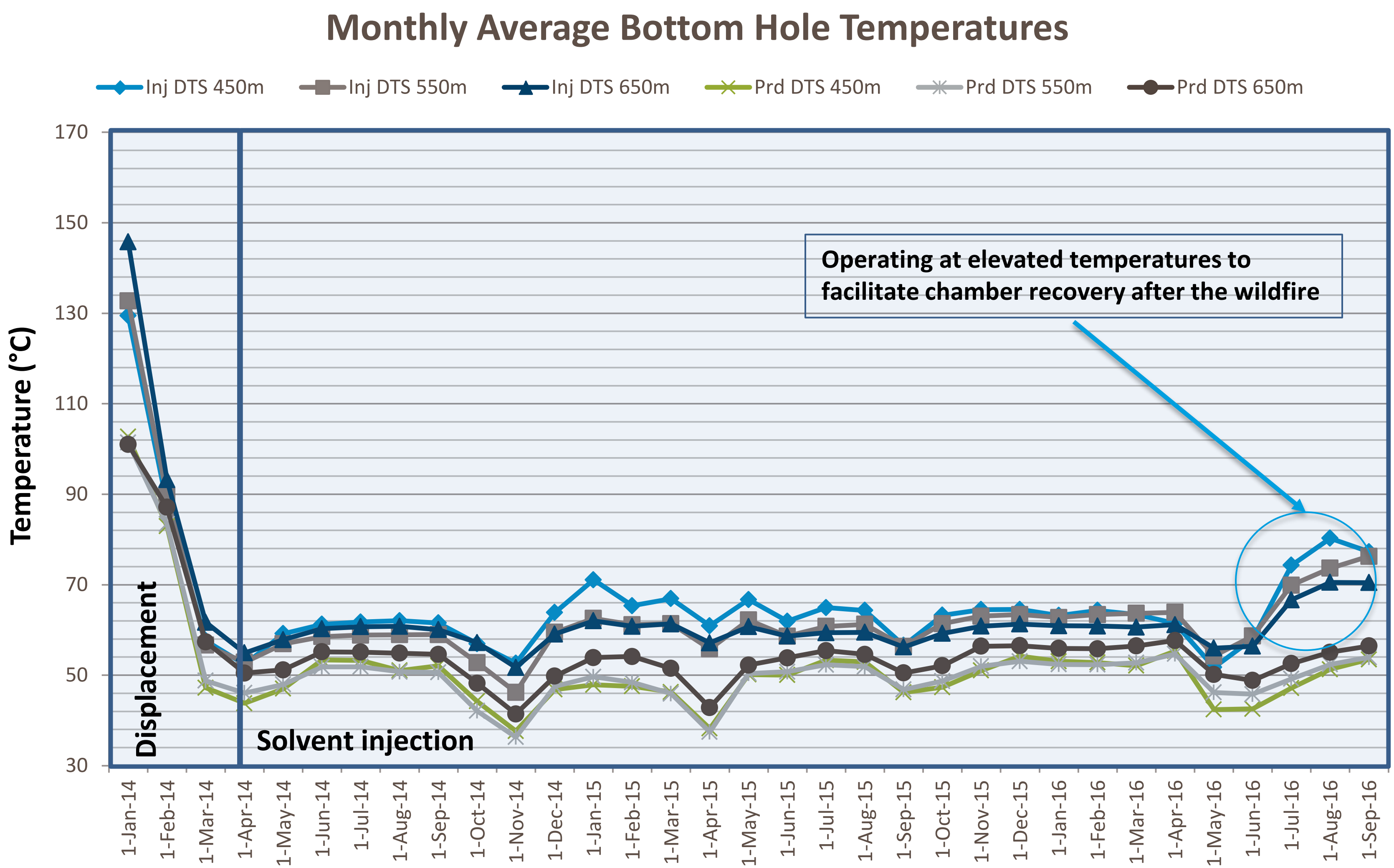
Scheme Performance – Solvent delivery

- Currently operating solvent chamber ~595 kPag and 58 deg C
- Solvent vapourizer temperature setpoint is adjusted to target vapour conditions downhole
- Solvent purity, non-condensables (C1 and C2) injection maintained below 0.03 mol %

Scheme Performance – Bottom Hole Pressures



Scheme Performance – Bottom Hole Temperatures



Key Learnings

- Able to manage the chamber at or below initial reservoir pressure with no issues
- No issues achieving high solvent recycle rates
- Asphaltenes have not been an issue
- Oil / water separation achieved without chemical usage
- Significant amount of in-situ upgrading occurring
- Water cut varies with chamber pressure

Key Learnings

- Chamber able to recover after extended outage due to wildfire without issue
- Artificial lift
  - MTM PCPs struggle low viscosity fluid
  - Viton stators work well with solvent, but are challenged with any solids production
  - ESPs appear to be a good choice

Future Plans

- Continue testing of operational parameters:
  - Superheat testing: assess the impact of bottom hole temperatures on solvent demand
  - Solvent purity testing: assess the impact of non-condensable gases in the injected solvent stream
  - Solvent hold-up optimization
  - Chamber wind-down
  - Solvent recovery/blowdown from chamber at end of life
- Potential additional 4D seismic shots
- Potential testing of new surface equipment
- Potential coring of solvent chamber

AER Directive 054 - 2015 Performance Presentation

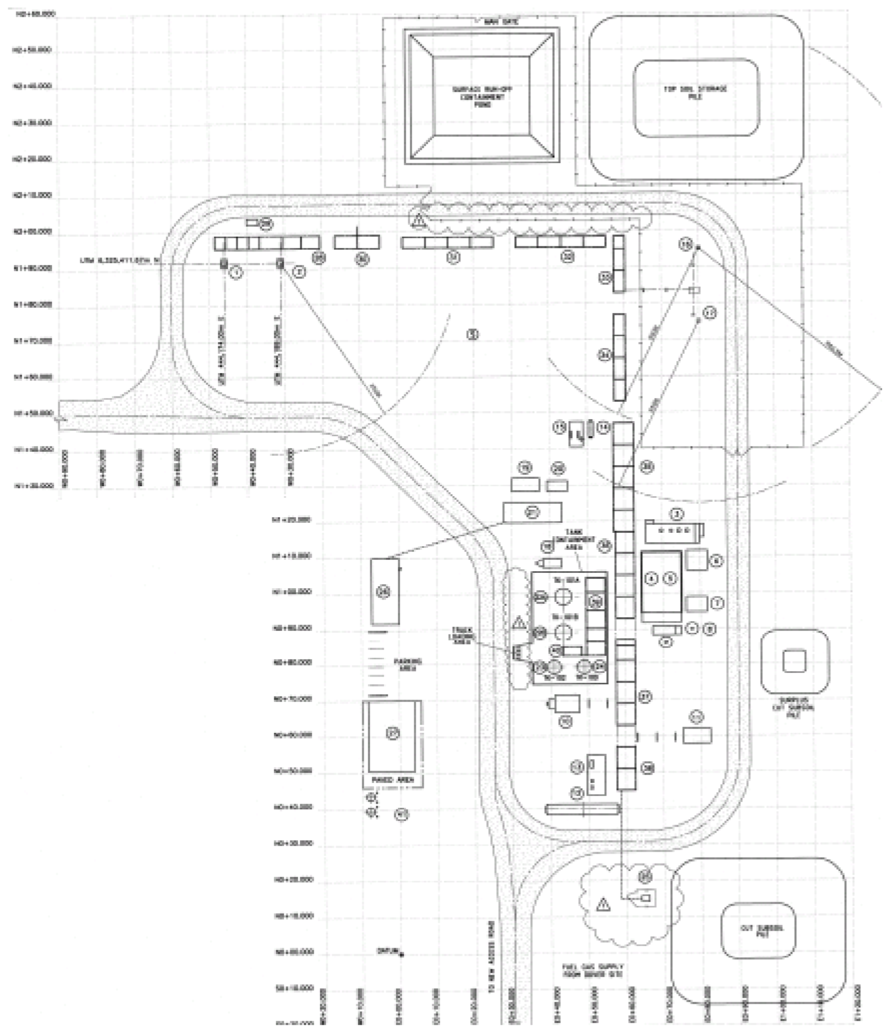
Section 3.1.2

Surface Operations, Compliance, and Issues not related to Resource Evaluation and Recovery

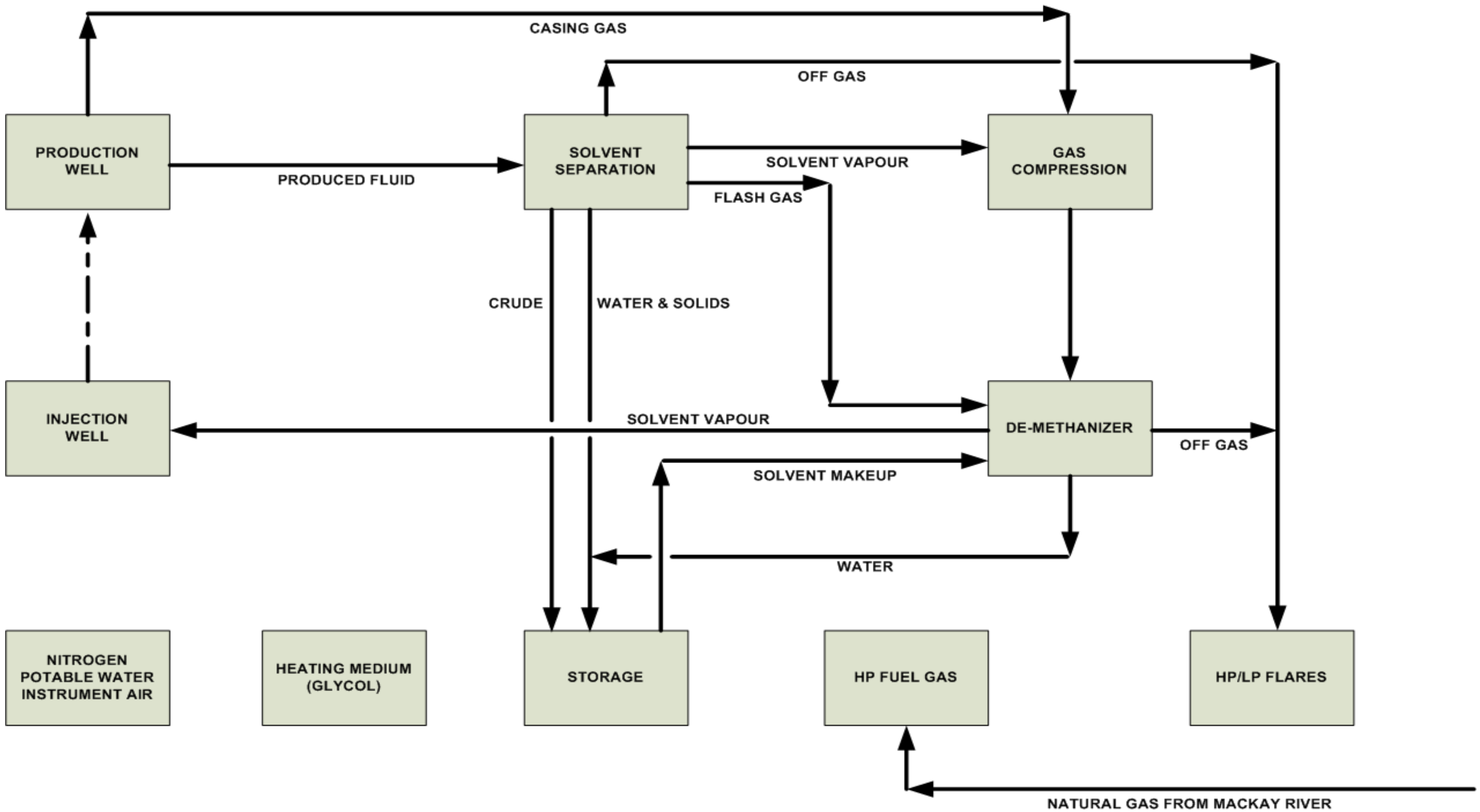
Table of Contents

- Facilities
- Central Processing Facility (CPF) Performance
- Measurement and Reporting
- Water, Production, Injection and Use
- Sulphur Production
- Environmental Performance
- Future Plans

Facilities – Plot Plant



Facilities – Production Schematic



Facilities Modification

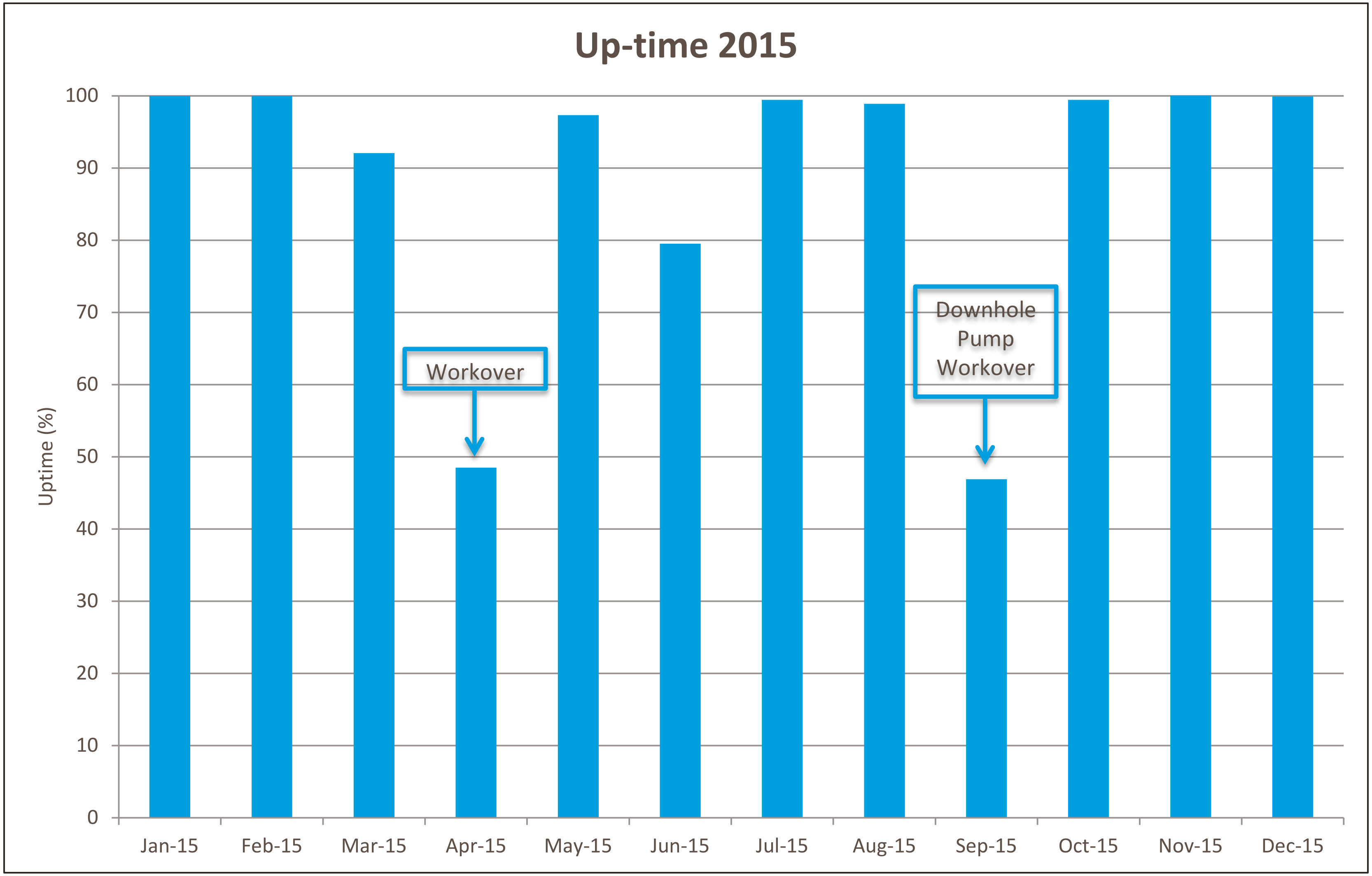
2016

- No significant facilities modifications in 2016

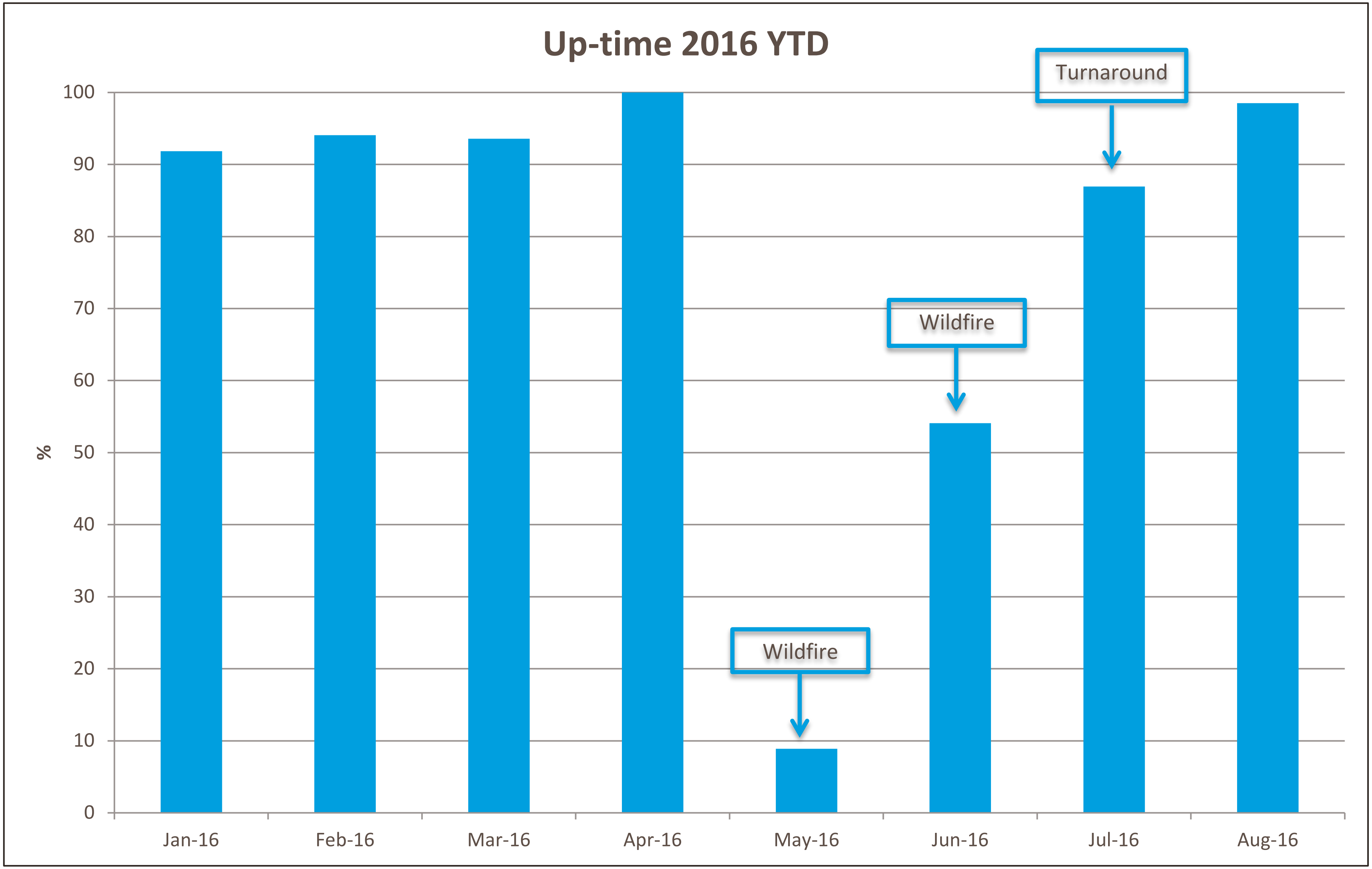
CPF Performance

- Facility is operating very well
- Able to maintain an average up-time of 96.1% since August 2015, excluding workover and the wildfire, despite limited redundancy
- Fluid separation without chemicals
  - Oil with only trace water
  - Very clean produced water
- No issues maintaining solvent purity

CPF Performance



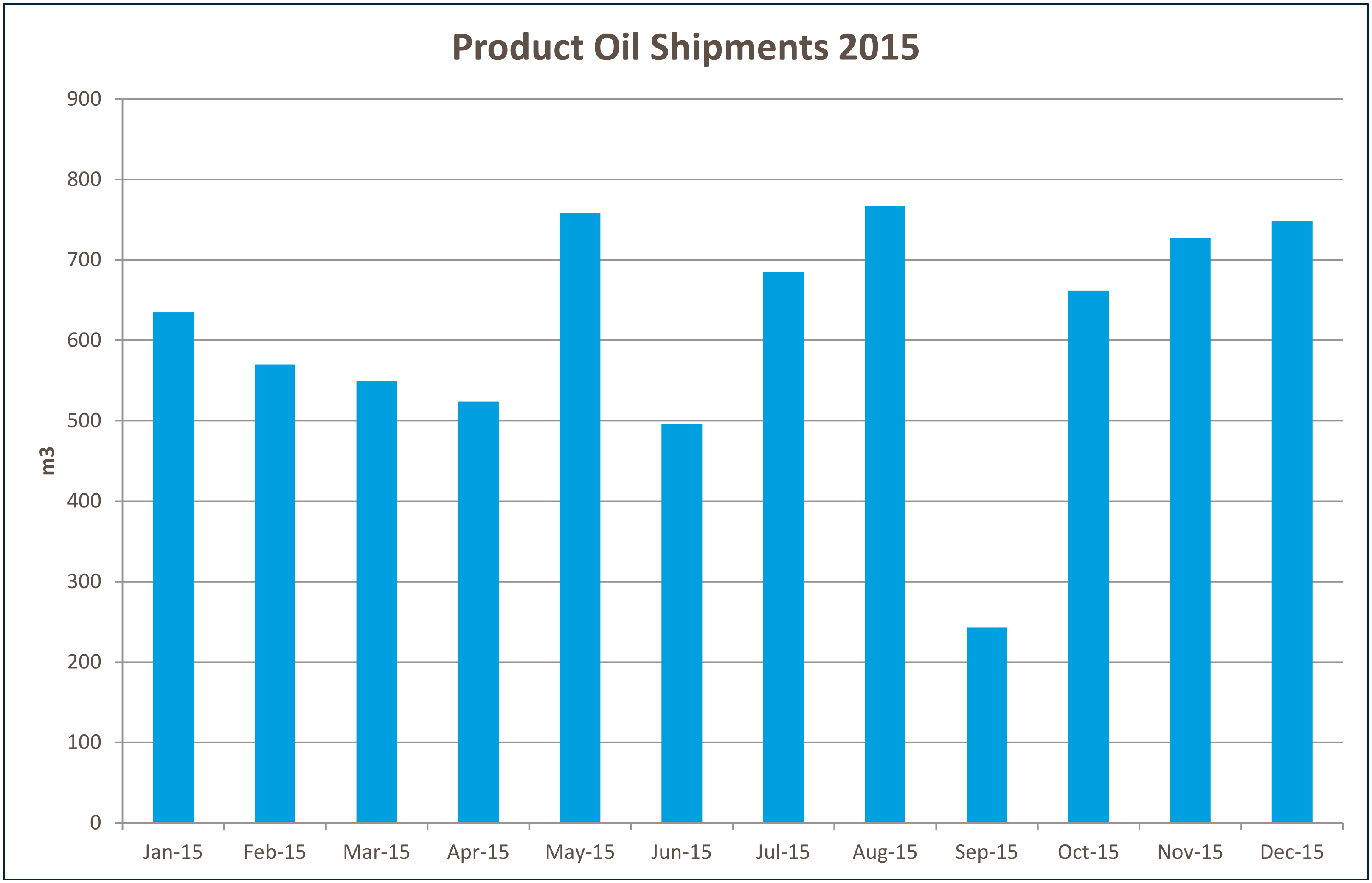
CPF Performance



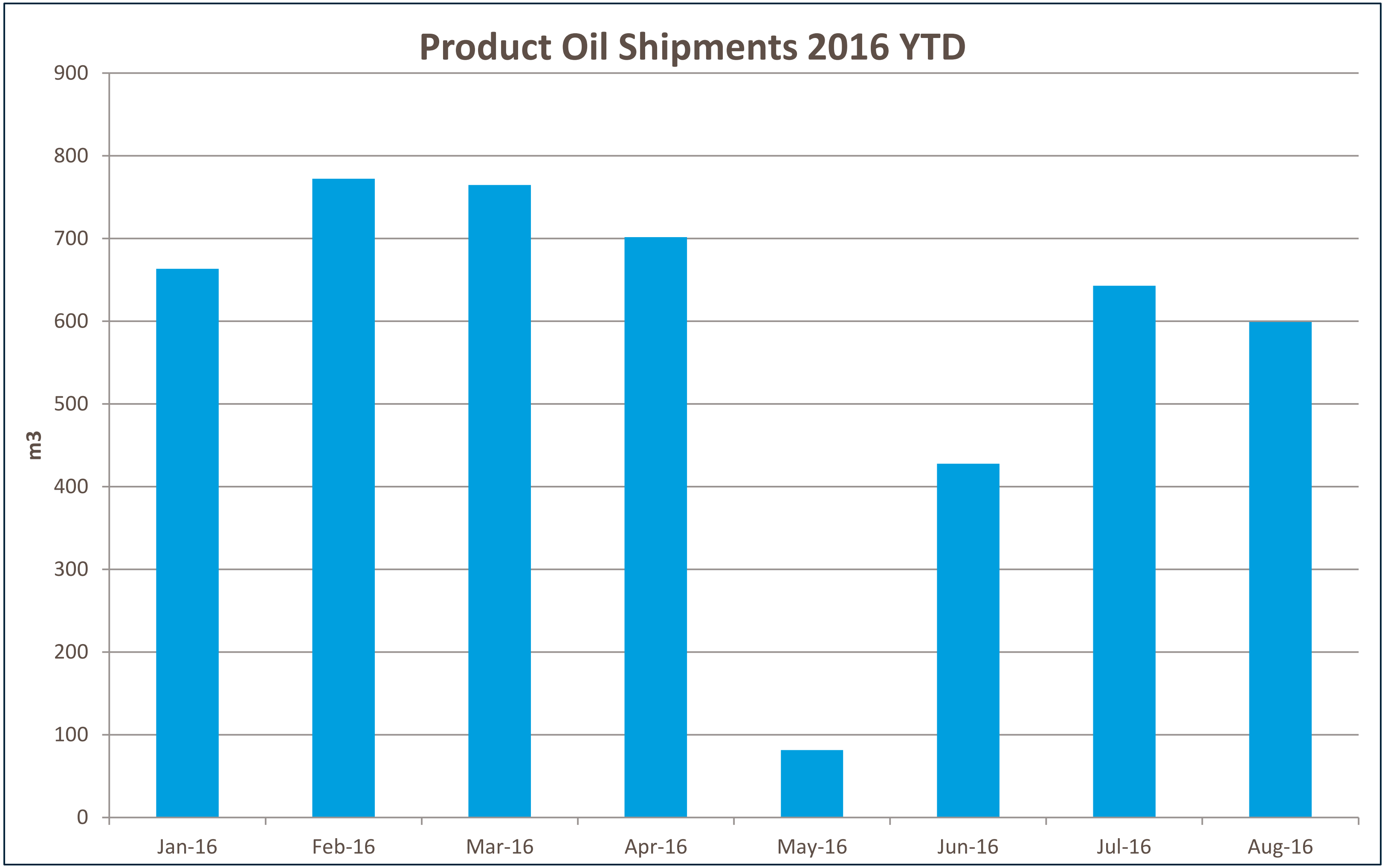
CPF Performance – Bitumen Treatment

- Able to produce dry oil without use of separation chemicals or external diluent

CPF Performance – Bitumen Treatment



CPF Performance – Bitumen Treatment



CPF Performance – Water Treatment

- No water treatment required on-site
- Residual oil is recovered in the Skim Tank

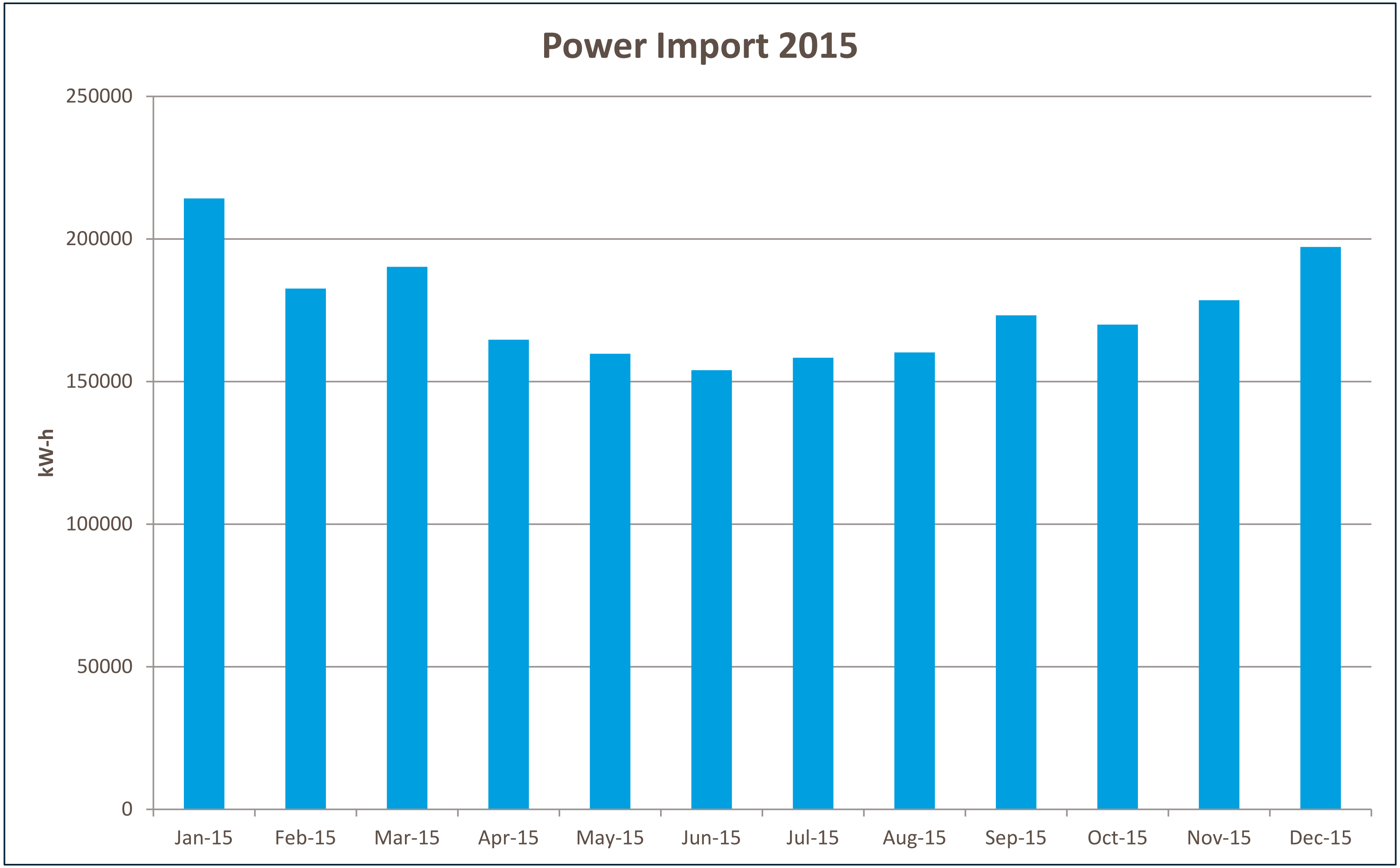
CPF Performance – Solvent Treatment

- Solvent purity is critical to the Nsolv process
  - Defined in terms of non-condensables (C1, C2) mol%
  - C3 to C5+ is considered solvent
- Solvent is purified in a distillation column
  - Target non-condensables mol%: < 0.03

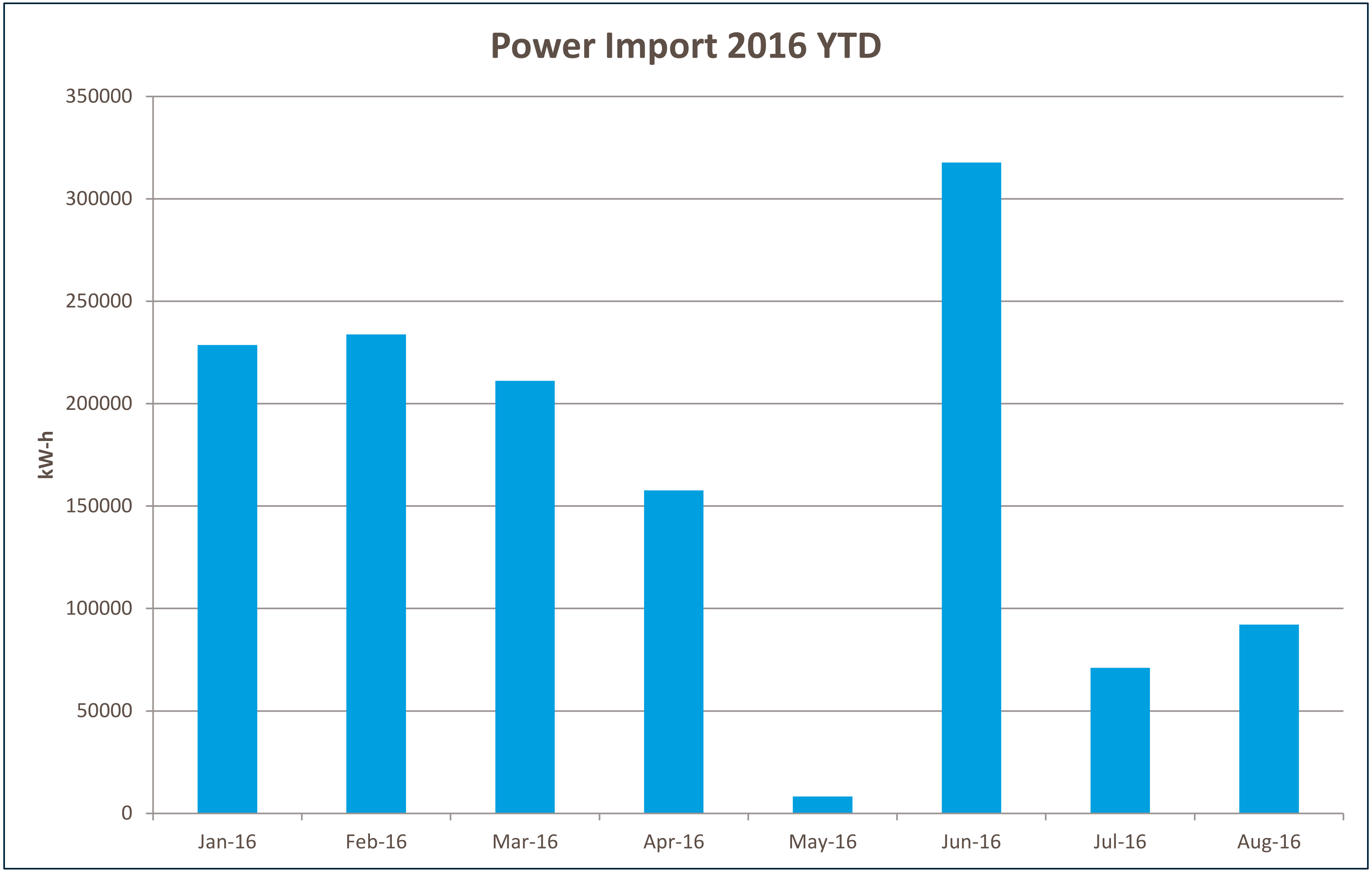
CPF Performance – Power

- Power imported from ATCO
- Emergency backup provided by 500 kW generator

CPF Performance – Power



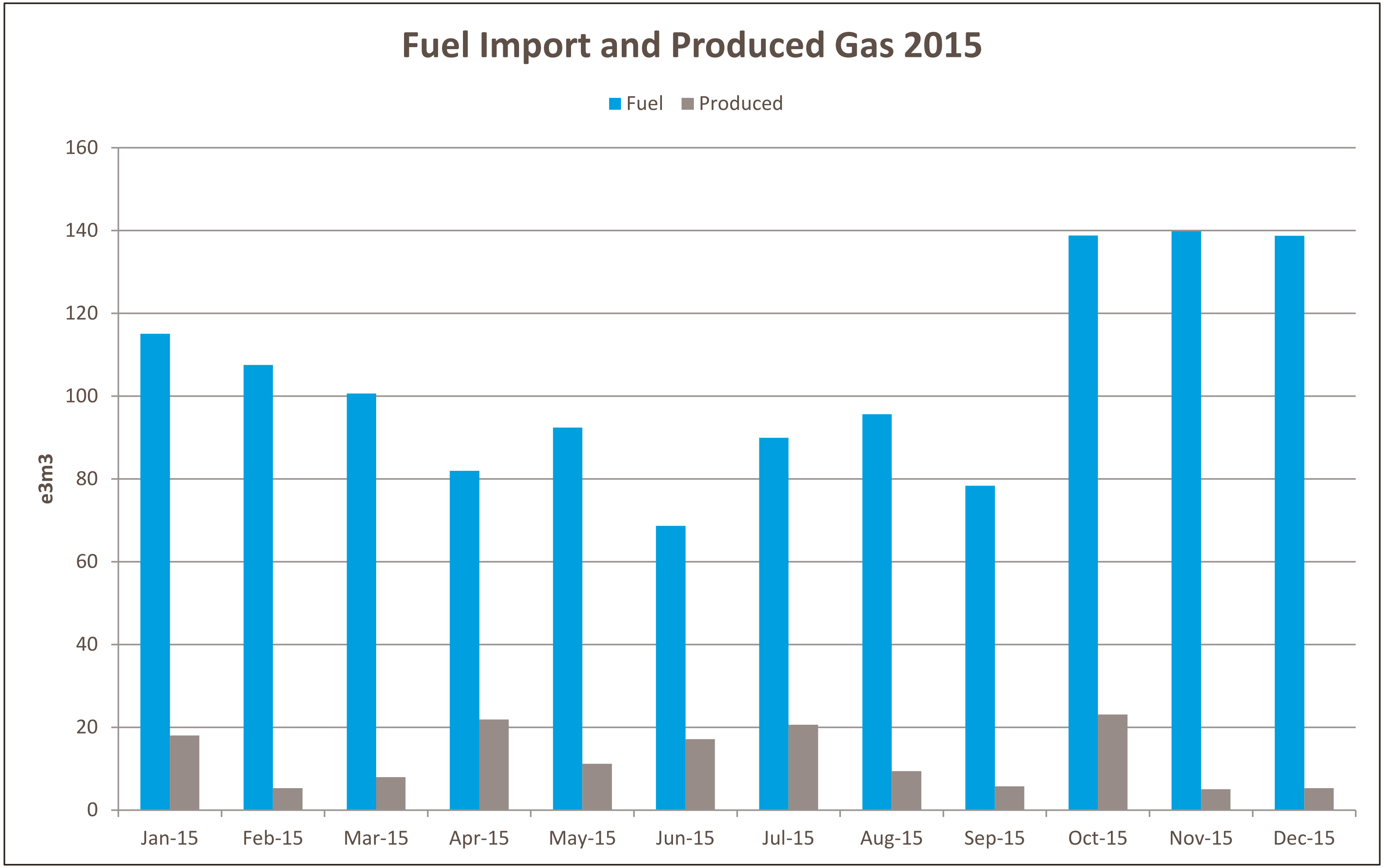
CPF Performance – Power



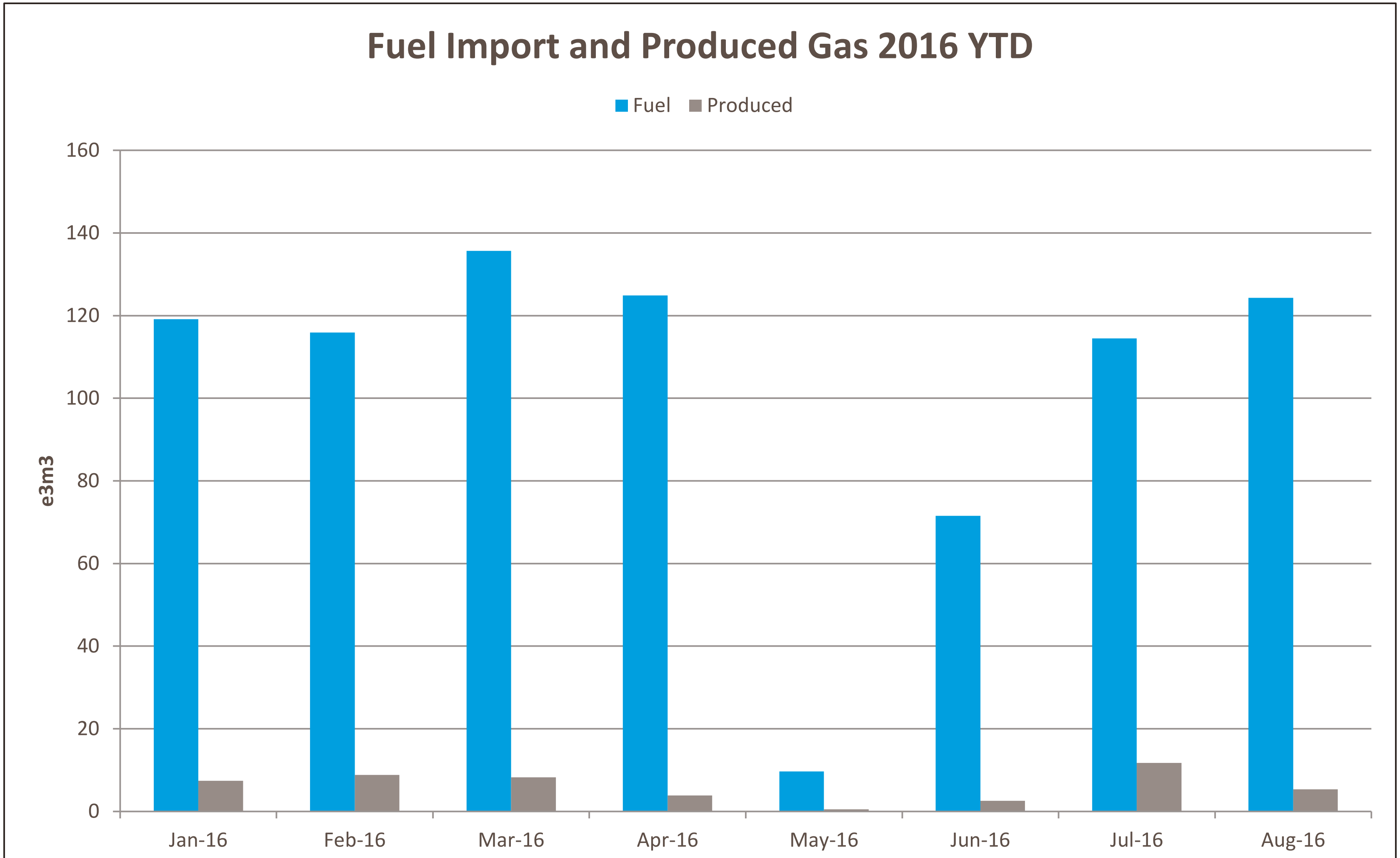
CPF Performance – Gas

- Fuel gas imported from Suncor
- Produced solution gas is flared
- Solution gas production commenced with recycle of injected solvent on 5th April 2014

CPF Performance – Gas



CPF Performance – Gas

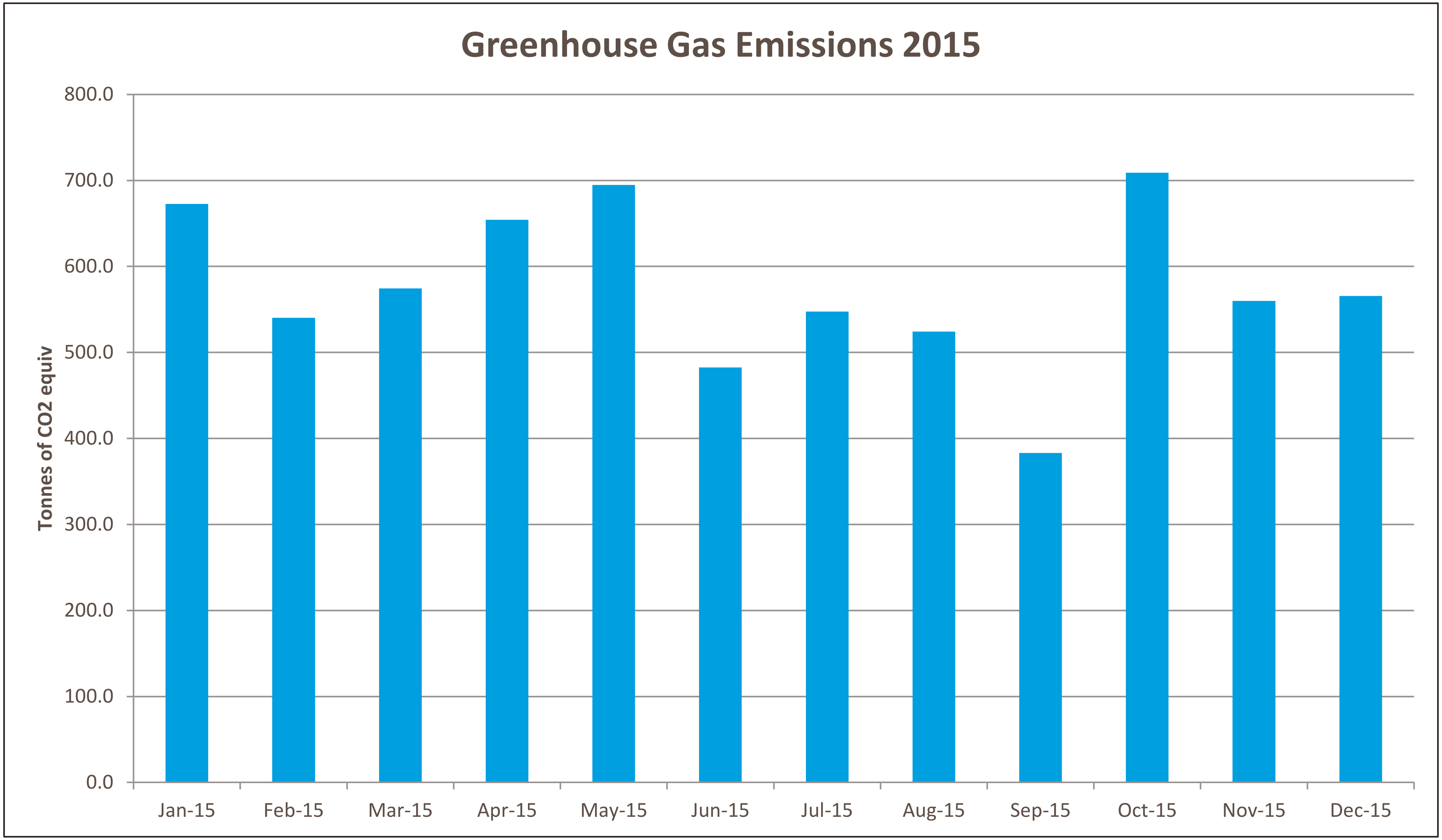


CPF Performance – Green House Gas Emissions

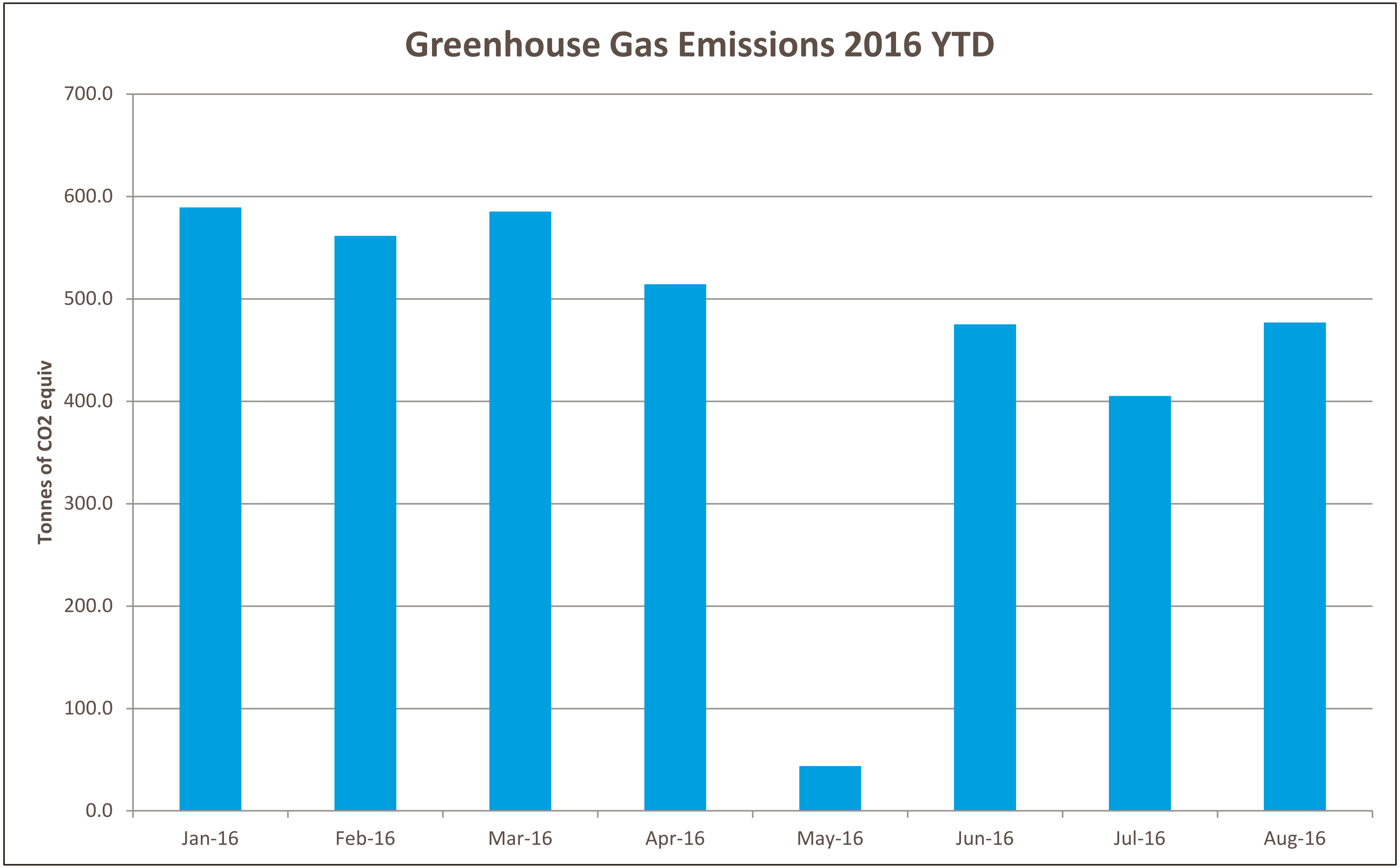
nsolv

- CO_2 emissions YTD: 3,651 Tonnes CO_2 equiv.
- Total CO_2 emissions: 16,023 Tonnes CO_2 equiv.
- GHG factors:
  – Power: 820 kg/MWh
  – Fuel gas production and transport: 0.29 kg/m^3
  – Solvent production and trucking: 121 kg/m^3
  – Solvent flaring: 1.91 kg/m^3

CPF Performance – Green House Gas Emissions



CPF Performance – Green House Gas Emissions



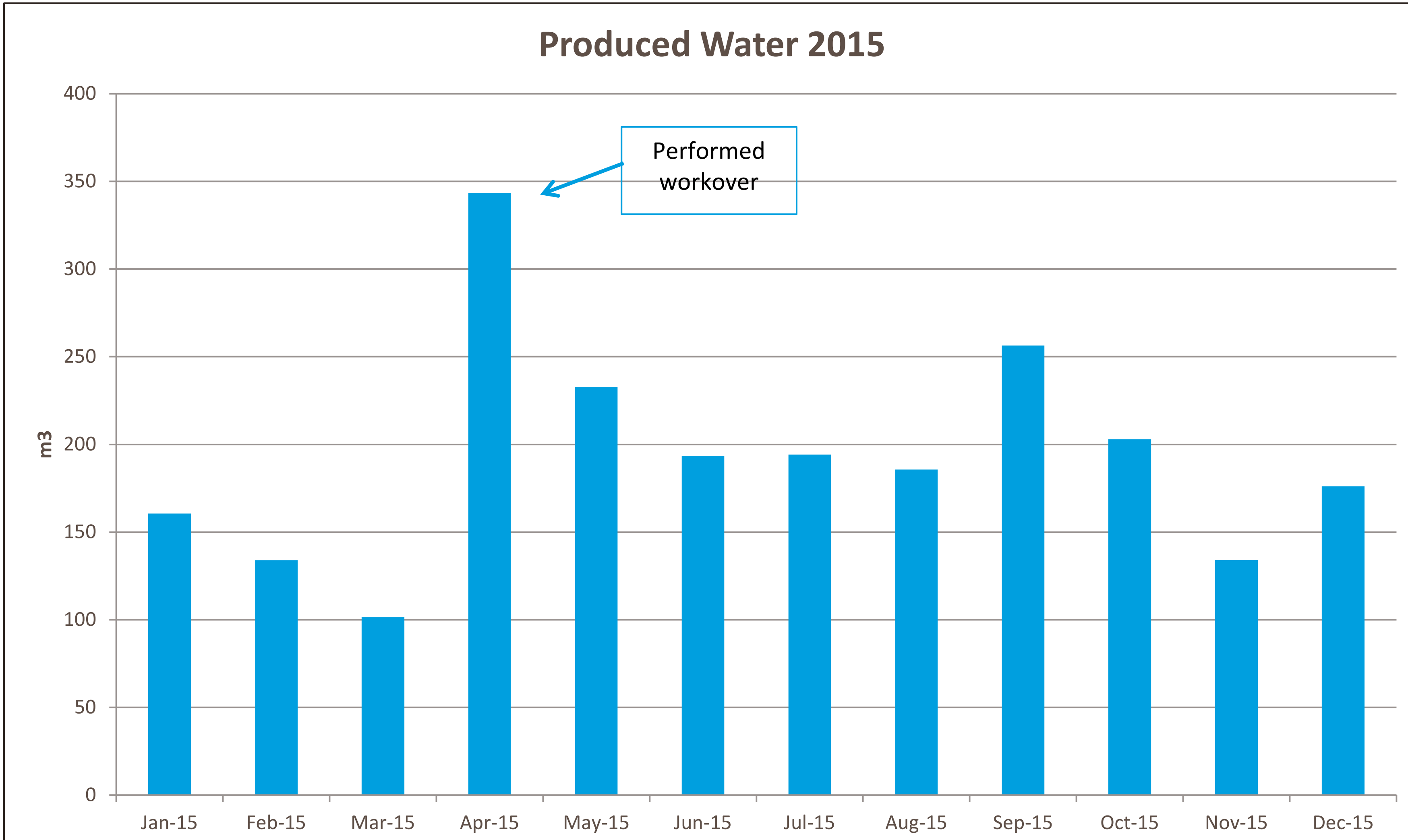
Measurement & Reporting

- Single well pair facility:
  - All production attributed to the production well
  - No individual well testing required
- Facility Codes associated with Suncor BEST Approval 11825:
  - AB BT0126919
  - AB IF0126920

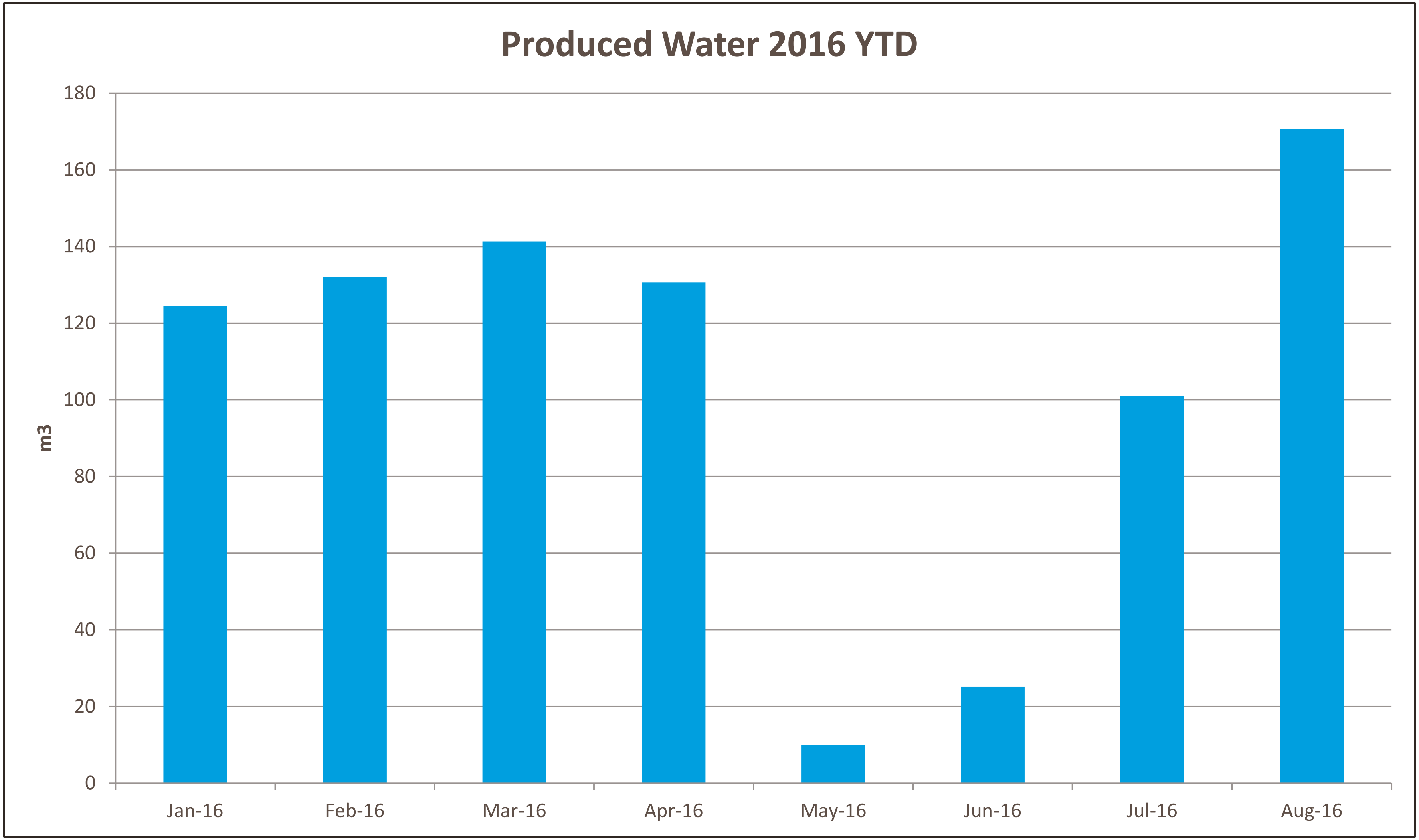
Water Production

- 21% water cut on average
- Water is hauled off-site to disposal a Newalta facility:
  - ABWP0000688
- Produced water is sampled and analyzed by third party lab:
  - Avg. TDS: 17,036 mg/L
  - Avg. pH: 8.13
  - Avg. Na: 6,609 mg/L
  - Avg. Cl: 9,793 mg/L
  - HCO3: 1,433 mg/L

Water Production



Water Production



Sulphur Production

- Produced gas is sampled and analyzed by third party lab
- H2S is below measurable limits

BEST Regulatory Summary

- AER Experimental Scheme Approval No. 11825 issued May 8, 2012
- EPEA Amending Approval No. 705-02-01 issued May 17, 2012
- Measurement, Accounting & Reporting Plan approved September 29, 2012
- Facility License F-45241 issued October 12, 2012
- Well License 0445932 (NS-S1) issued May 16, 2012
- Well License 0445946 (NS-P1) issued May 17, 2012
- RMWB Development Permit 2012-DP-00991 issued August 3, 2012
- AER Directive 051 approval for both wells issued February 7, 2013
- Production of Surface Casing Vent Flow Approval issued July 29, 2014

Suncor Energy Inc. is in compliance with all regulatory approvals, decisions, regulations and conditions as described in Experimental Scheme Approval 11825

BEST Environmental Summary

- Disturbance: no new disturbance in current reporting period
- Stormwater: surface run-off from the project is contained on the site through the use of a stormwater pond. Water is sampled & released if it meets EPEA requirements.
- Domestic Wastewater: wastewater is contained & trucked to an approved treatment facility
- Spill Containment: consists of storage & secondary containment that complies with Directive 055 requirements. Other measures include: collection of surface run-off; spill prevention & loss control systems; groundwater monitoring; proper maintenance, operating procedures & inspections; spill contingency & response plans.
- Air Emissions: monitoring & sampling as per the EPEA approval requirements
- Groundwater: monitoring & sampling as per the EPEA approval requirements
- No reportable releases or enforcement actions are associated with the project to date.

SUNCOR