



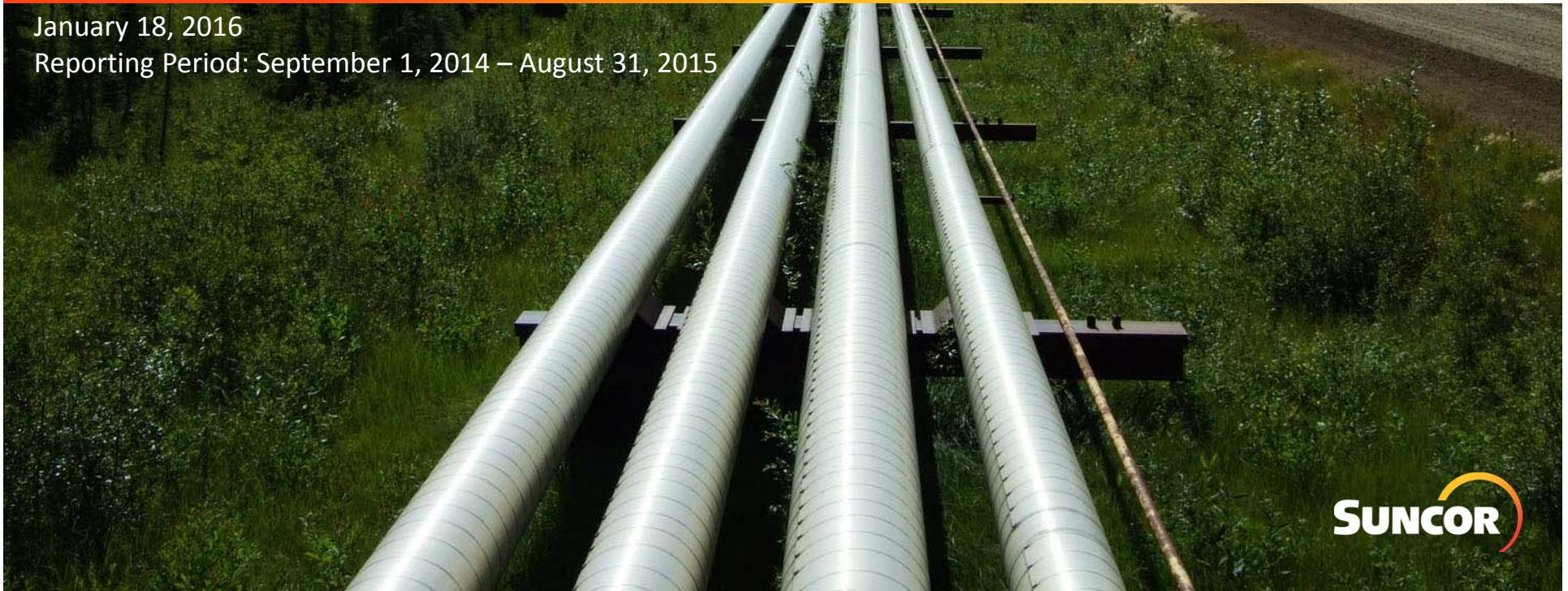
Suncor BEST (Nsolv) Pilot Project

2015 AER Performance Presentation

Experimental Scheme Approval No. 11825

January 18, 2016

Reporting Period: September 1, 2014 – August 31, 2015



AER Directive 054 - 2015 Performance Presentation



Section 3.1.1

Subsurface Issues Related to Resource Evaluation and Recovery



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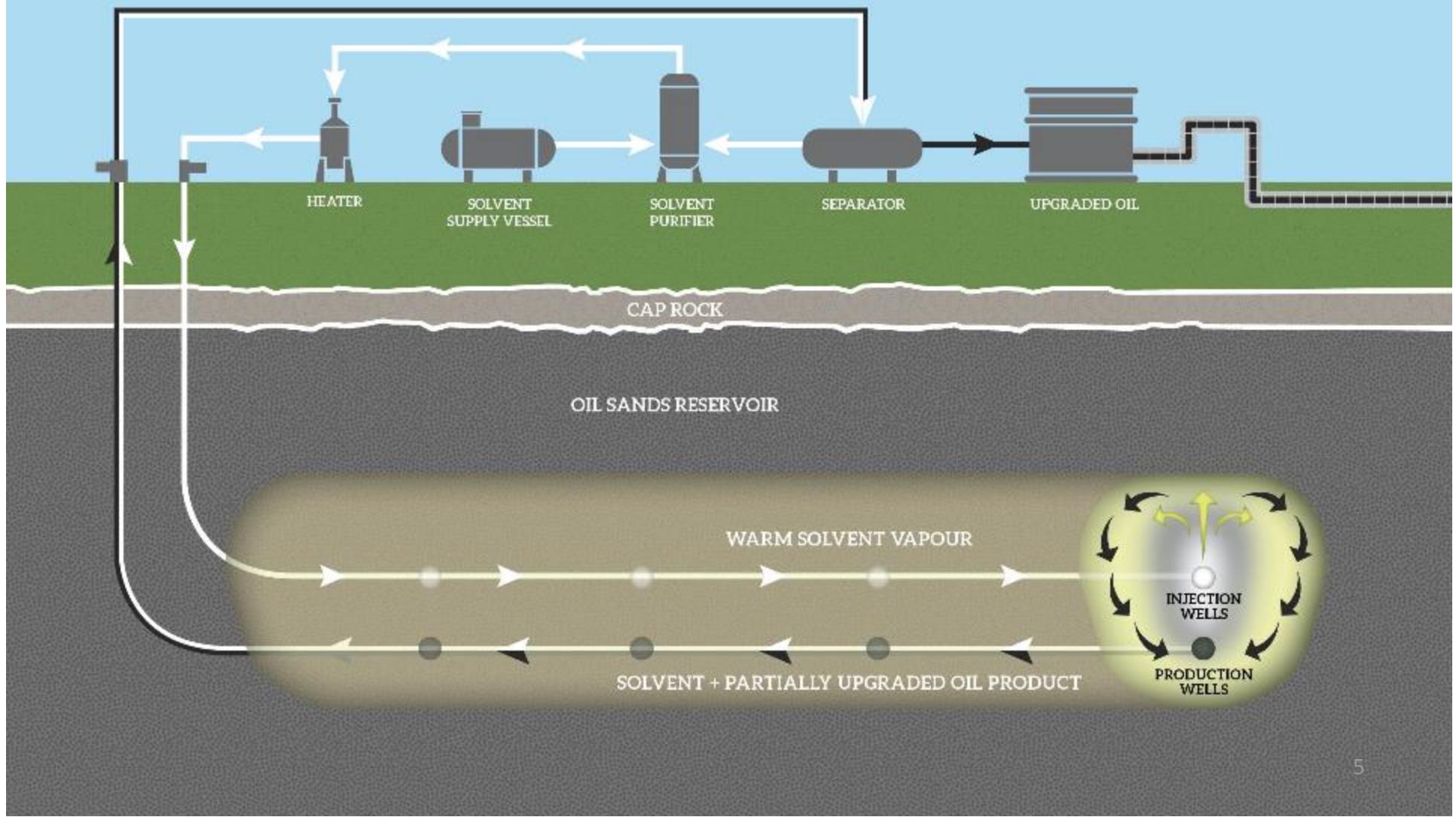
Background



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

- 69 kg per barrel less GHGs than SAGD
- In-situ upgrading → downstream GHG benefits
 - Currently observing upgrade from 8 to 14 API
- Zero process water usage

How it works



Background – BEST Pilot Plant



- Bitumen Extraction Solvent Technology
- 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 m³/d (1500 bpd) solvent delivery capability
- 79.5 m³/d (500 bpd) oil processing capability

Background – BEST Pilot Plant



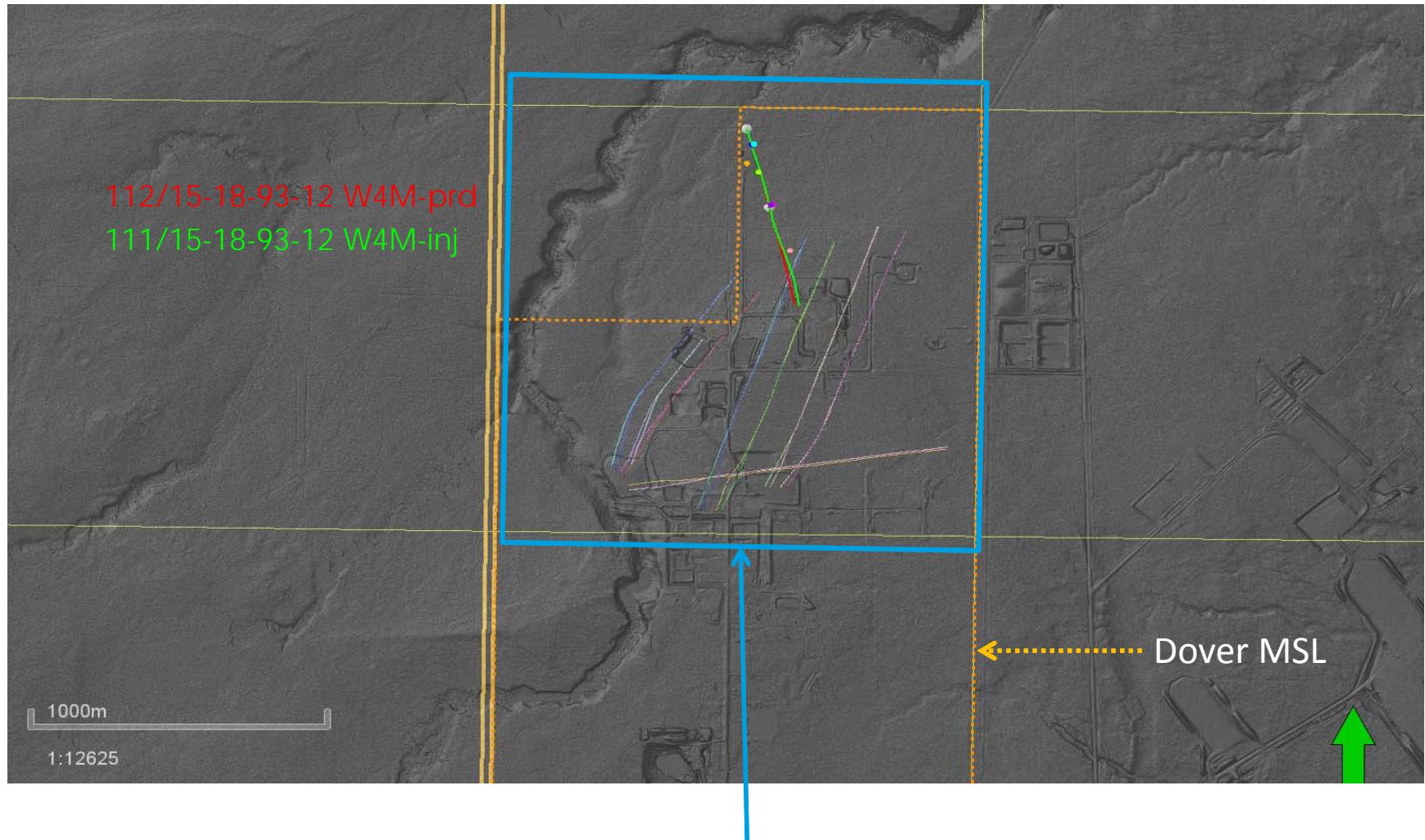
- Ability to use either propane or butane
 - In order to minimize any potential for solvent losses, the solvent chamber is kept in balance with the native reservoir pressure
 - The ideal operating temperatures are between 35-75 °C as this provides an adequate rise in the bitumen temperature to significantly 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 kPa

Background – Project Location





Project Location



BEST Pilot Plant – Commissioned Summer 2013

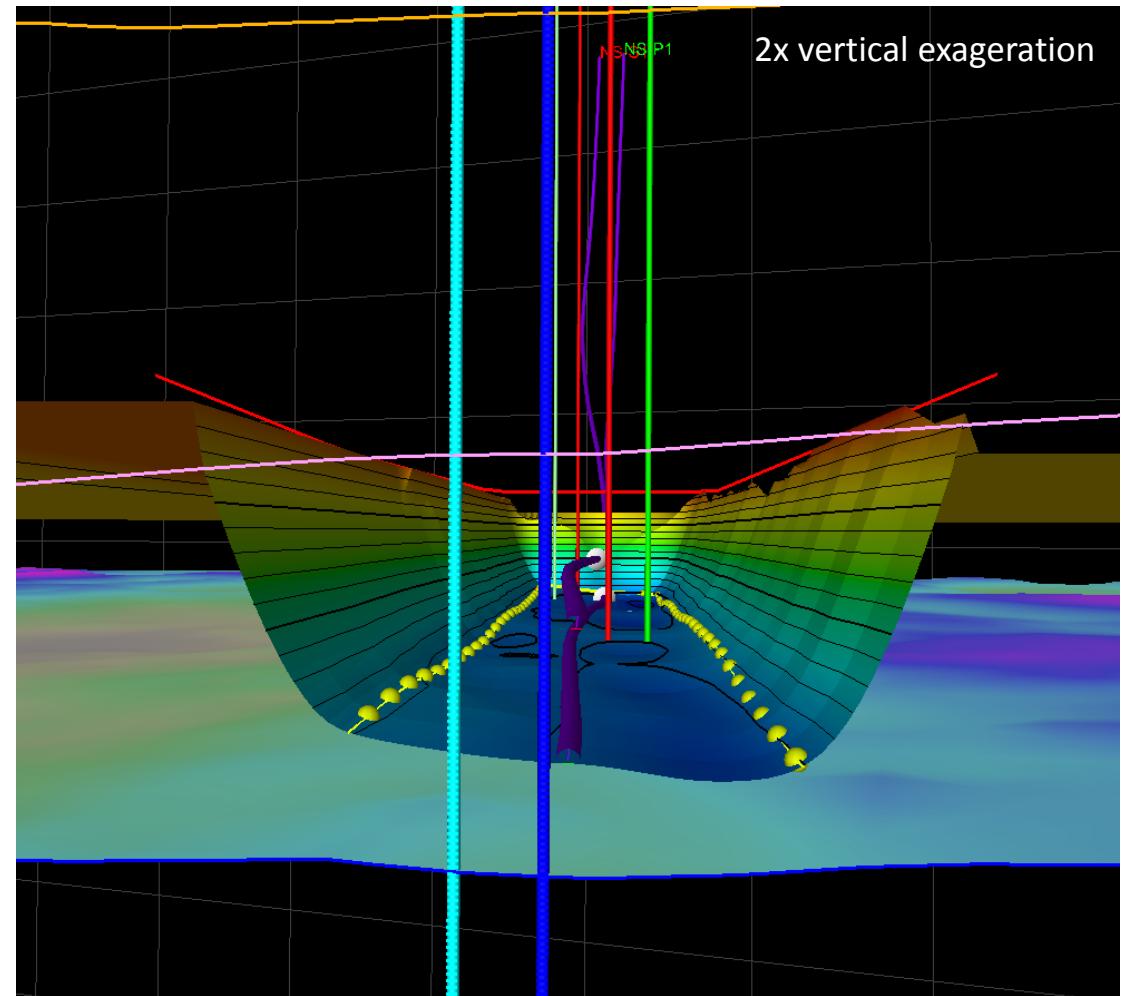


Volumetrics

(Based on ~35m drainage radius)

Volume Calculation

- Drainage Area = 24,313m²
- Pay Thickness = 13m above producer
- $S_o=75\%$, Porosity=33.4%
- 79,175m³ Exploitable PIIP
- Recoverable Bitumen
 - 10° drainage angle (~24% reduction)
 - 75% chemical yield
 - 45,130m³ (57% recoverable)
 - 8,984 m³ bitumen recovered as of Oct 14, 2015
 - 19.9% of recoverable
 - 11.3% of exploitable PIIP



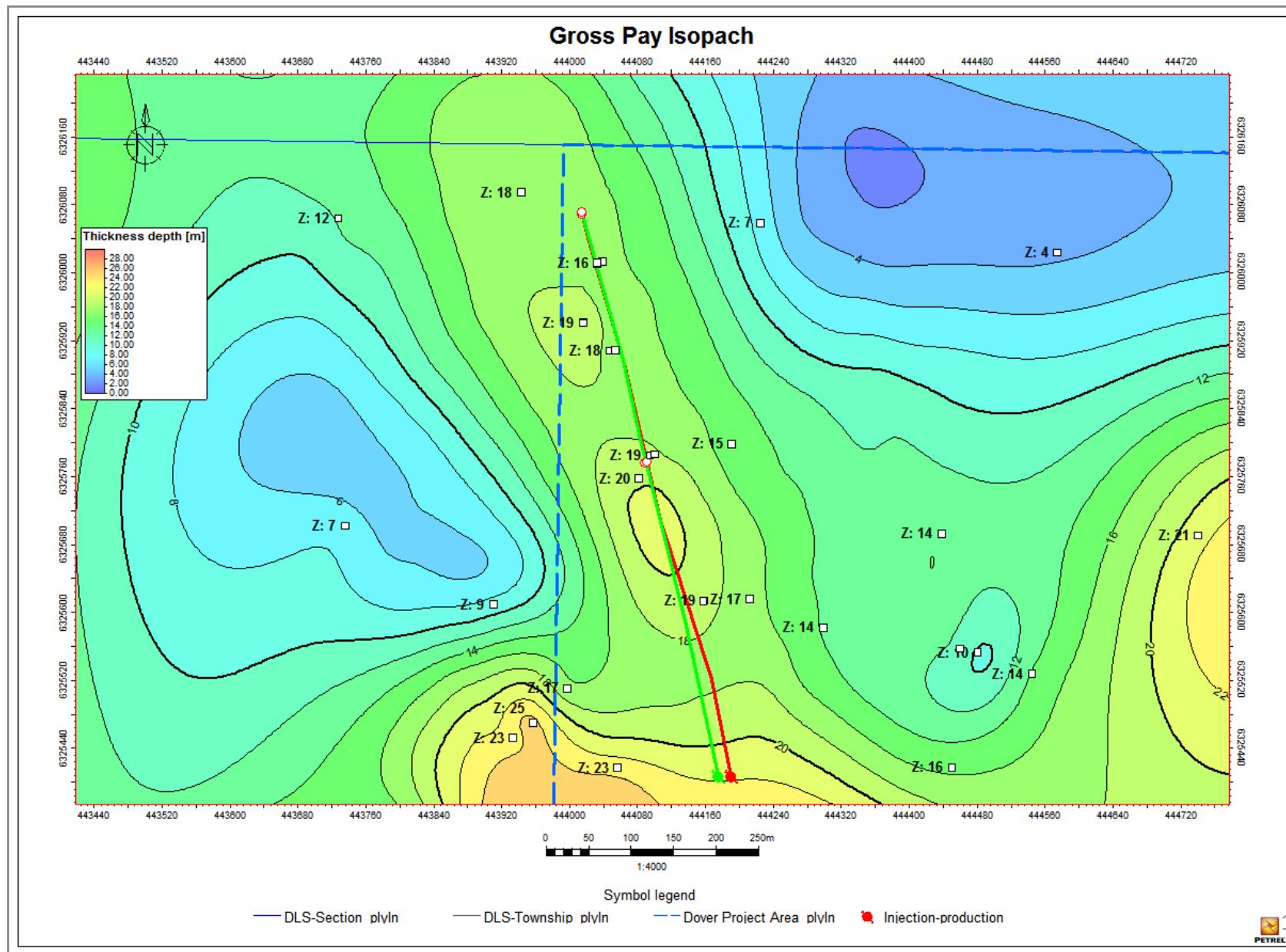
$$\text{PIIP} = \text{Area} * \text{Pay thickness above producer} * \text{Oil Saturation} * \text{Porosity}$$

Average Reservoir Parameters

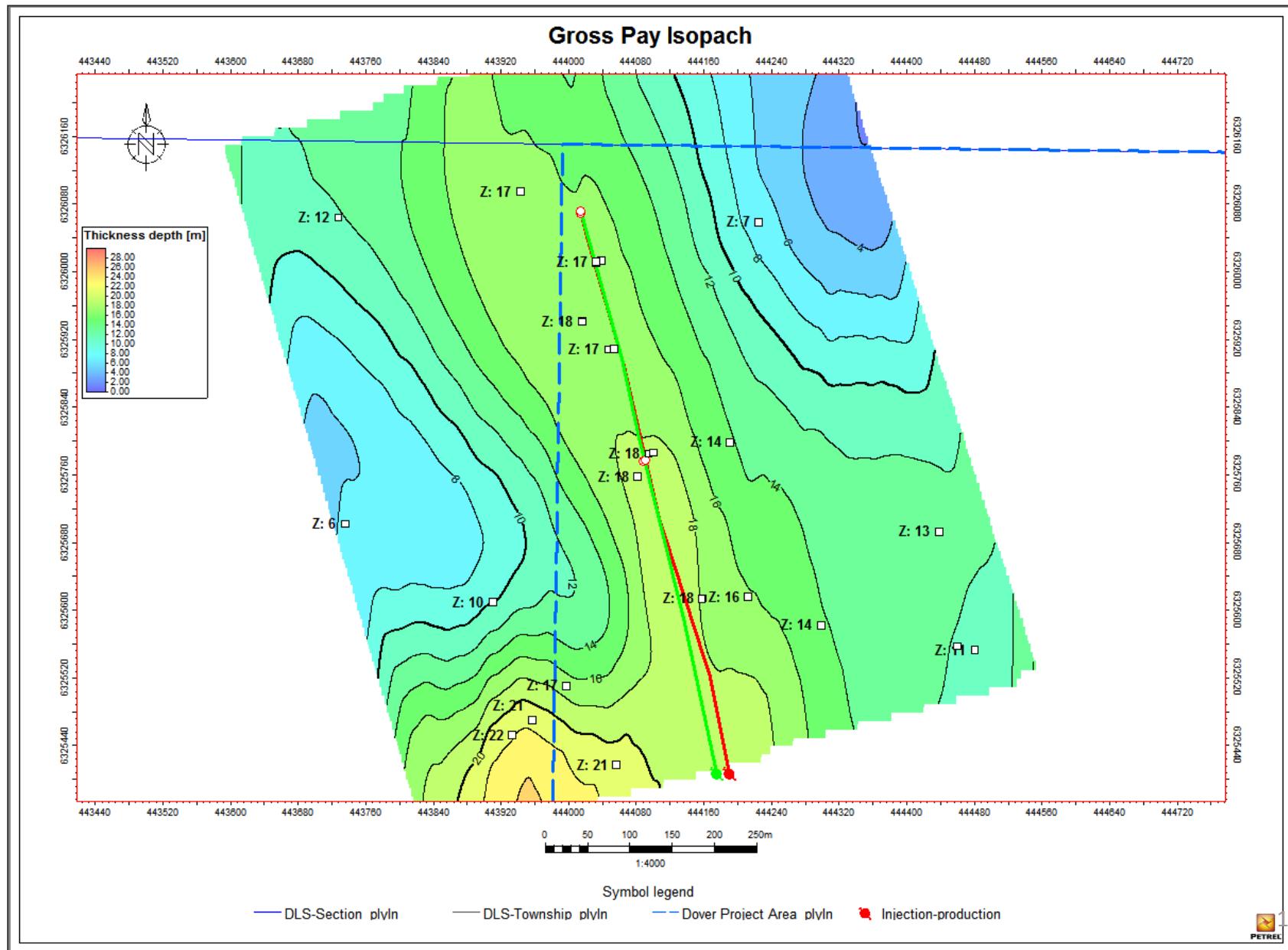


Porosity	33.4%
Effective Porosity	29%
Oil Saturation	75%
Horizontal Perm Petrel	6500mD, (3670 breccia)
Vertical Perm Petrel	5370mD, (2400 breccia)
Horizontal Perm Core Data	6817mD
Vertical Perm Core Data	5300mD (arithmetic ave)
Exploitable Pay	13m
Net Pay	18m
Depth to top of Pay	123.5m

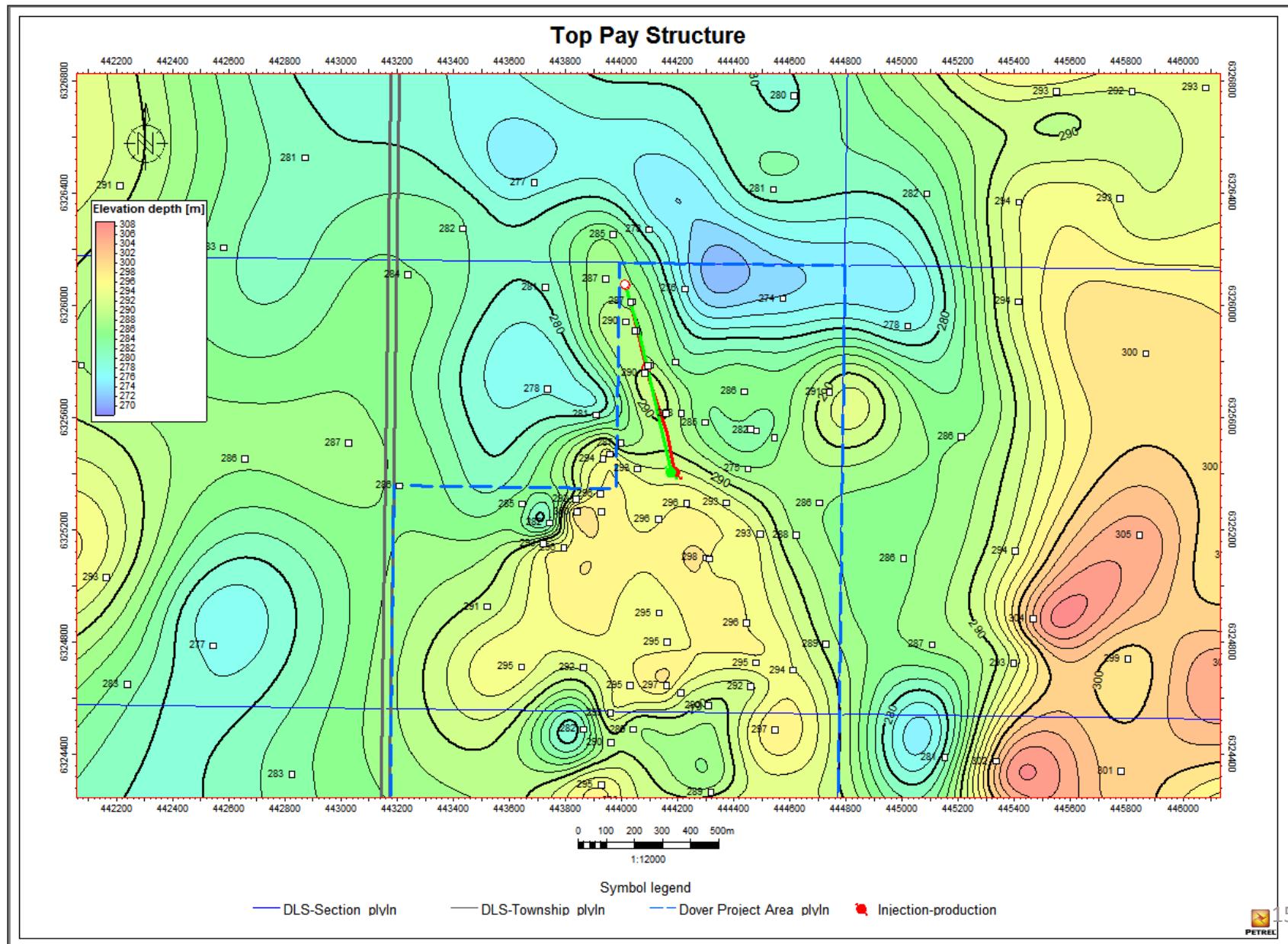
Geology – Gross Pay Interval



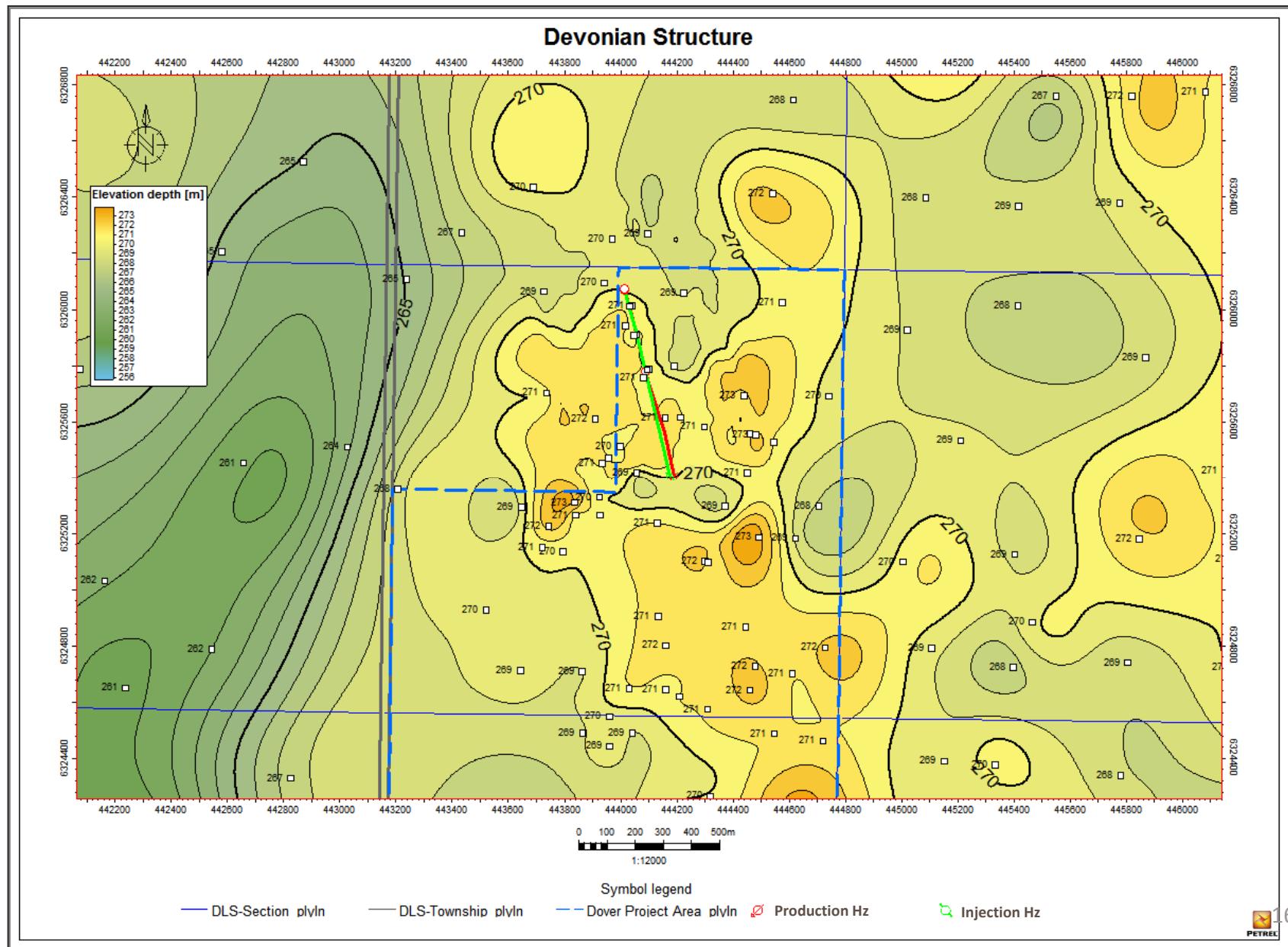
Geology – Net Bitumen Pay



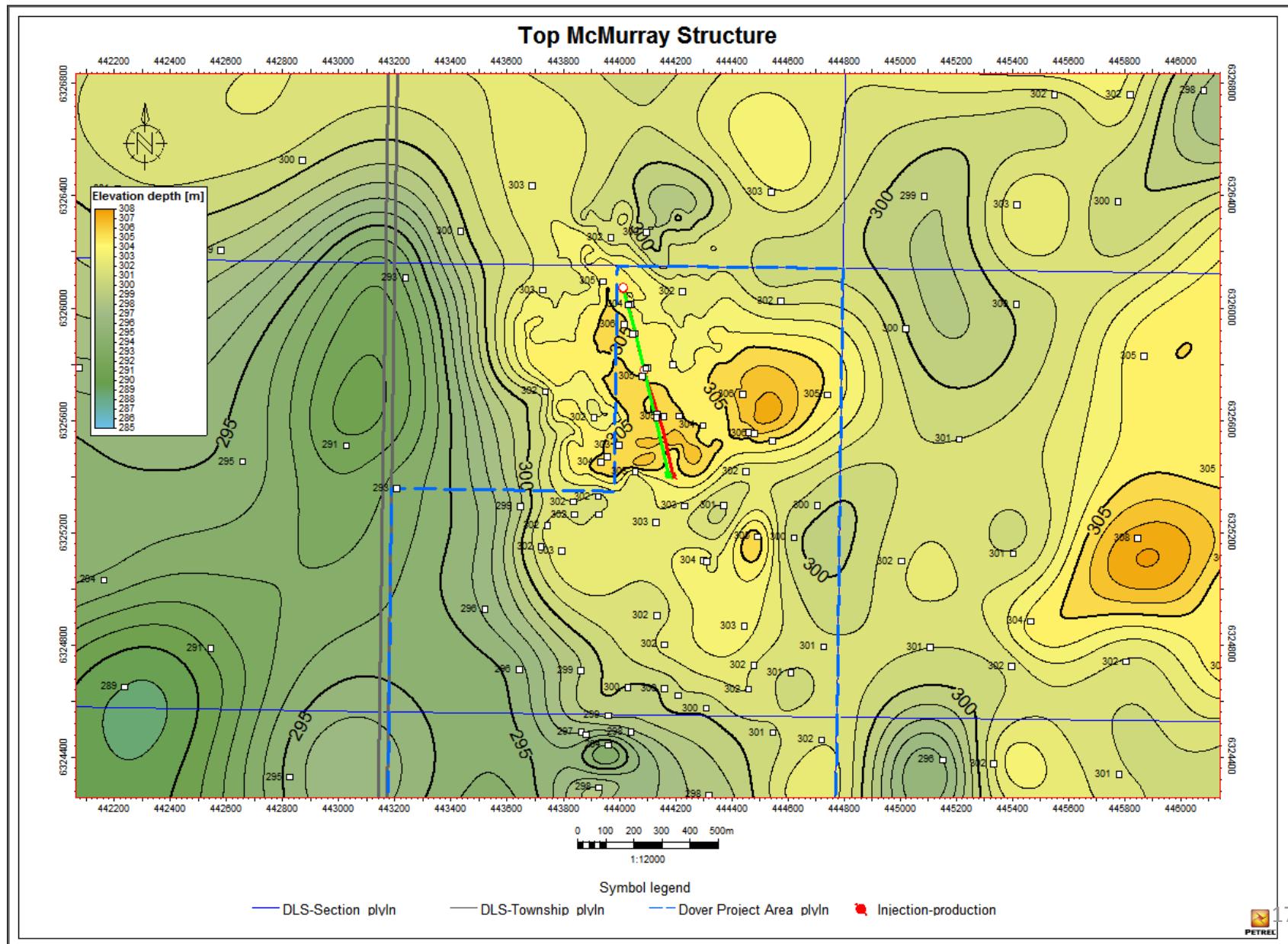
Geology – Top Pay Structure



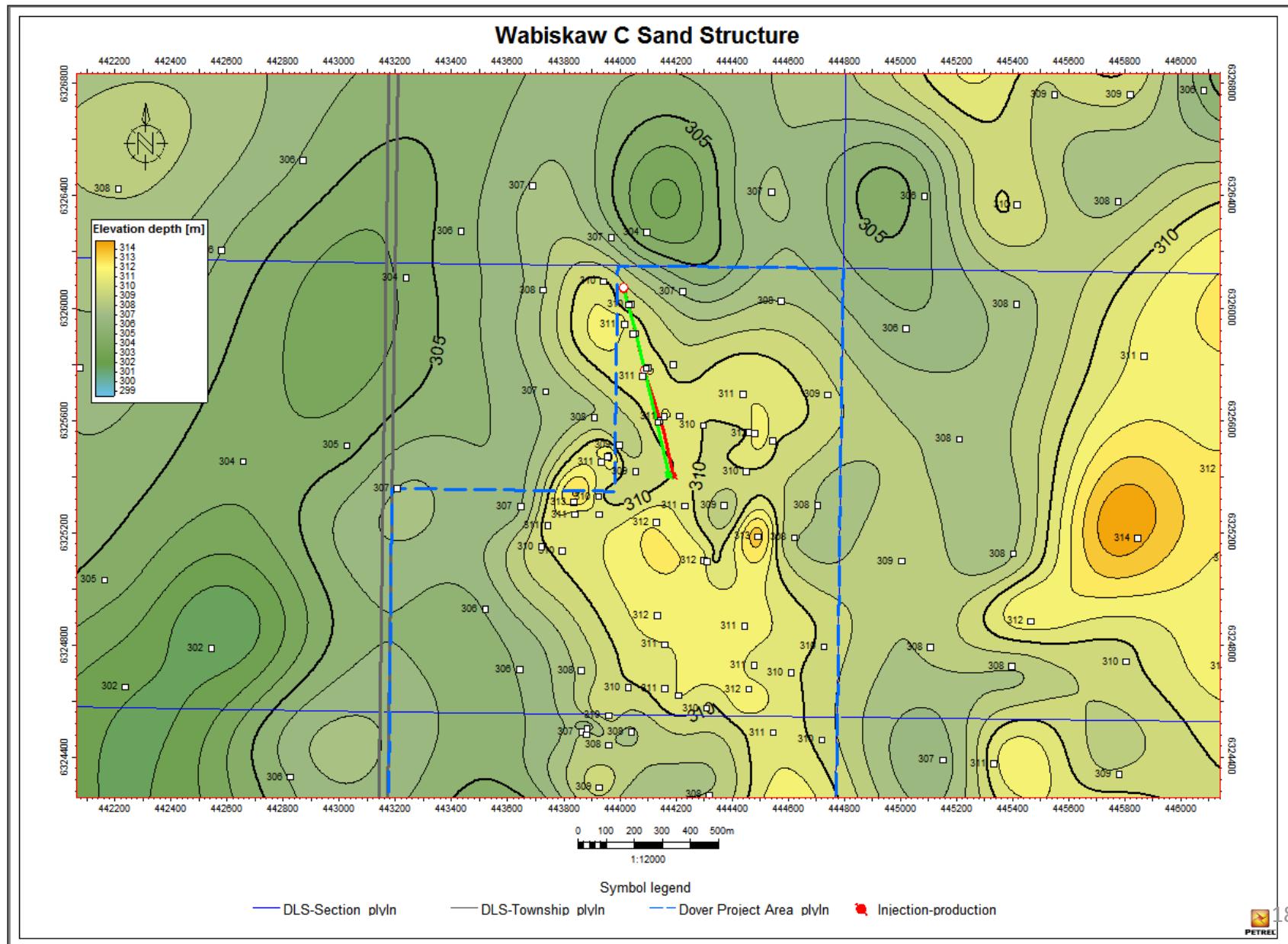
Geology – Devonian Structure



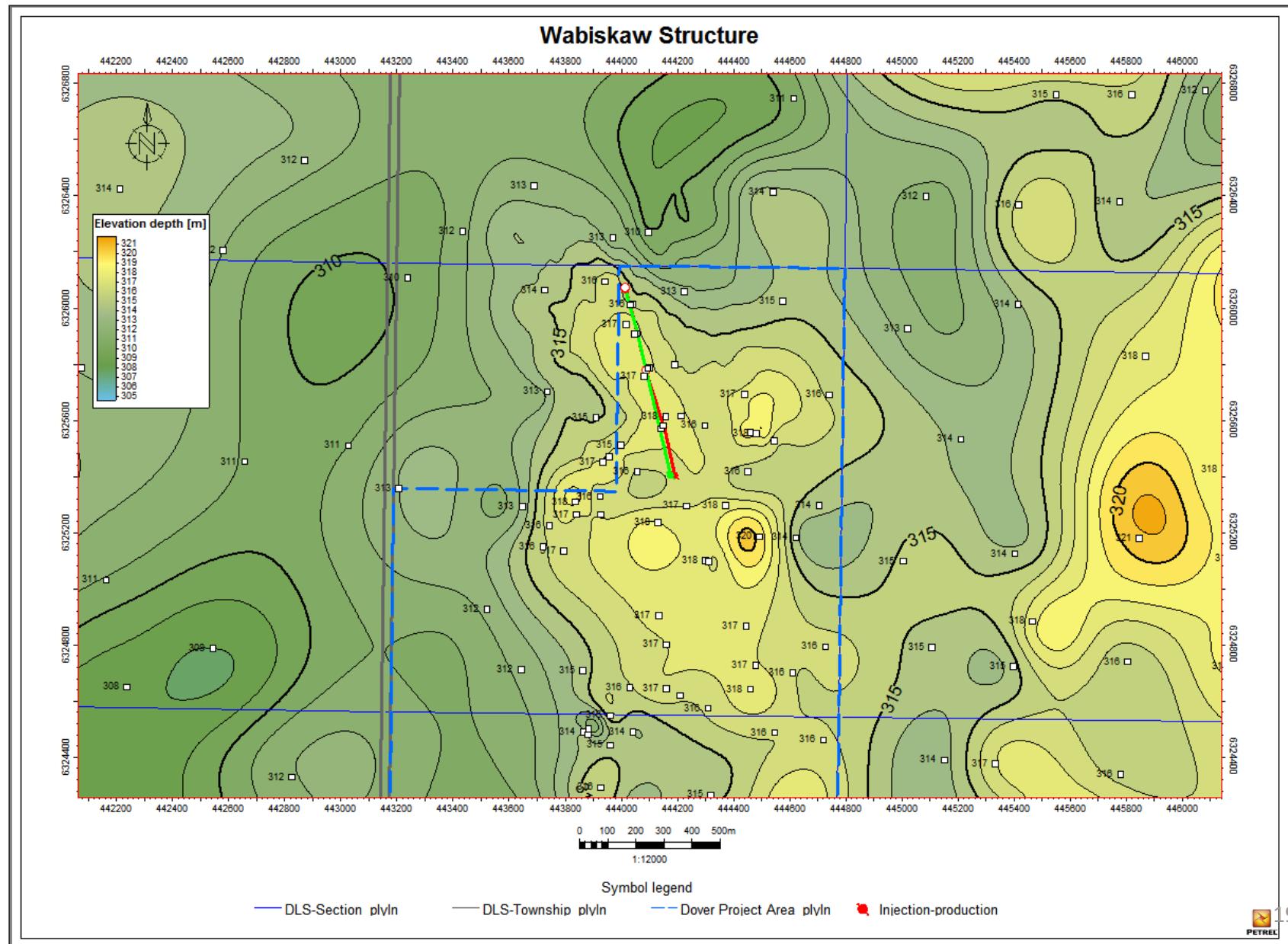
Geology – McMurray Structure



Geology – Wab C Sand Structure

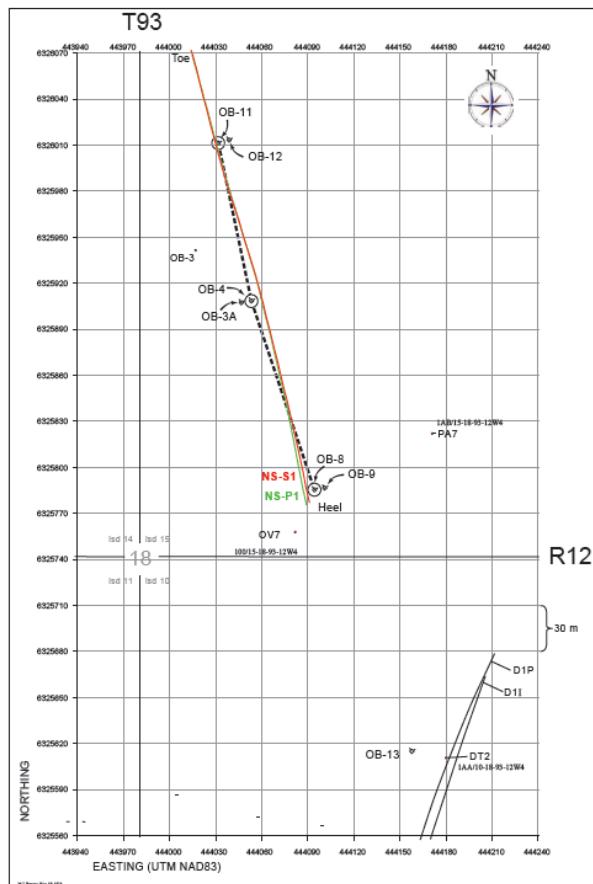


Geology – Wabiskaw Structure

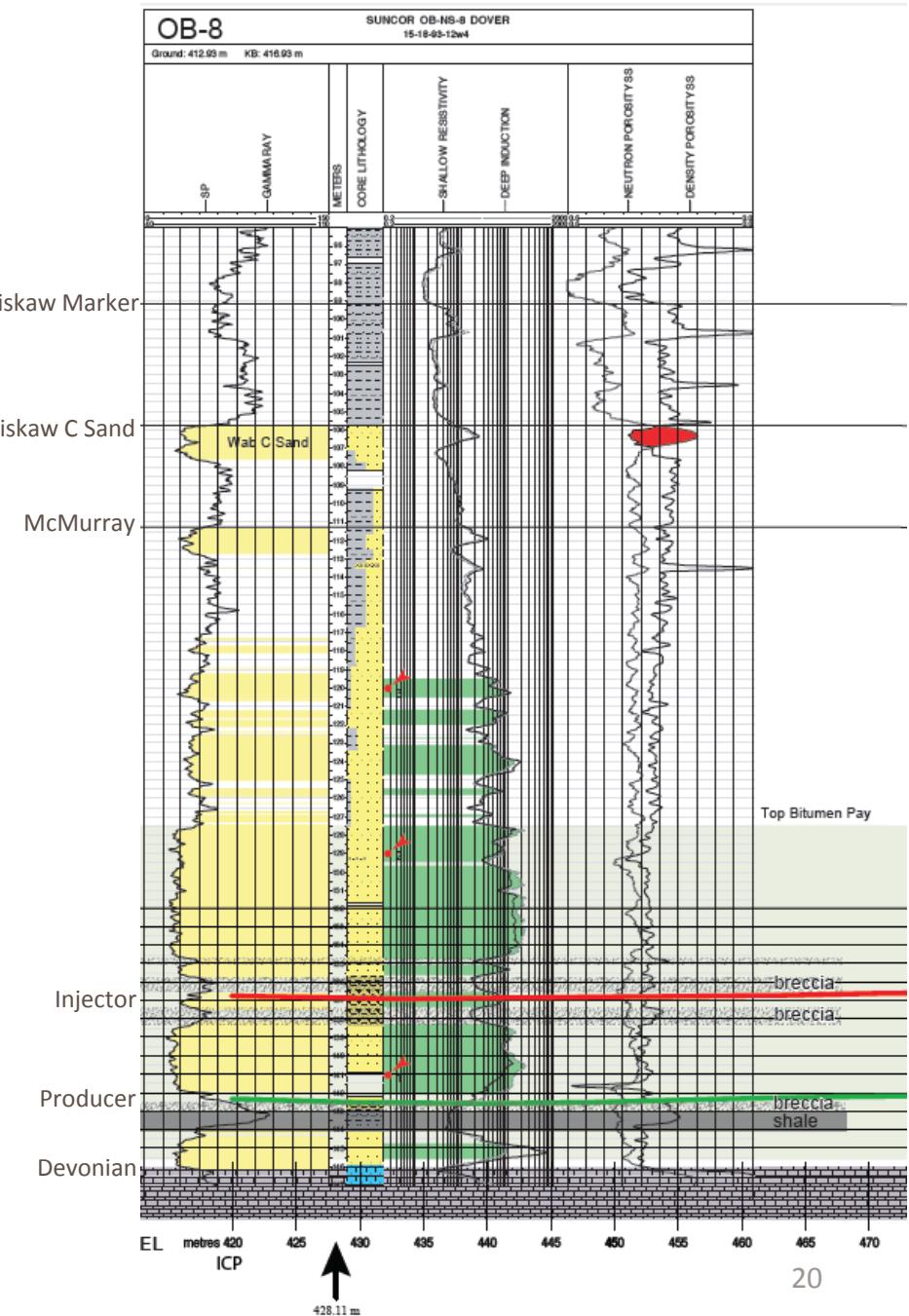


Geology – Logs

OB-08
Offset 6.7m

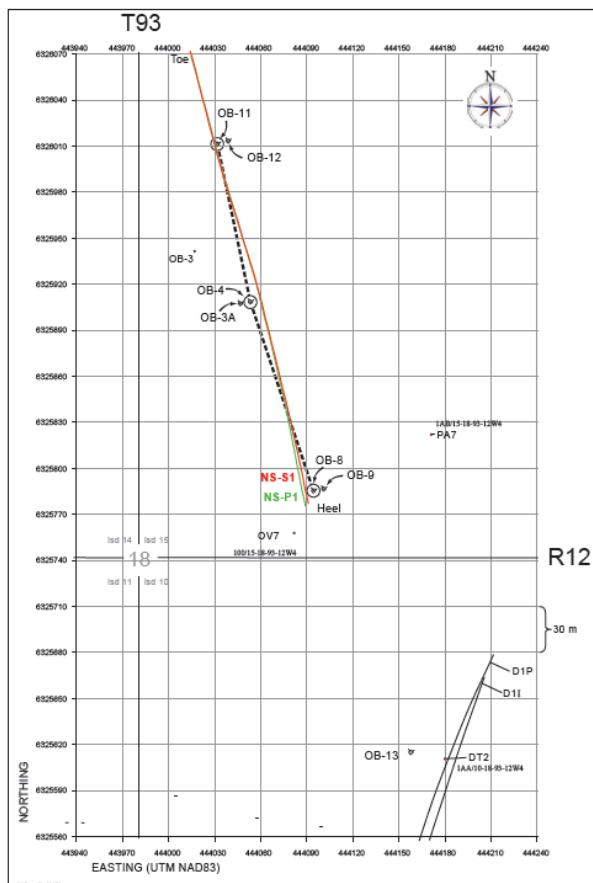


110/15-18-093-12W4

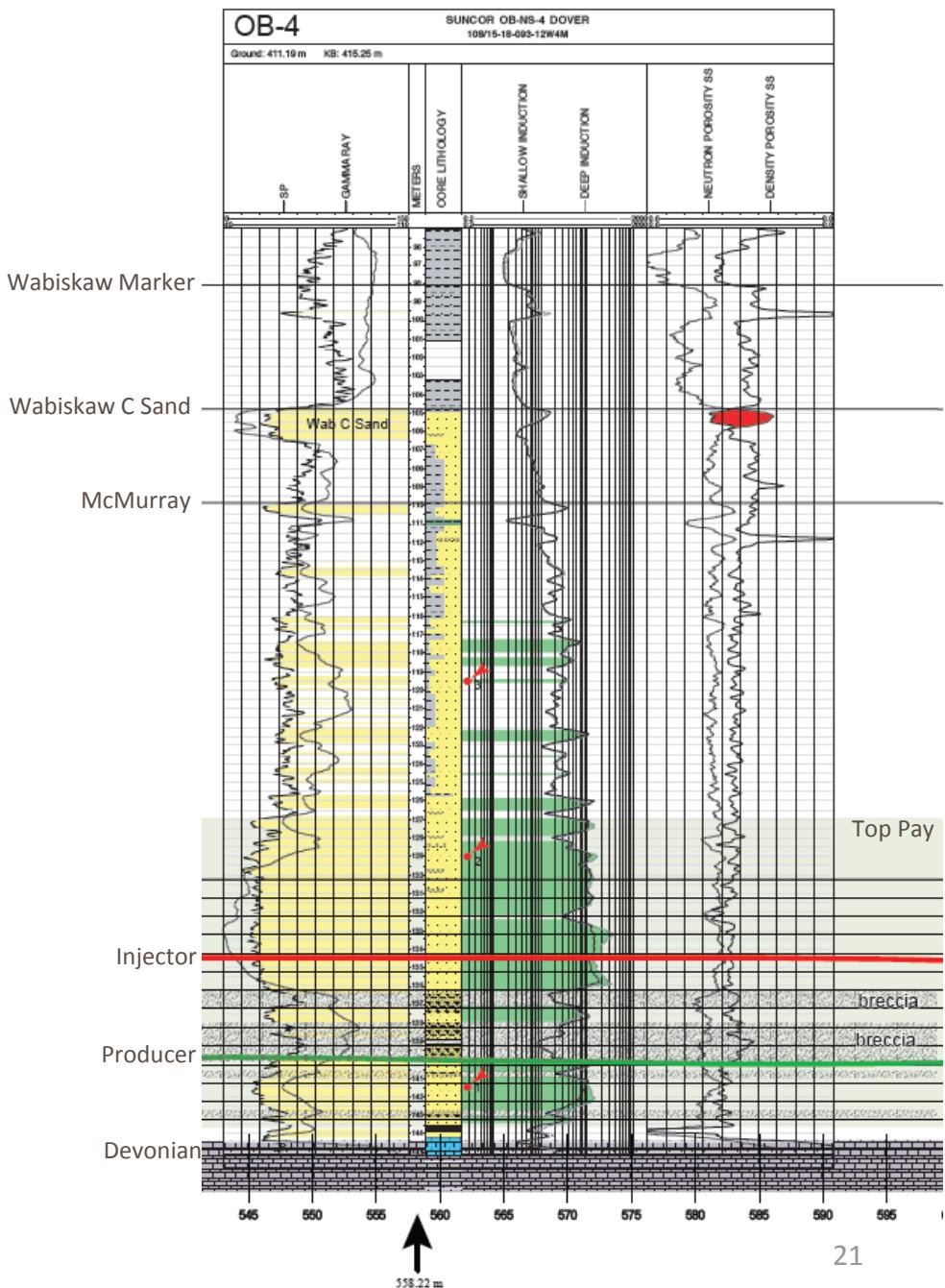


Geology – Logs

OB-04
Offset 3.6m

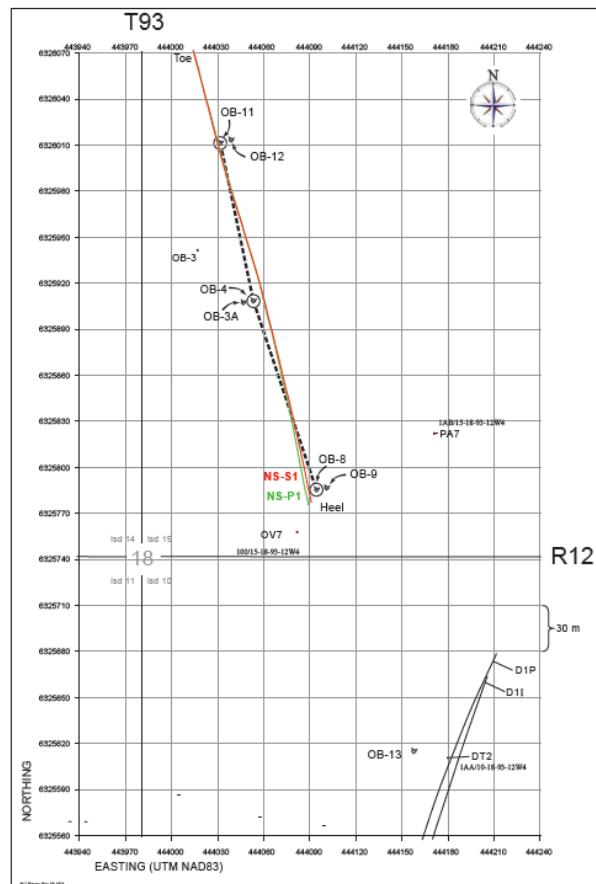


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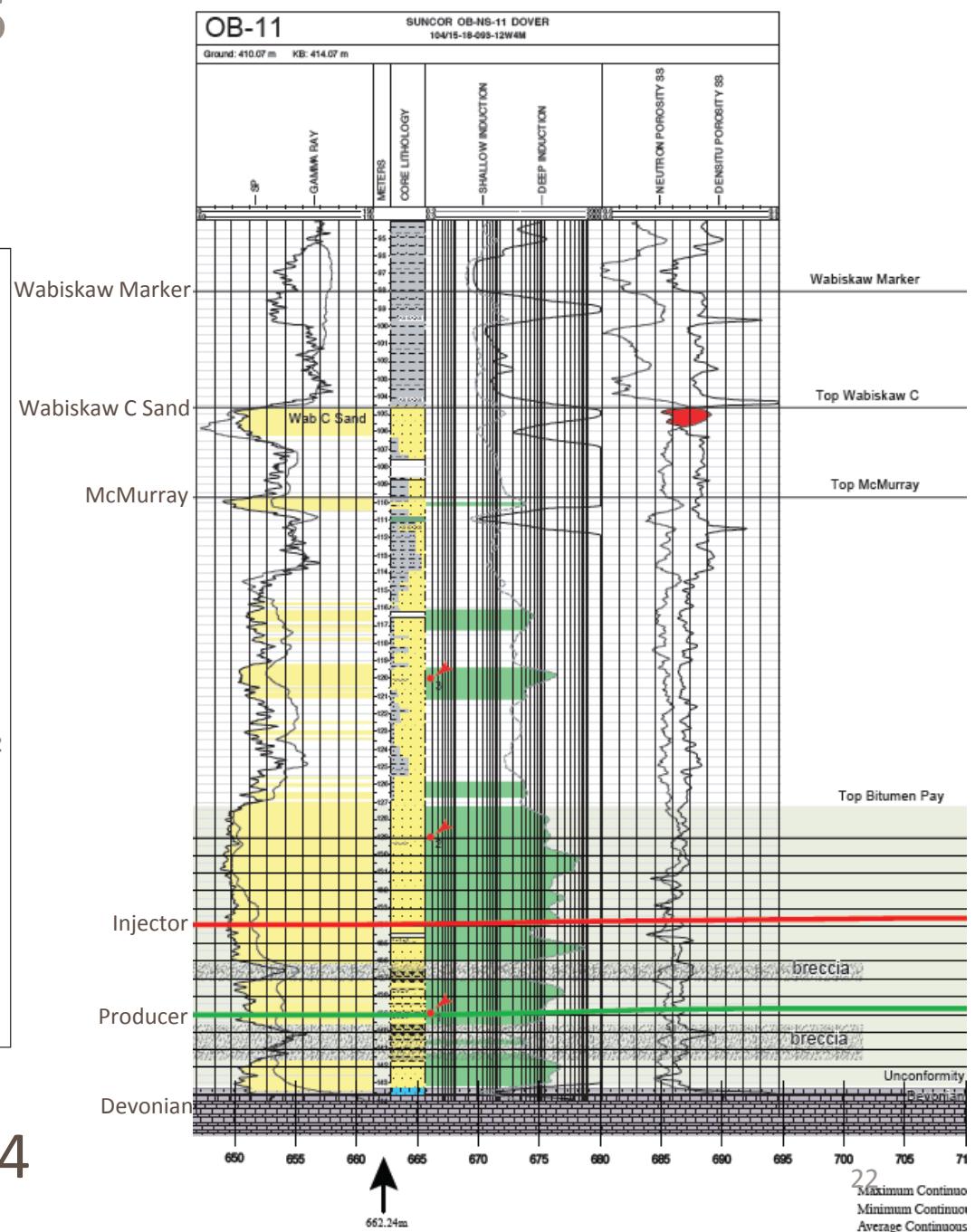


Geology – Logs

OB-11
Offset 4.3m



104/15-18-093-12W4

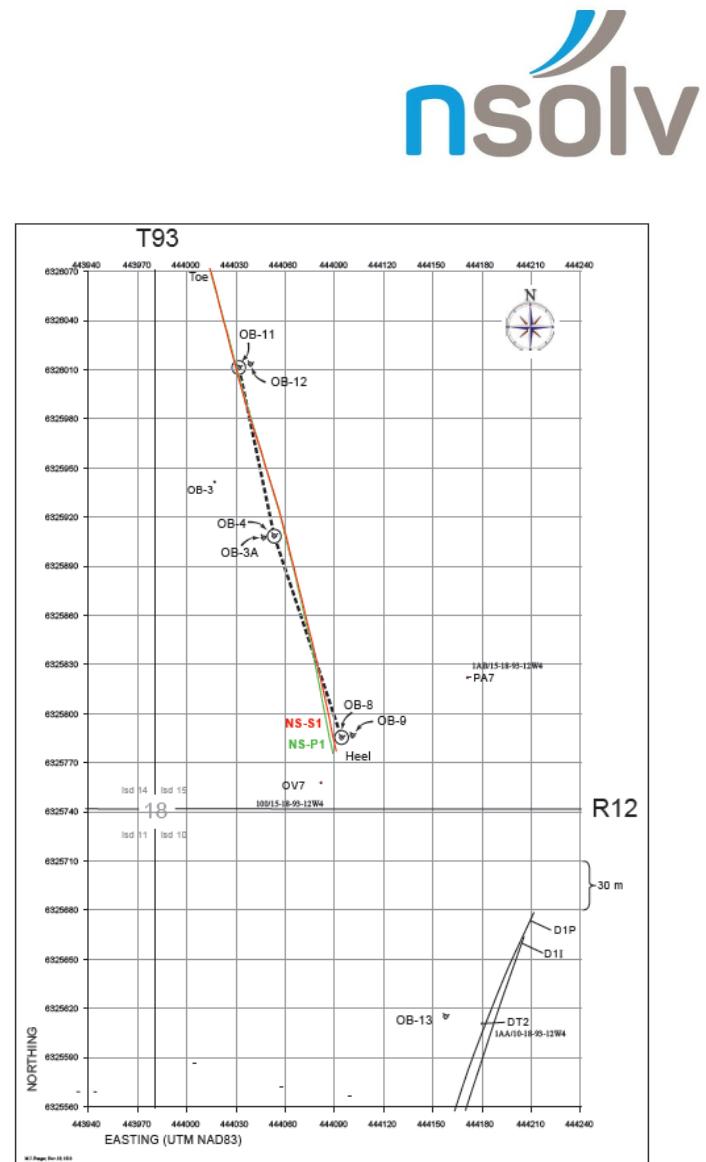


Geology

Cored Wells:

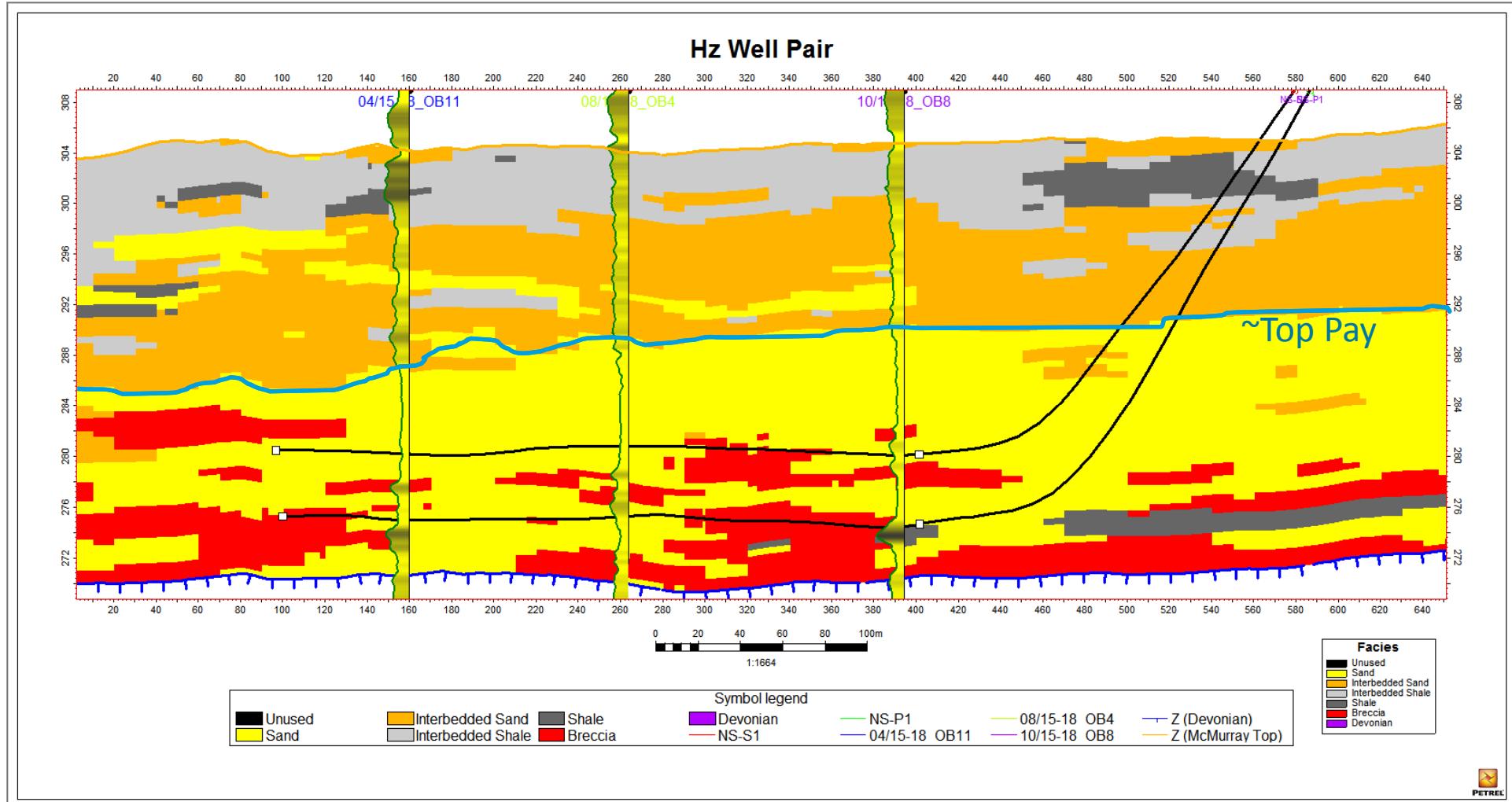
- OB 13
- OB 08
- OB 04
- OB 11

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

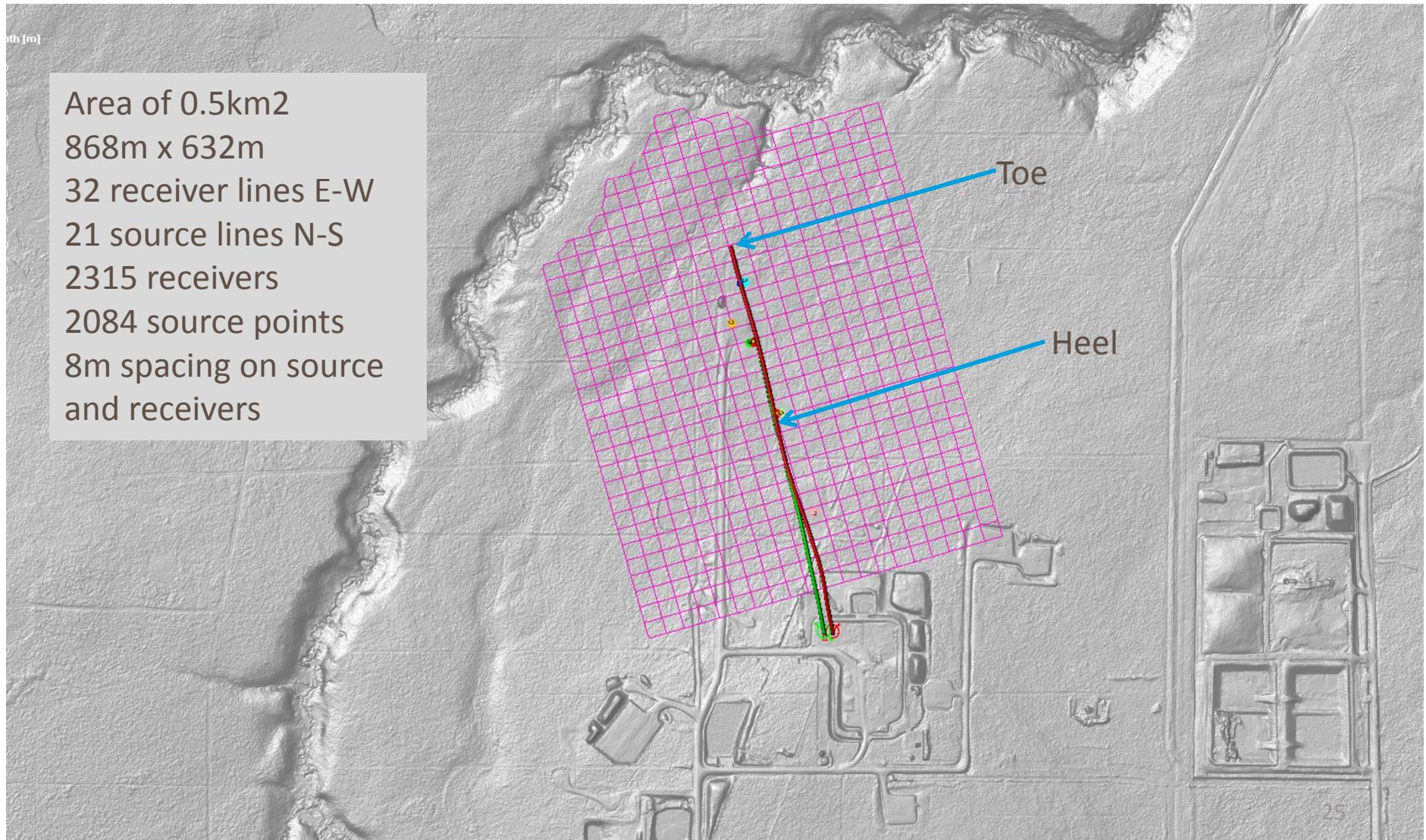




Hz Well Cross Section



Multicomponent 3D Seismic Acquired March 15th, 2015





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.

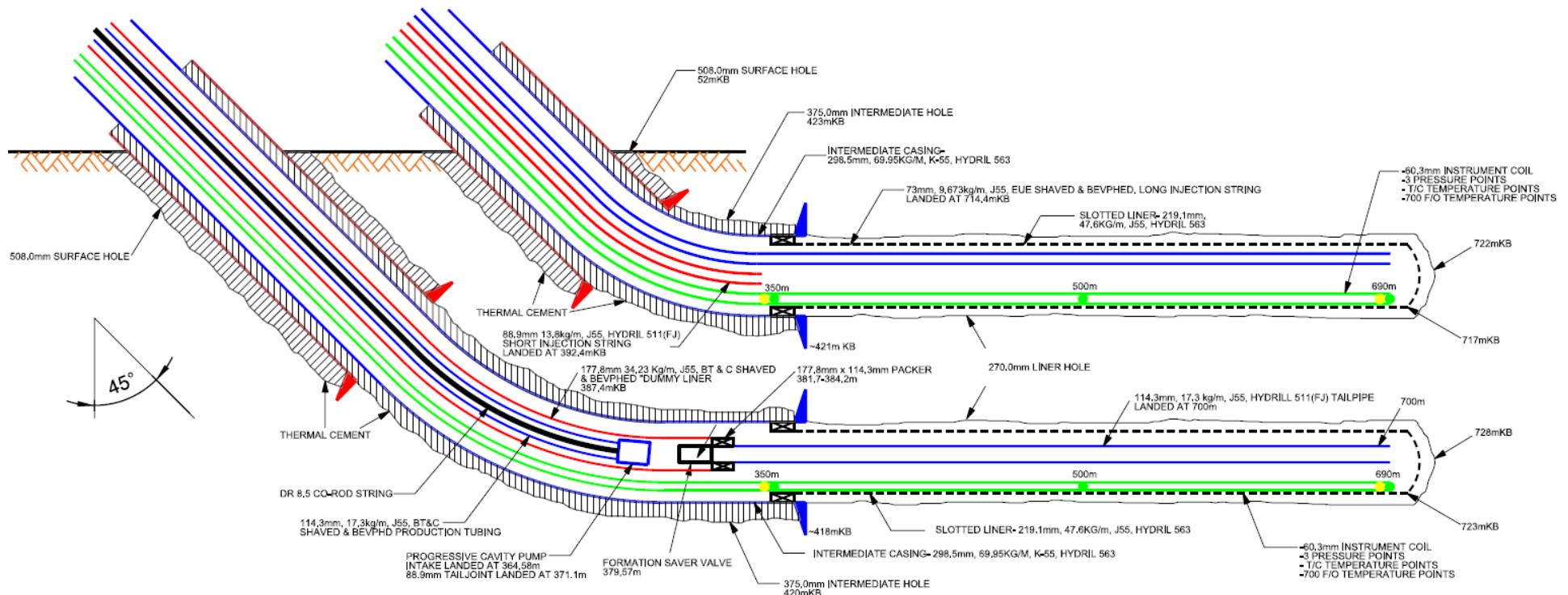
*From Suncor MacKay River mini frac analysis



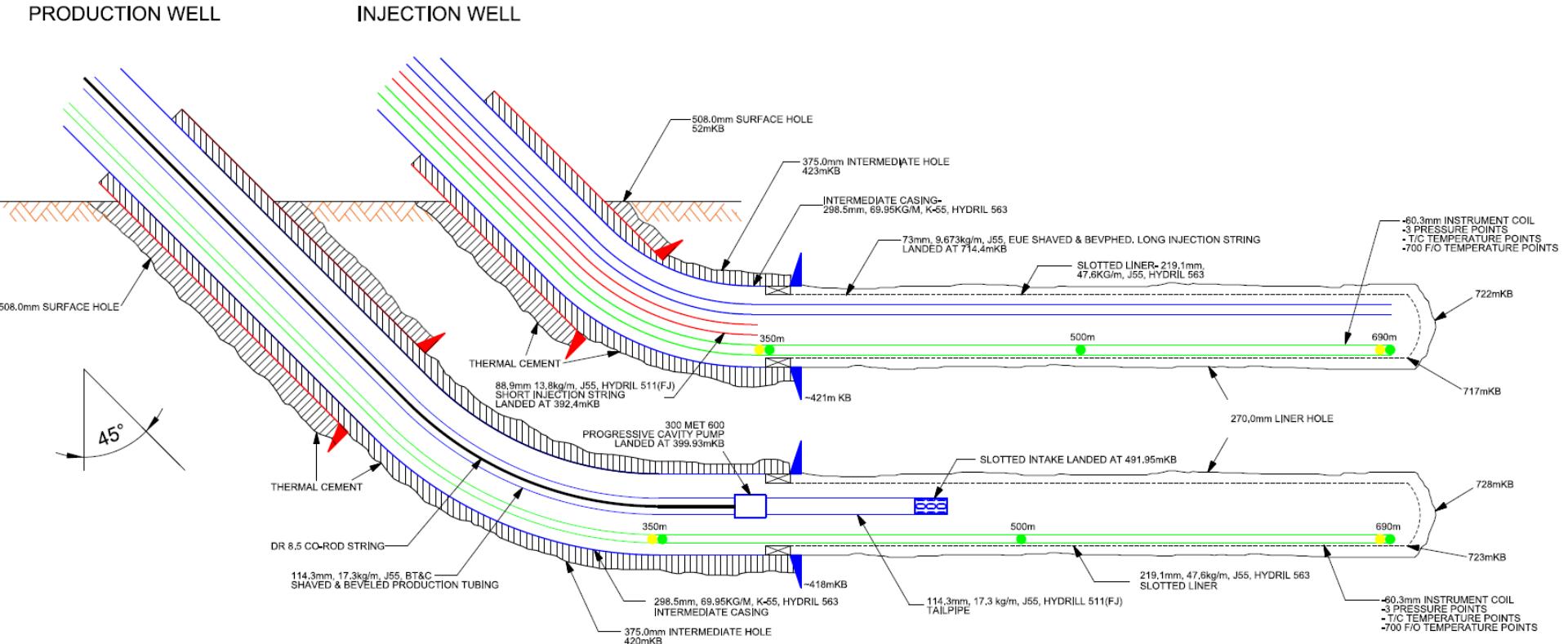
Completions – MTM PCP

PRODUCTION WELL

INJECTION WELL



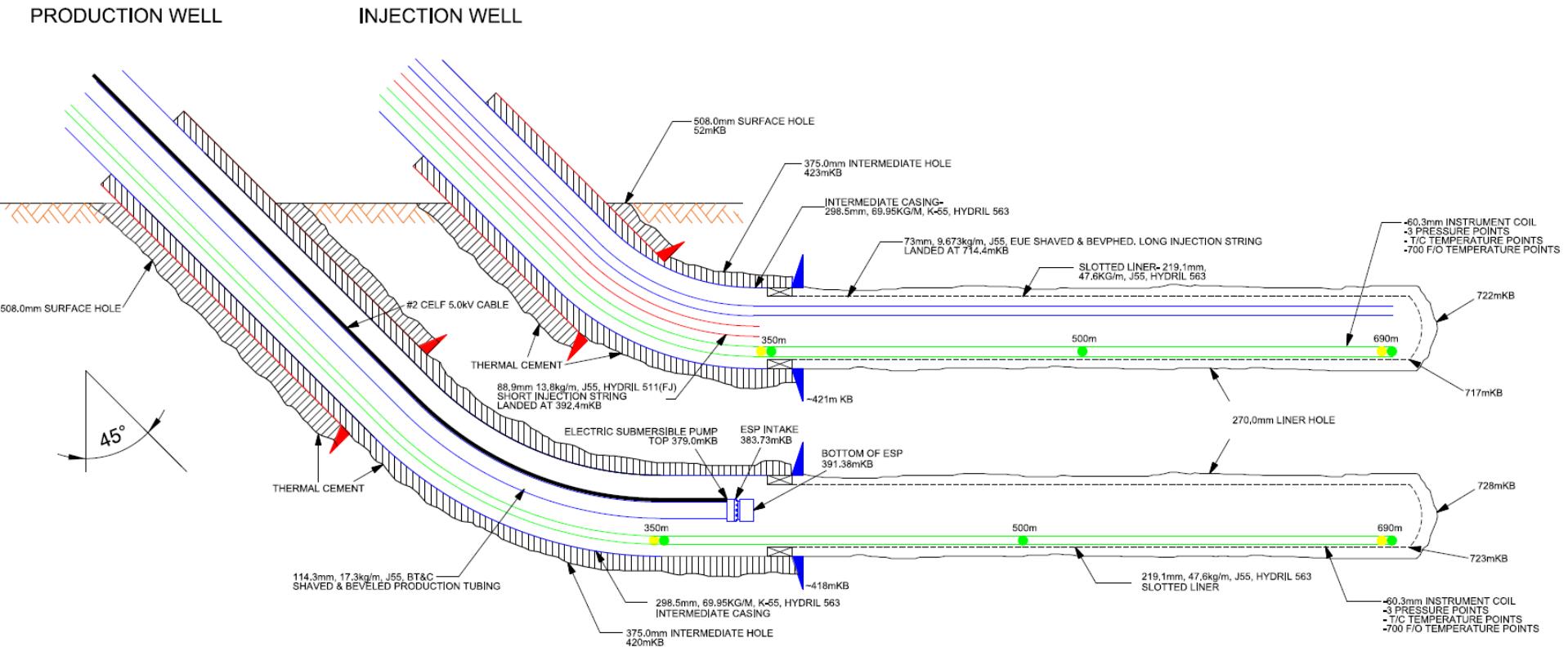
Completions – MTM PCP (2)

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 – end of reporting period), increasing lift capacity.
 - Capacity: 400 m³/ day



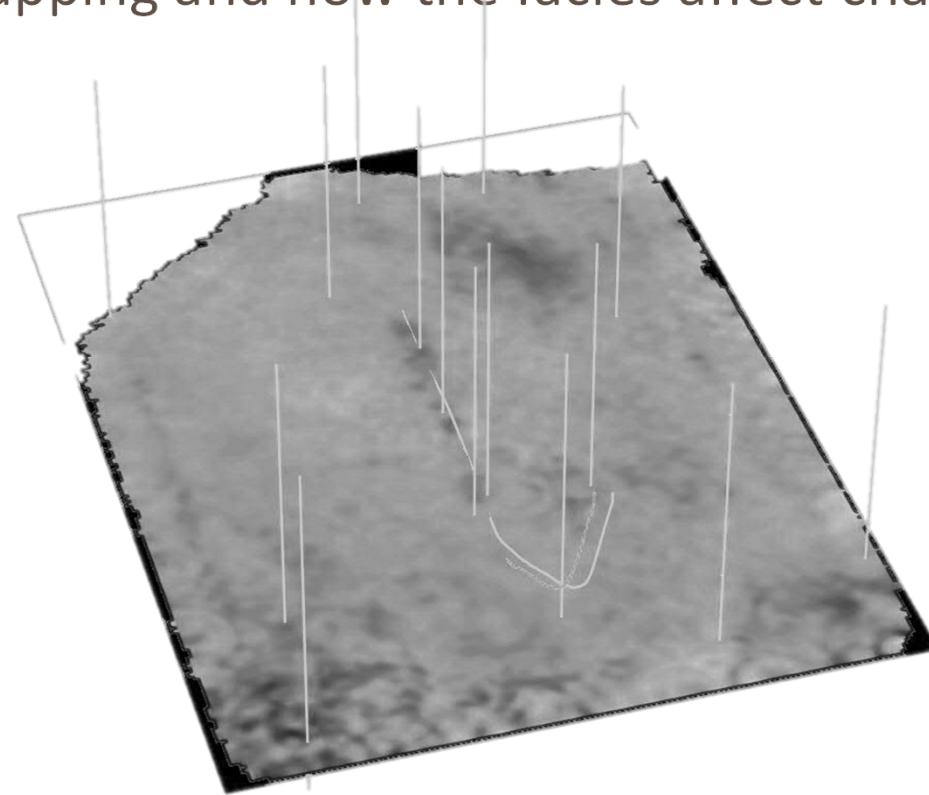
Instrumentation

- 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



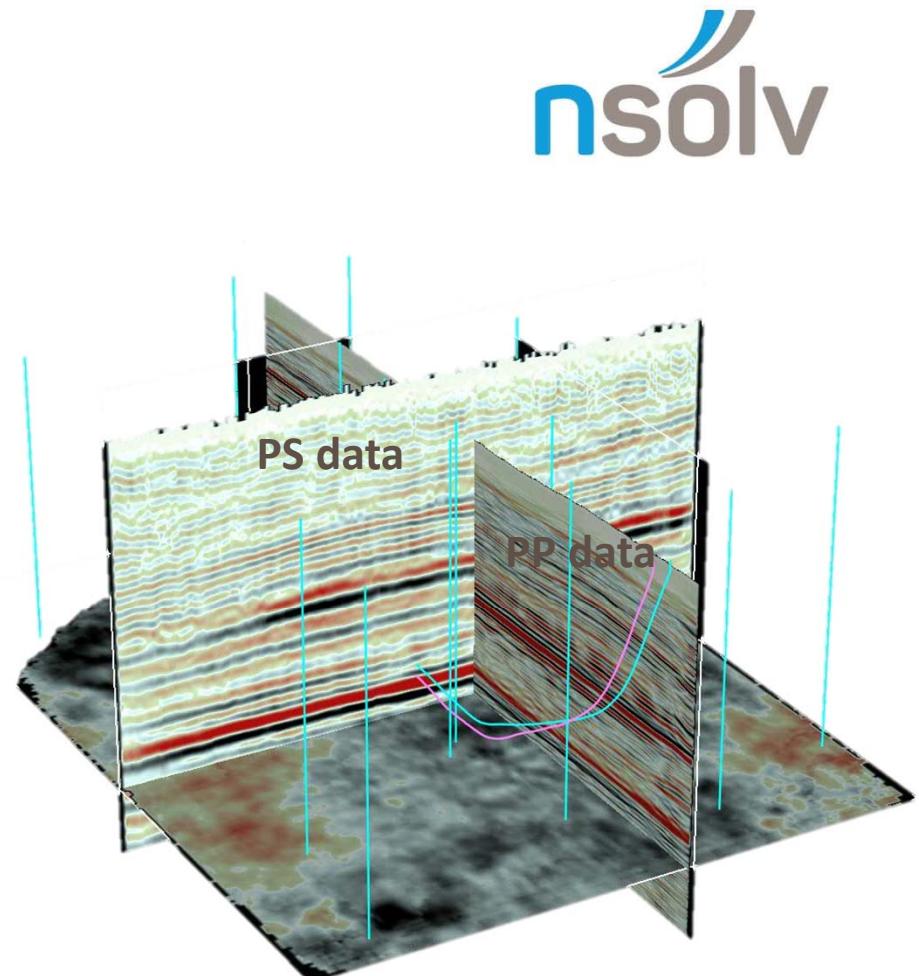
Seismic Objectives

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



Data

- AVO compliant pre-stack time migrated multi-component seismic data (MacKay 3D, March 15th 2015)
 - PP (Compression)
 - PS (Compression & Shear)
- 7 observation wells with thermocouples, 3 of them with RST (Reservoir Saturation Tool) logs.
- Temperature falloff data for injector and producer wells (recorded on March 30th 2015, two weeks post seismic).
- 29 vertical wells, 15 with 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.

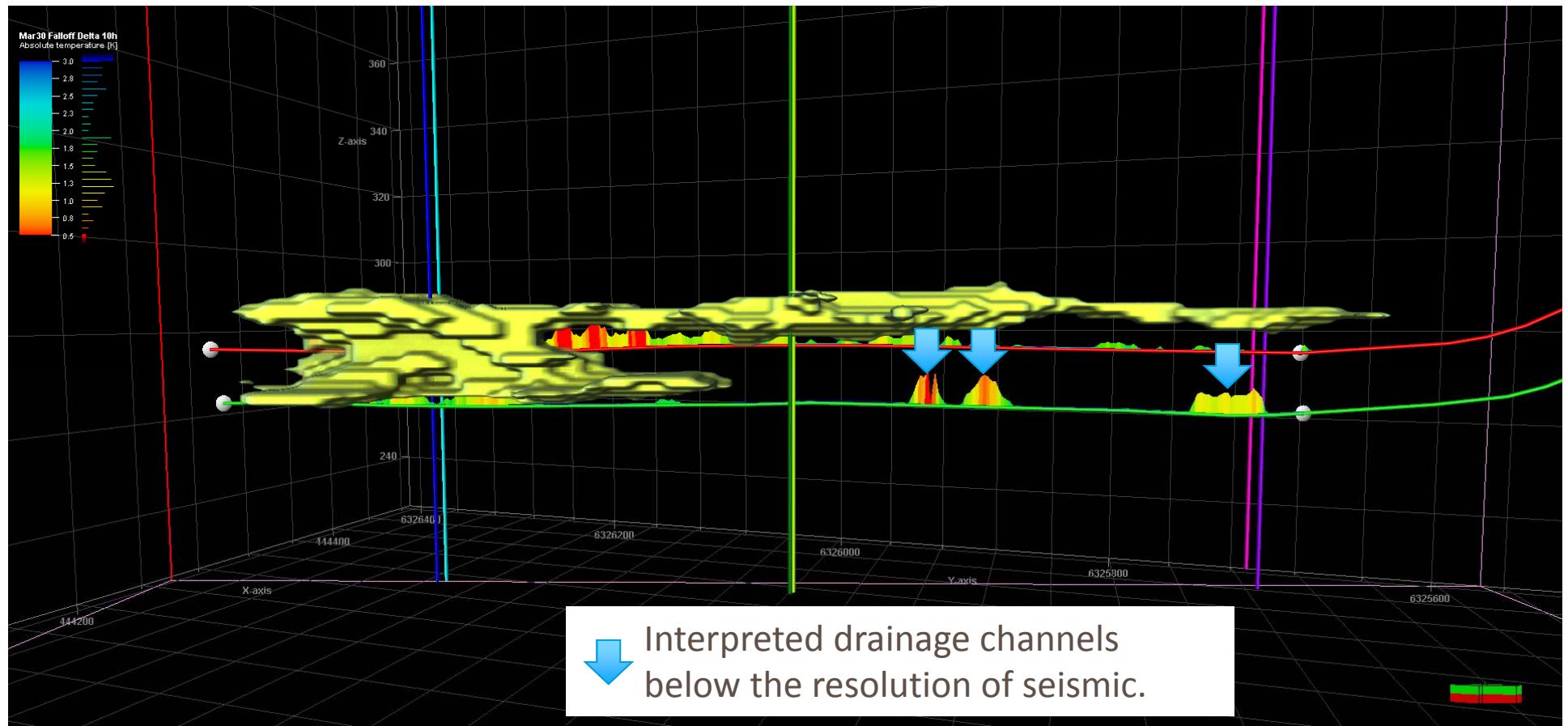




3D Seismic Results

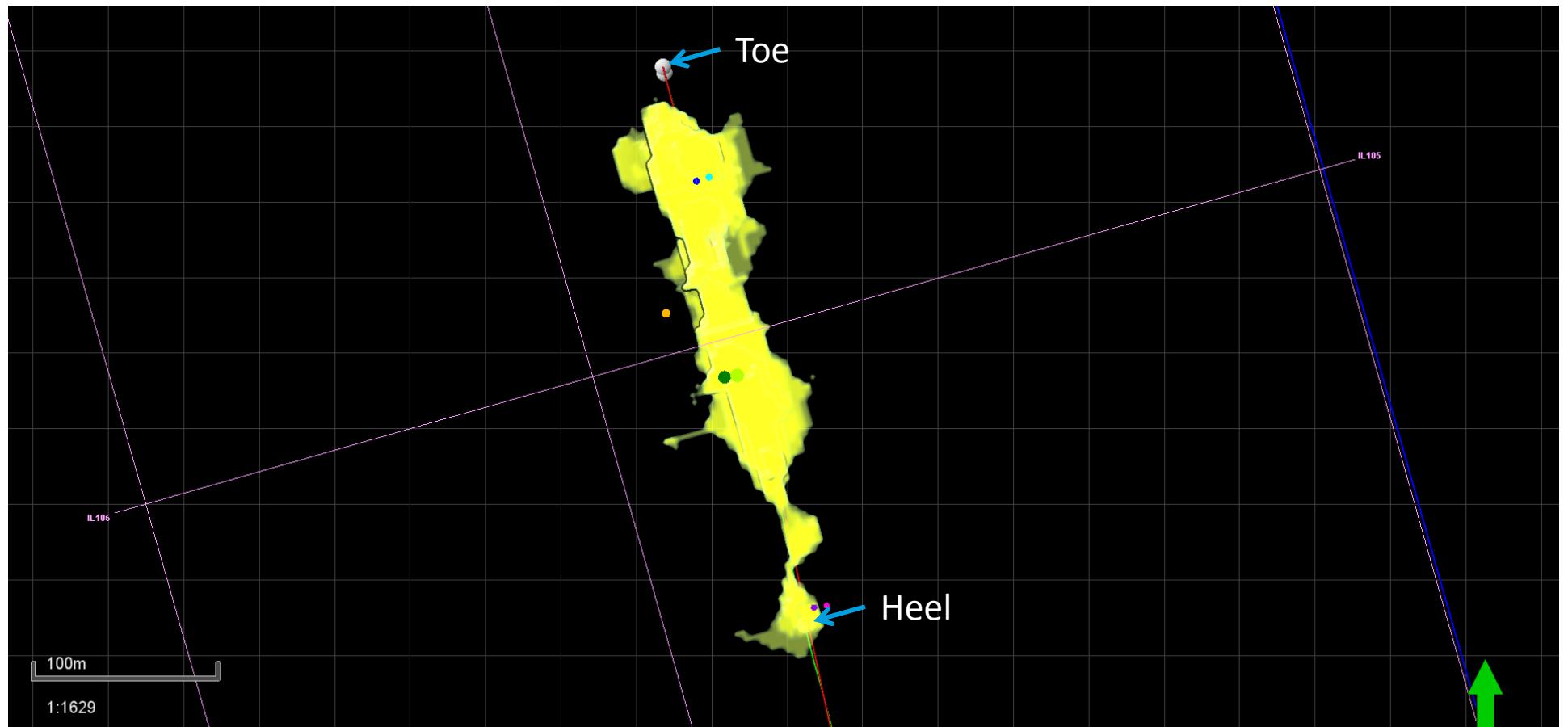
Acquired March 15th, 2015

4D not acquired yet



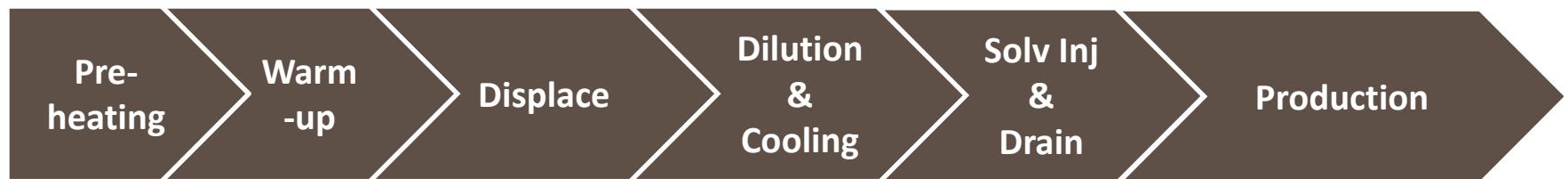
View of the solvent chamber looking east. Temperature falloff data along the hz wells shows good correlation with seismic interpretation.

Plan View of Chamber



Plan view of the solvent chamber showing variability in chamber lateral growth.

Scheme Performance – Timeline



2013							2014							2015				
Mar	Apr	May	...	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	...	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

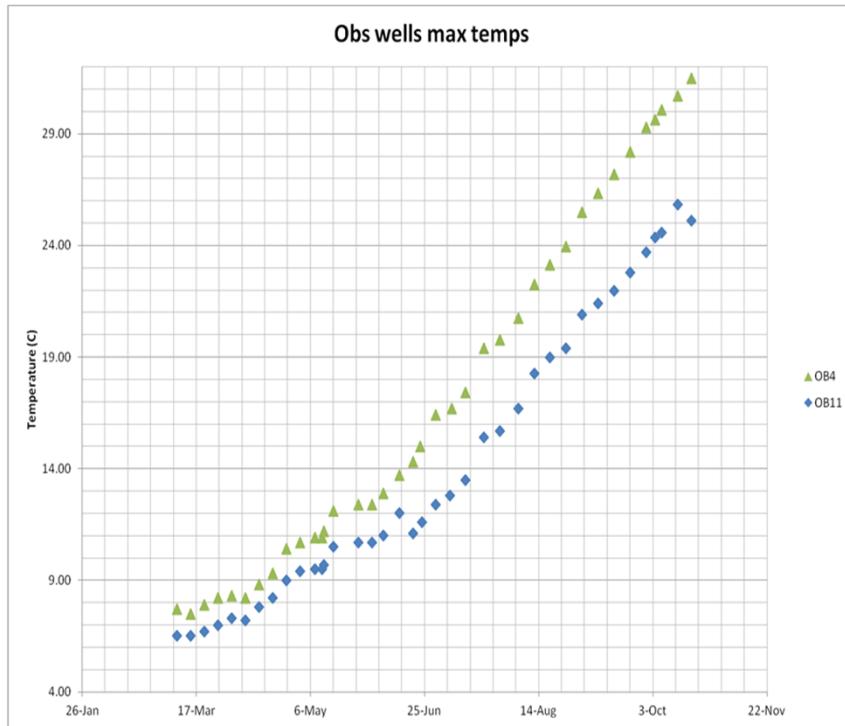


- Displacement:
 - Induce inter-well fluid communication with increasing differential pressure between the wells
 - Targeting minimum 50% conformance
- Dilution & Cool-down:
 - Reduction of sub-surface temperatures for solvent injection (allow for condensing action to occur)
 - Reduction of startup fluids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

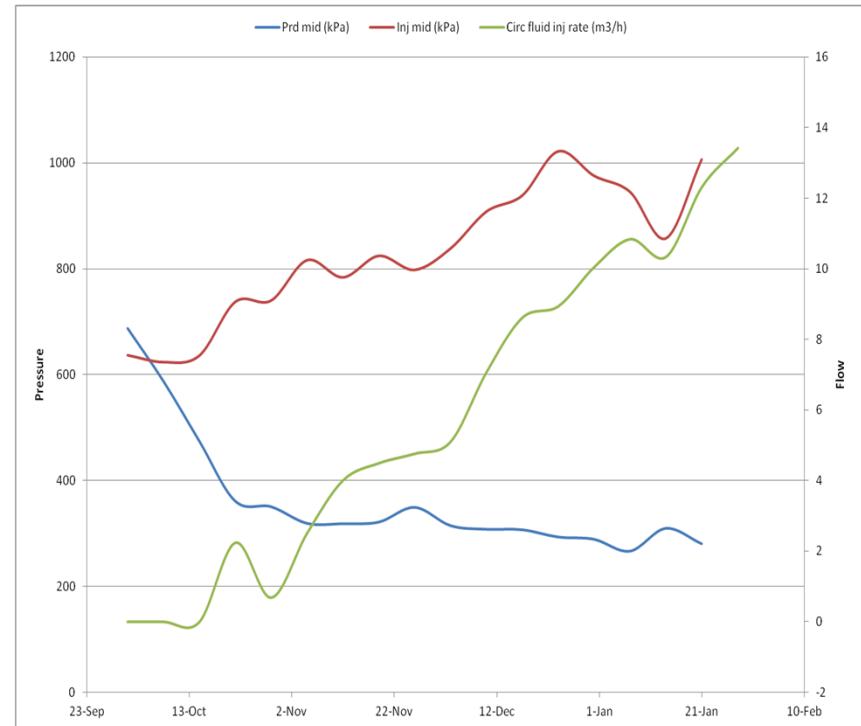
Scheme Performance – Startup Phases



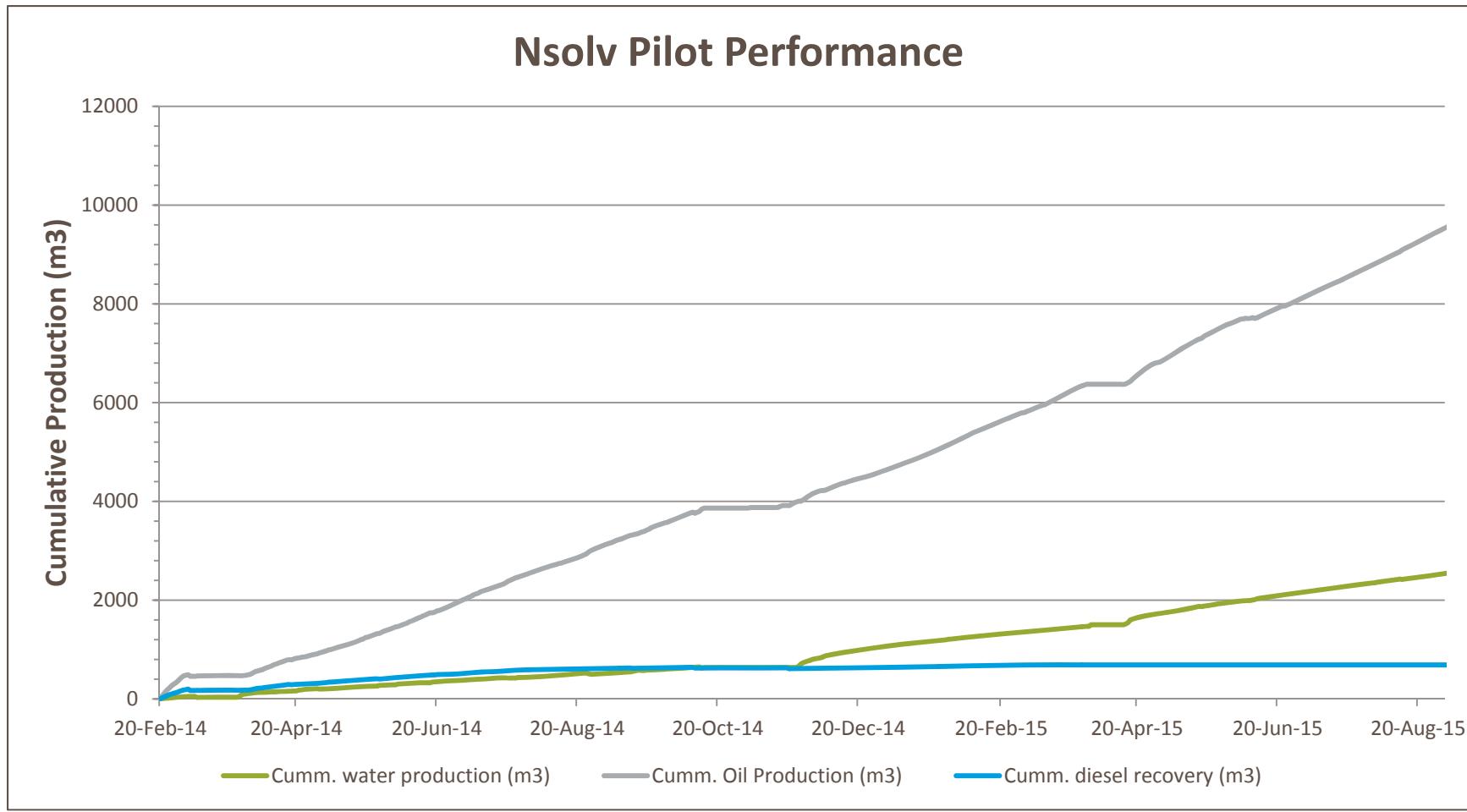
Warmup



Displacement

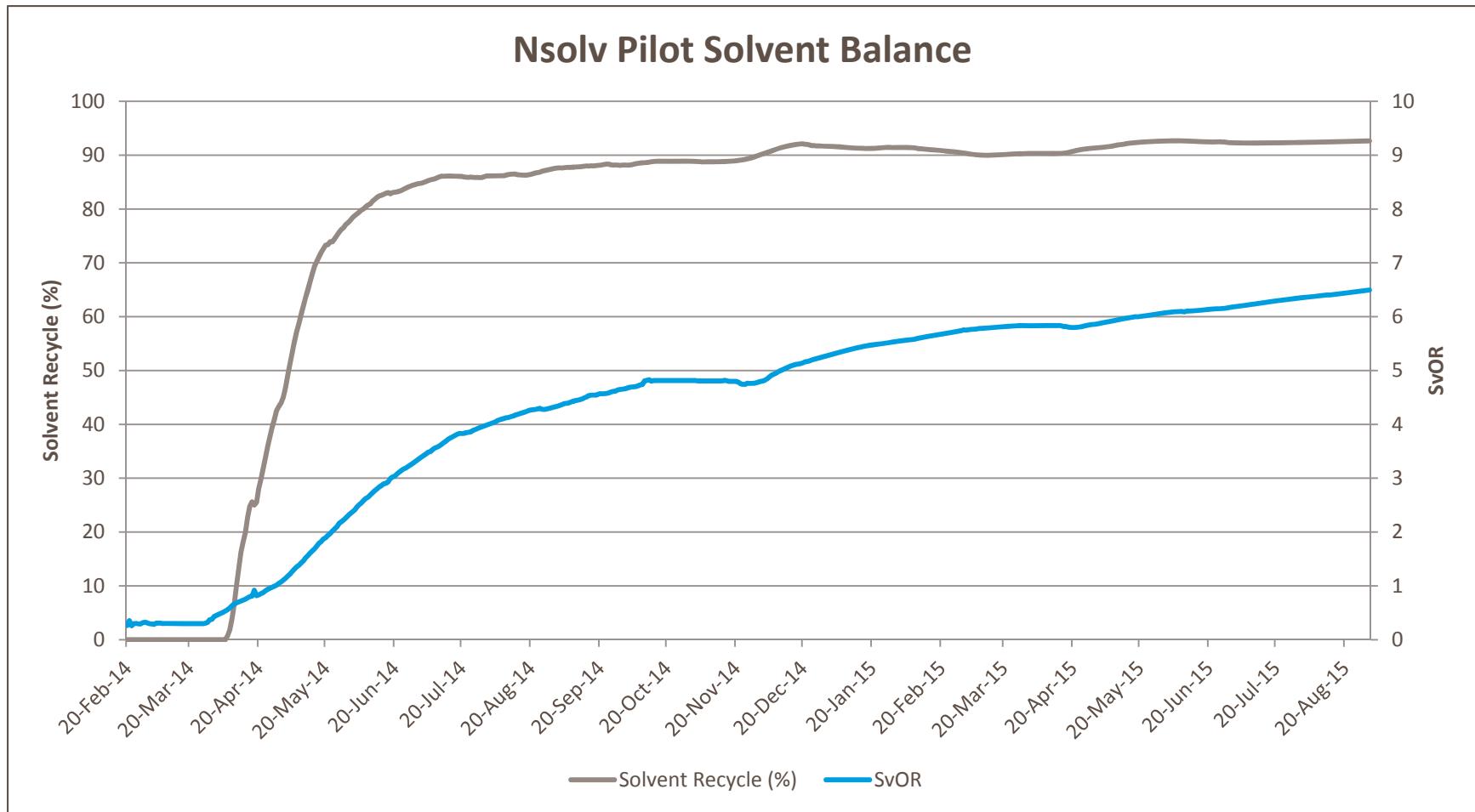


Scheme Performance – Cumulative Fluid Volumes



- 100% diesel recovery achieved in February 2015
- 19.9% recoverable bitumen recovered 11.3% of exploitable PIIP bitumen recovered (Refer to Slide 11 (Volumetrics) for calculation details)

Scheme Performance – Solvent Balance



Scheme Performance – Solvent Balance



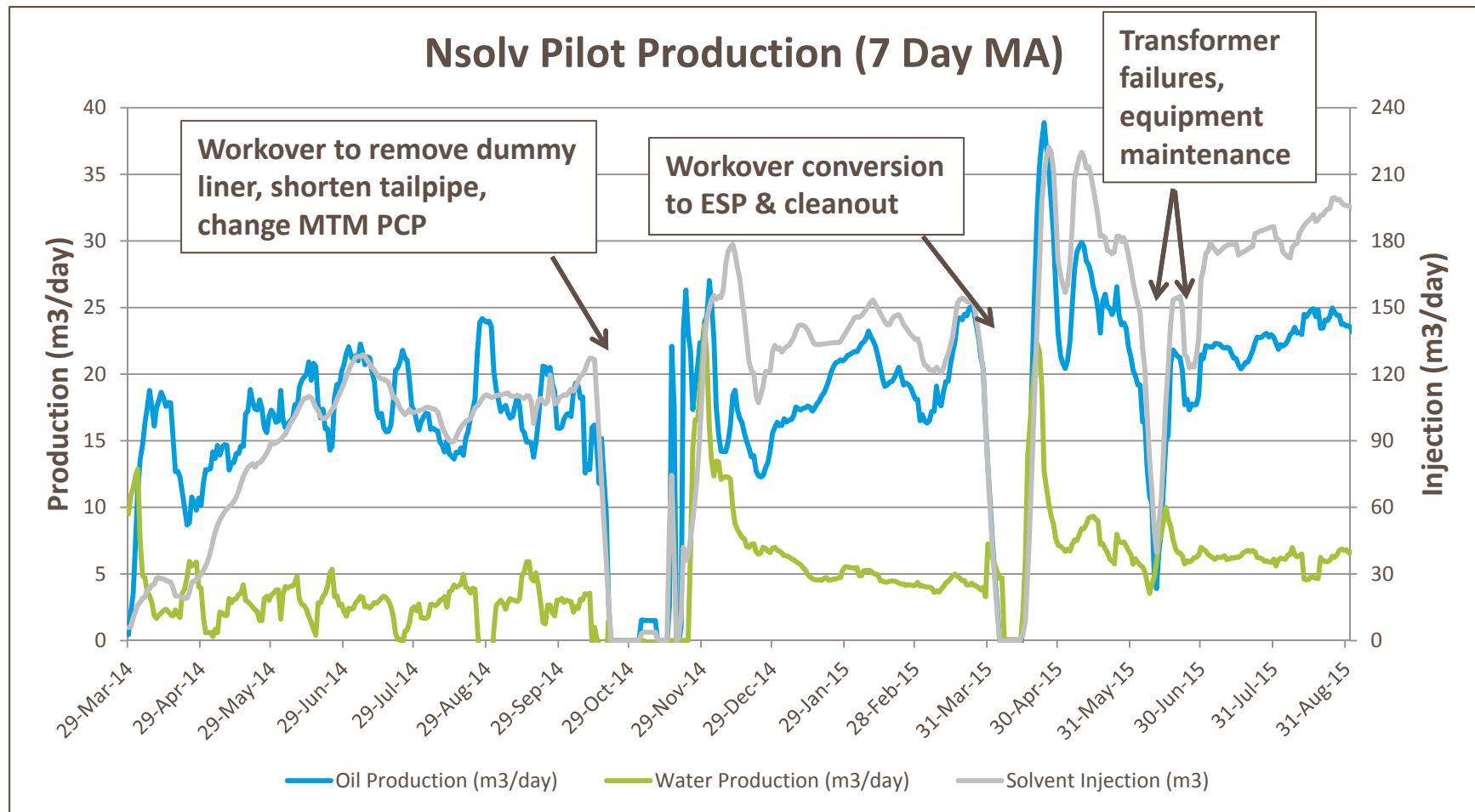
- Design SvOR of 5:1 or less
- Currently around 6.5:1 at the BEST pilot – there are several reasons why it is higher than originally anticipated:
 - Heat losses: 5:1 ratio was idealized and did not account for heat losses to the overburden and underburden
 - Conformance: Additional heat is currently 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

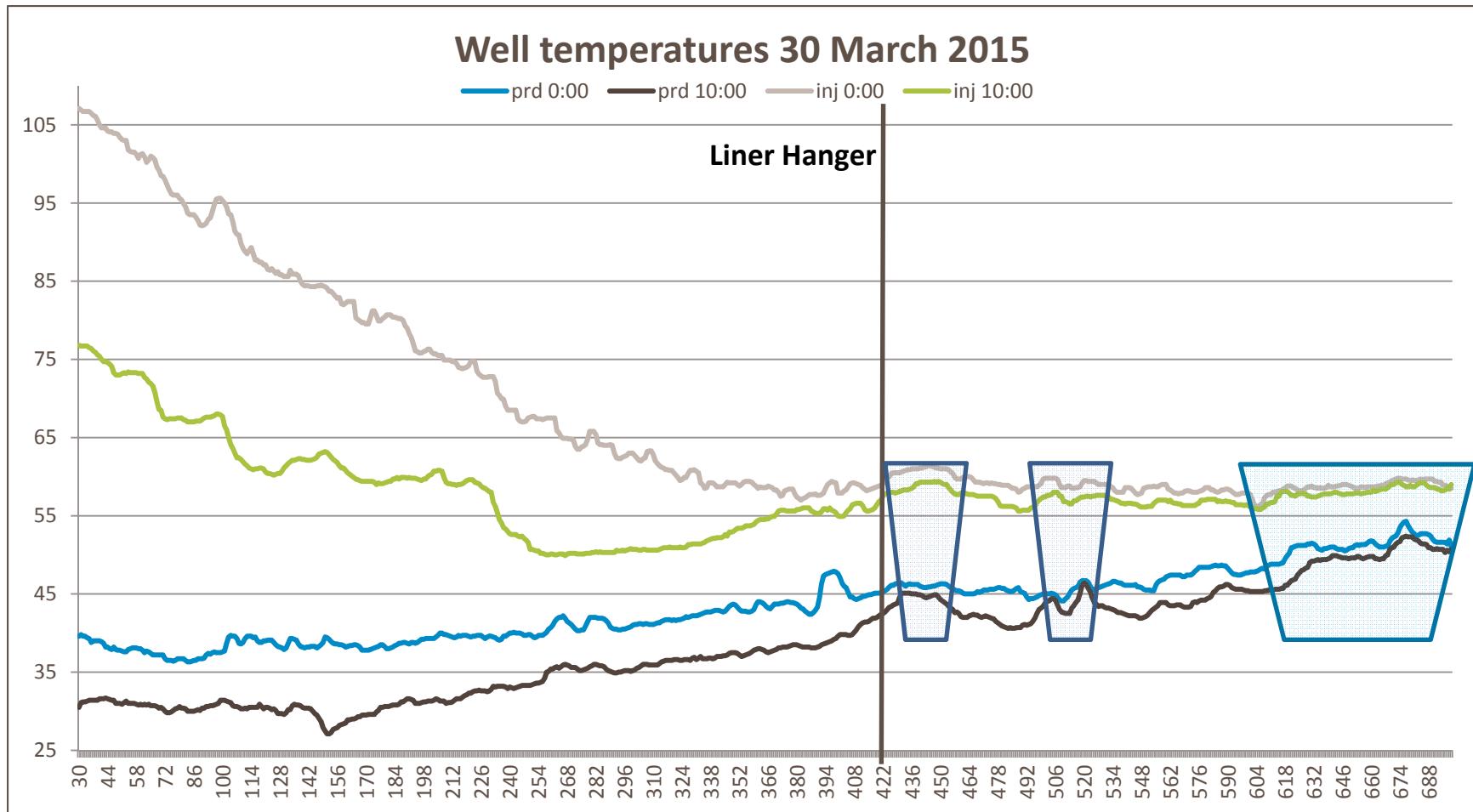


Scheme Performance – Fluid Rates



- Well pair conformance monitored by:
 - DTS data
 - temperature fall-off data
 - Seismic data
- Communication appears to be happening over ~200 m of the 300 m well

Scheme Performance – Well Pair Conformance

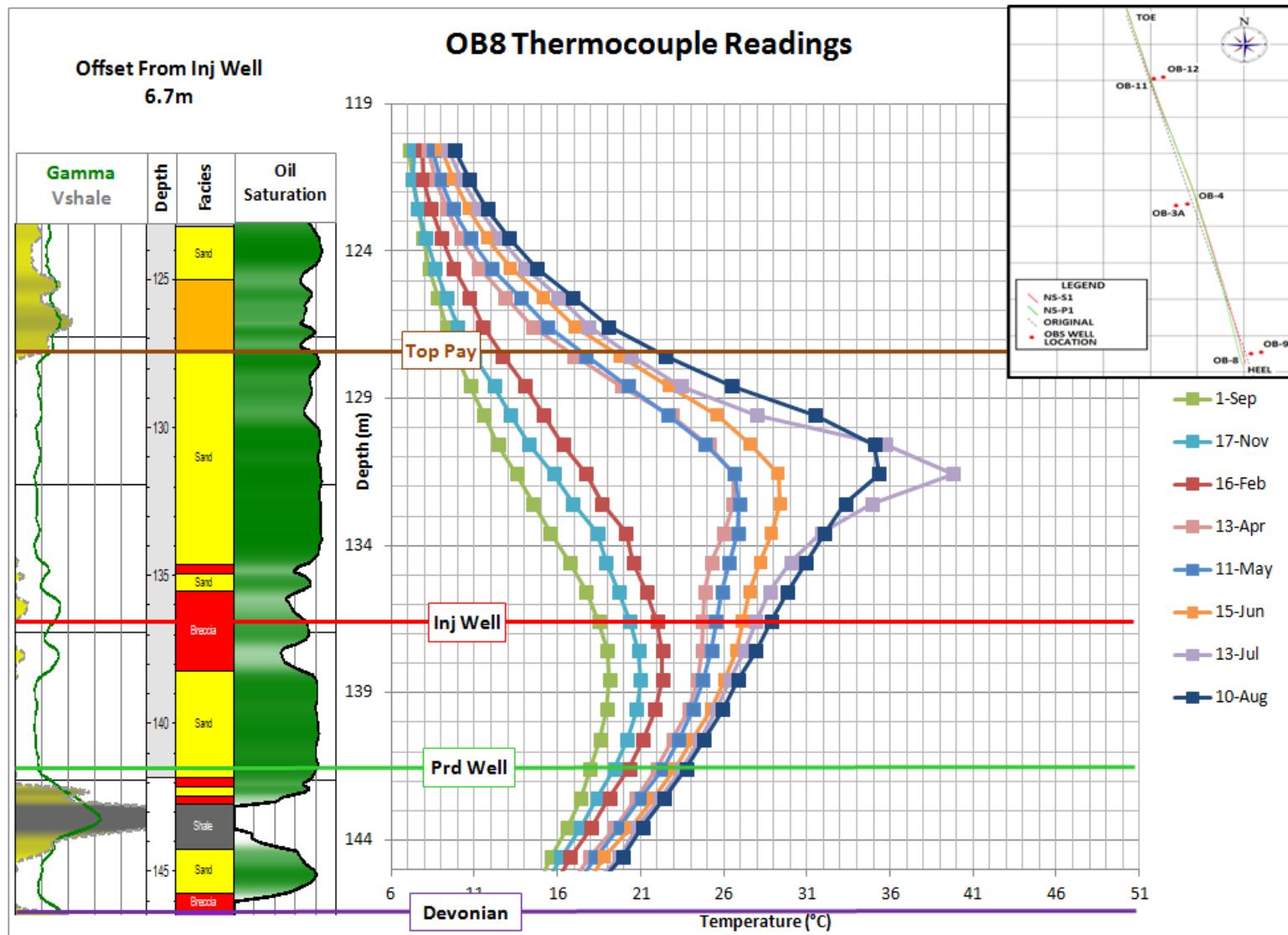


Scheme Performance – Chamber Growth

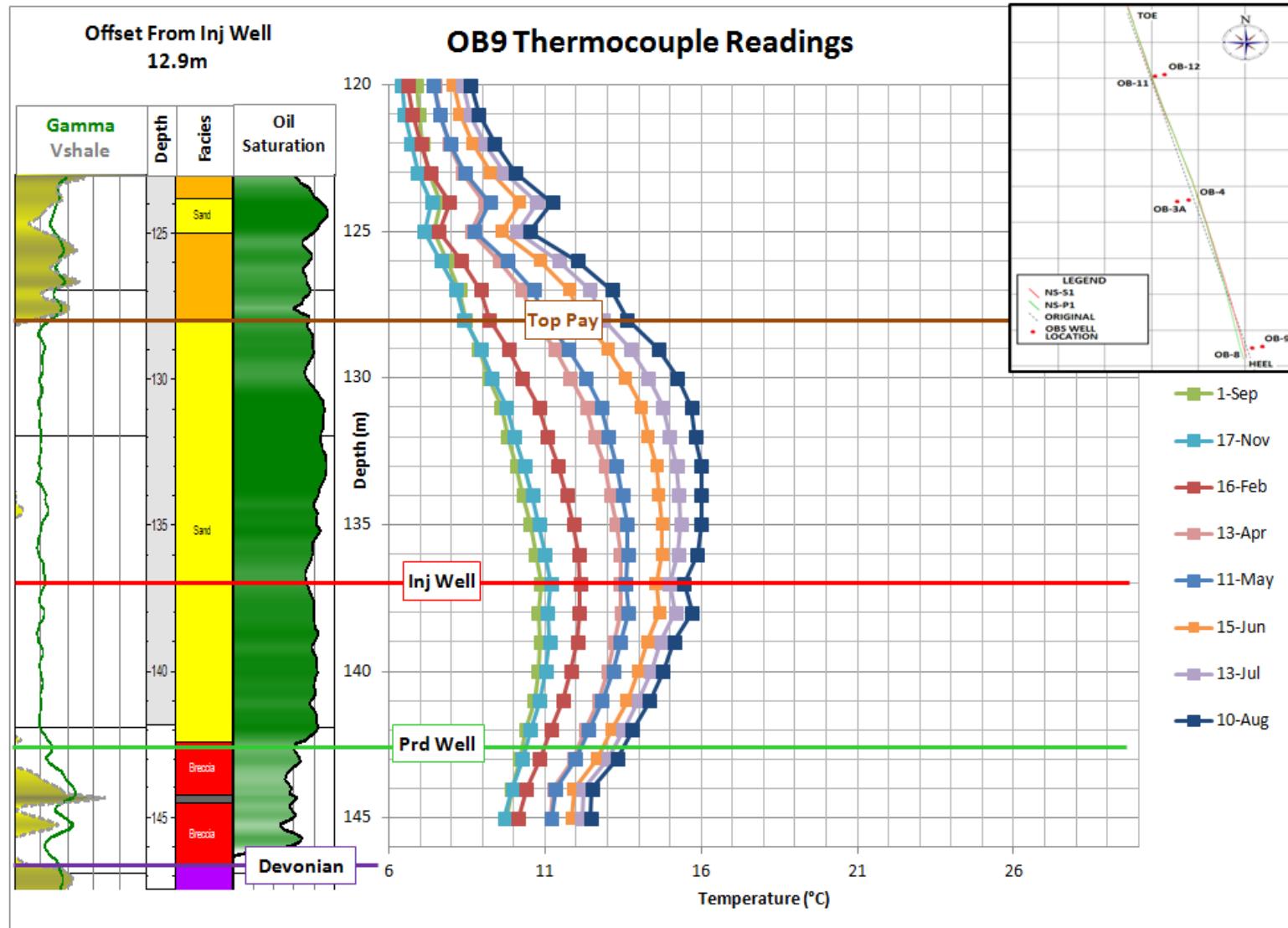


- Overall chamber growth monitored by temperature signal at observation wells
- Solvent chamber has intersected OB11 (4.3 m offset), OB4 (3.6 m offset), OB12 (11.4 m offset), OB8 (6.7 m offset) and is approaching OB3A (10 m offset)

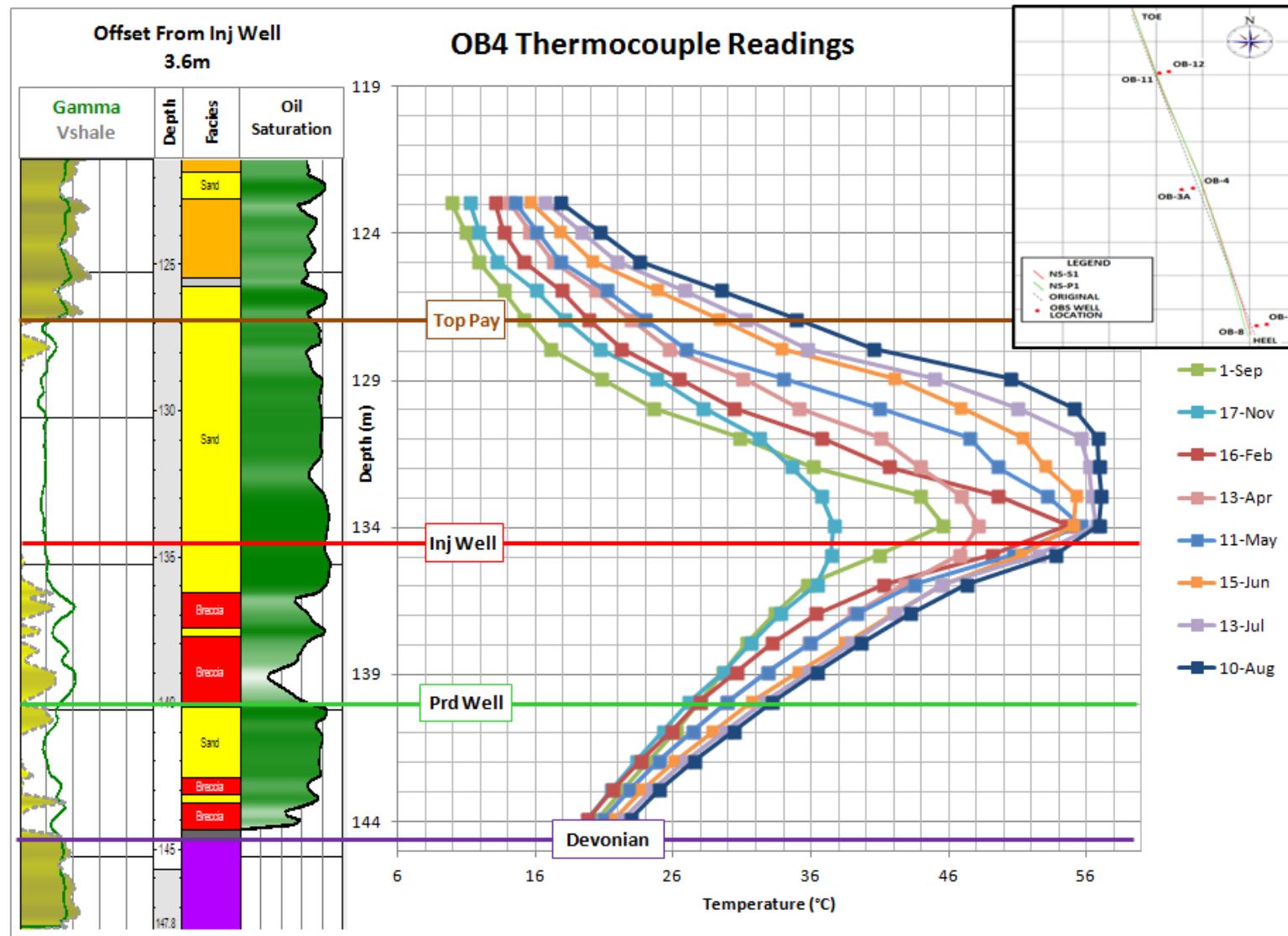
Scheme Performance – Chamber Growth



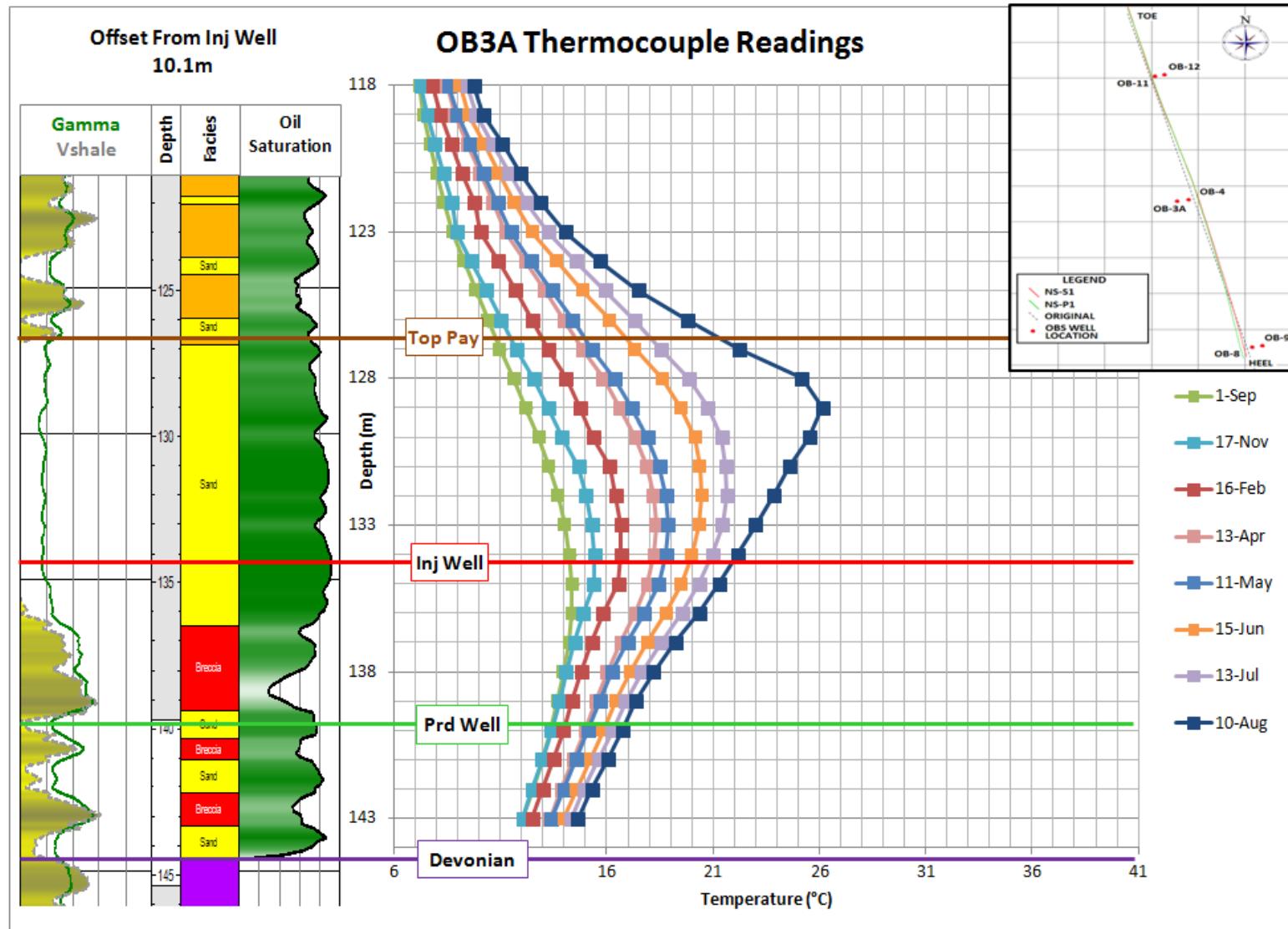
Scheme Performance – Chamber Growth



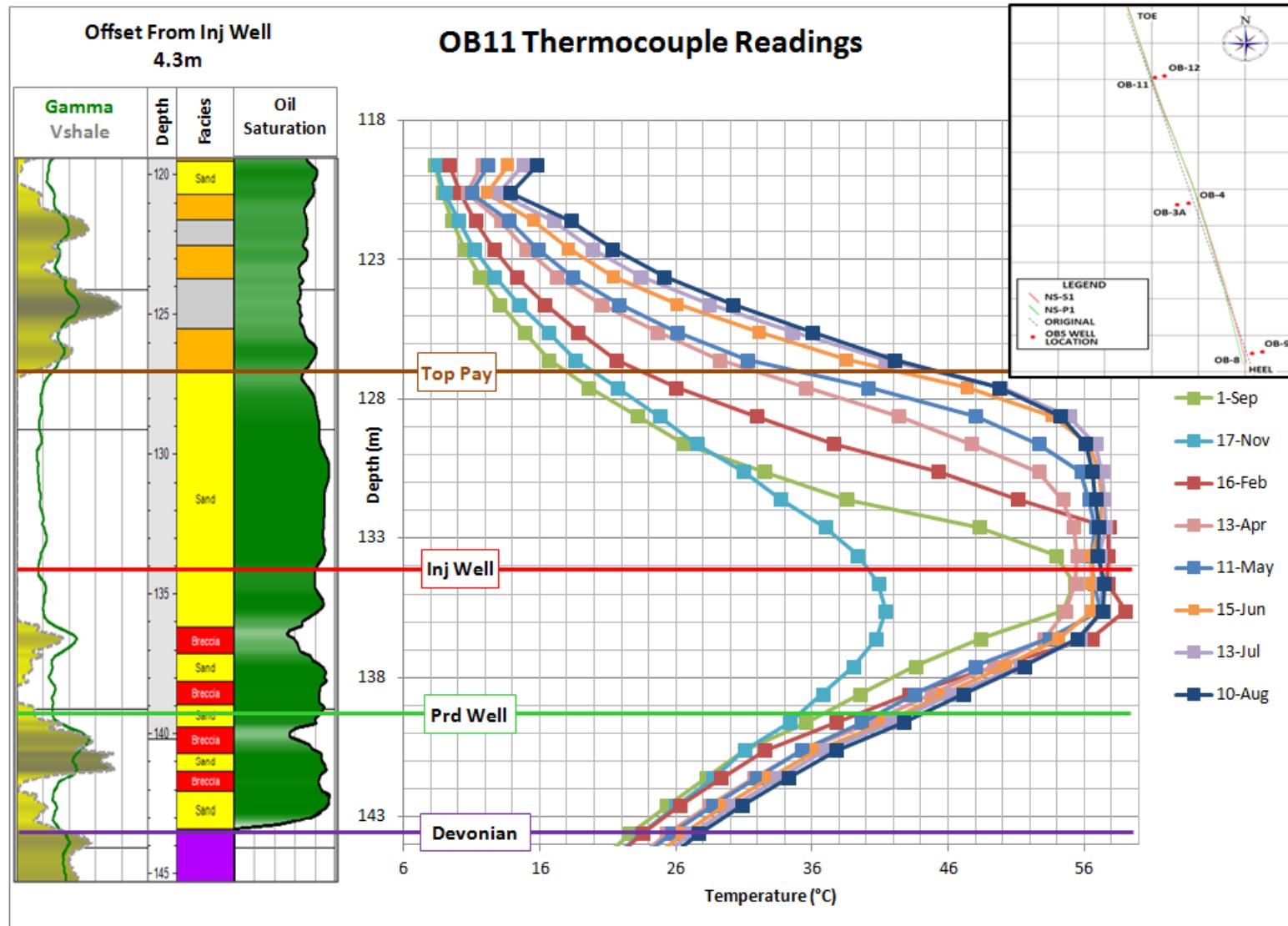
Scheme Performance – Chamber Growth



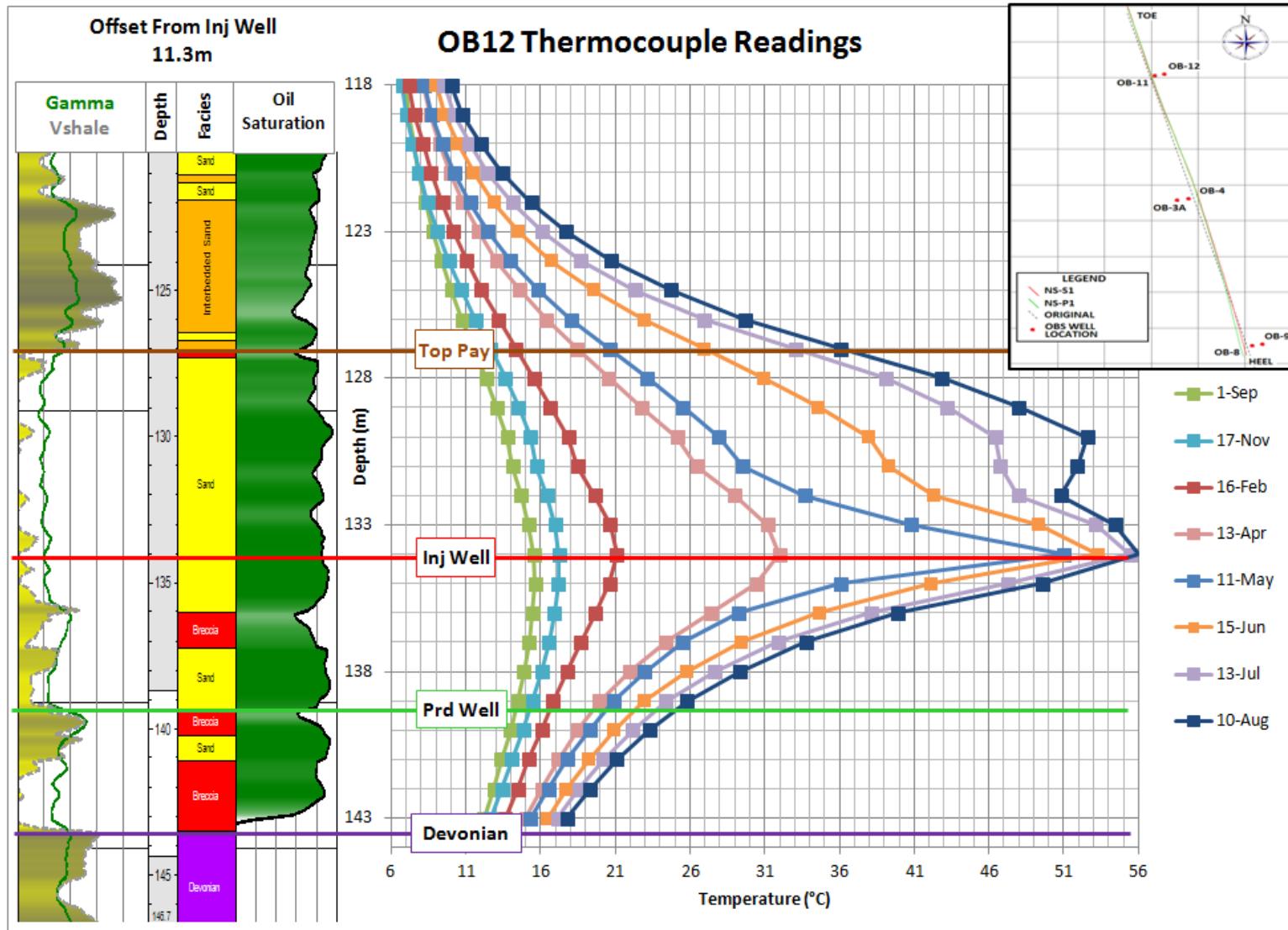
Scheme Performance – Chamber Growth



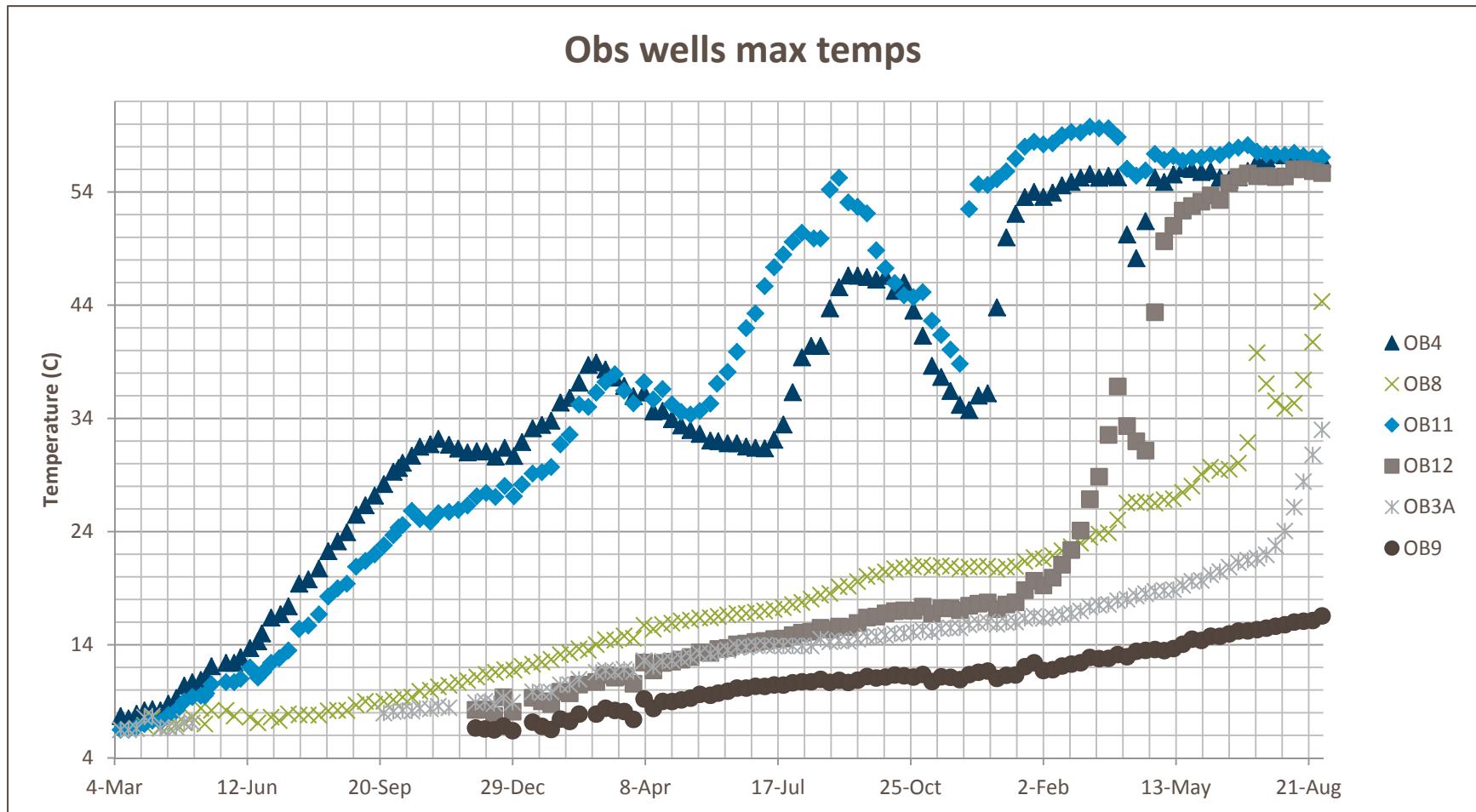
Scheme Performance – Chamber Growth



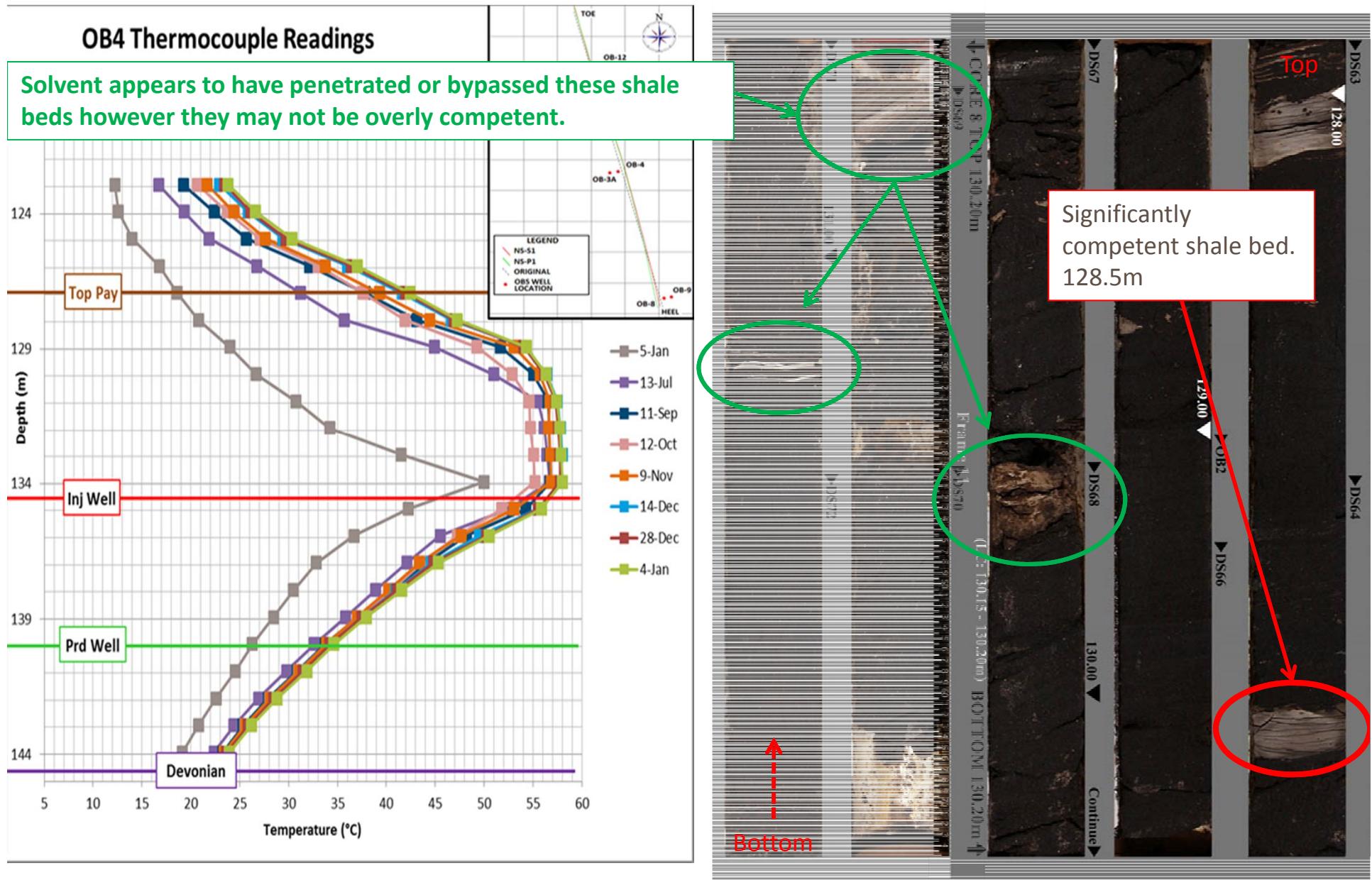
Scheme Performance – Chamber Growth



Scheme Performance – Chamber Growth



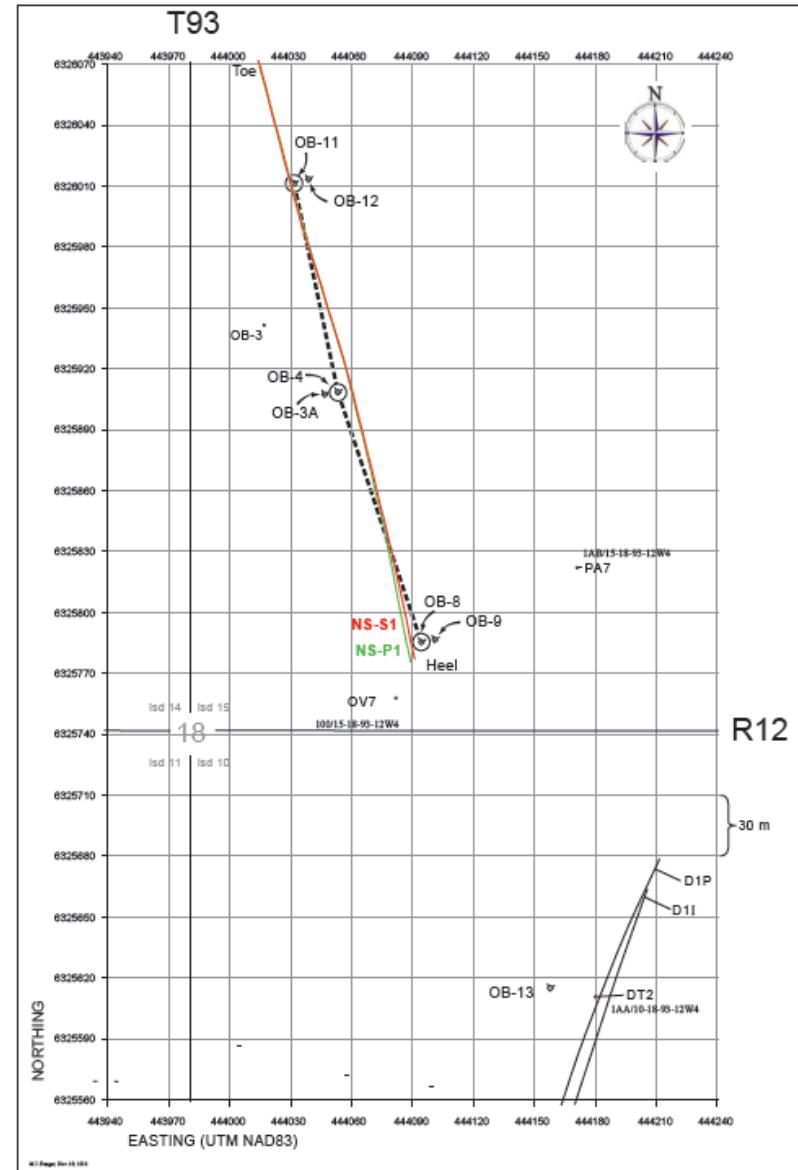
Chamber Growth Around Baffles



Reservoir Saturation Tool Results, (RST Logs)



RST logs ran on OB-11, OB-4, and OB-8 on March 18-19th following the seismic acquisition.





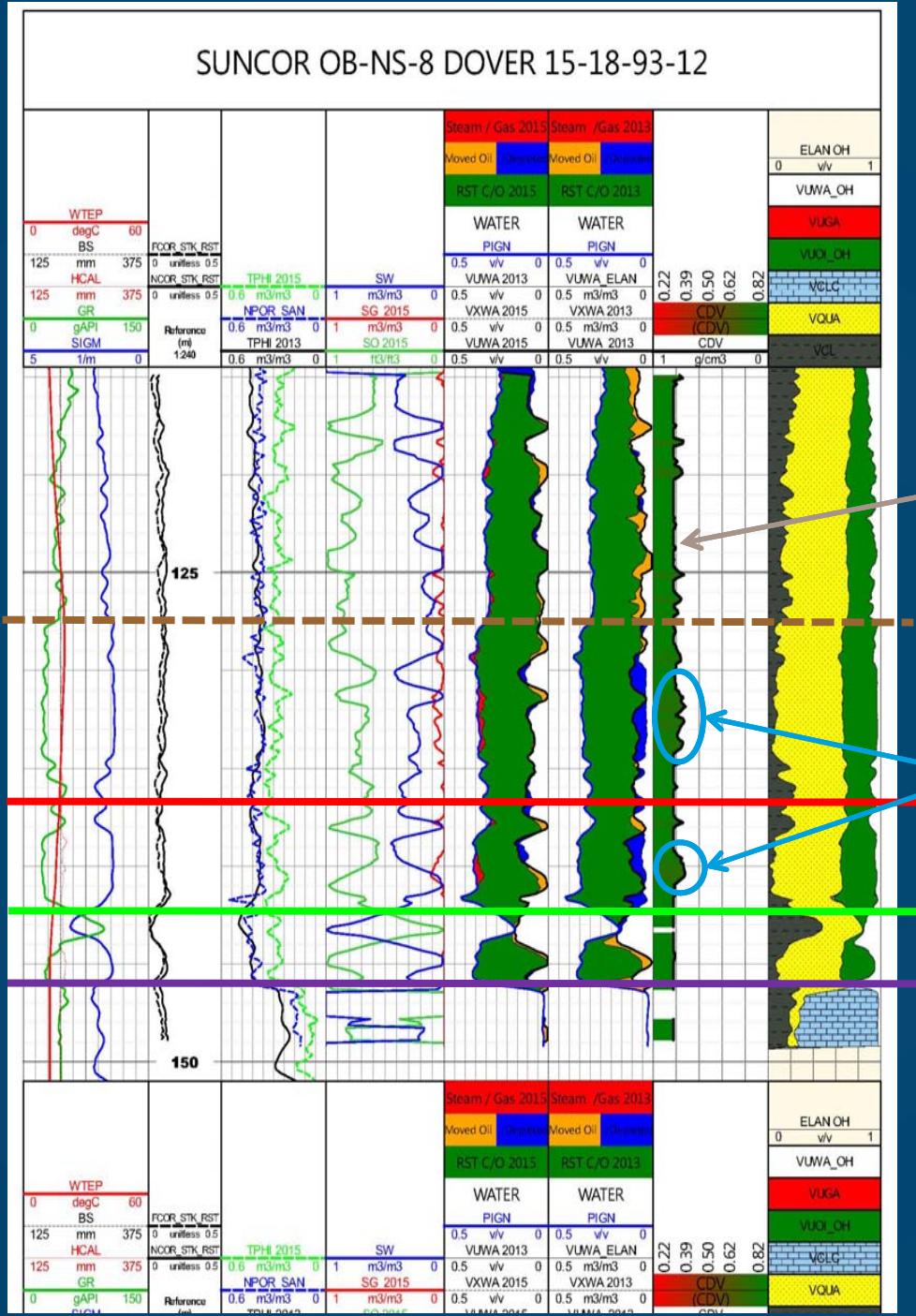
Reservoir Saturation Tool Log (RST)

Top of Pay

Injector

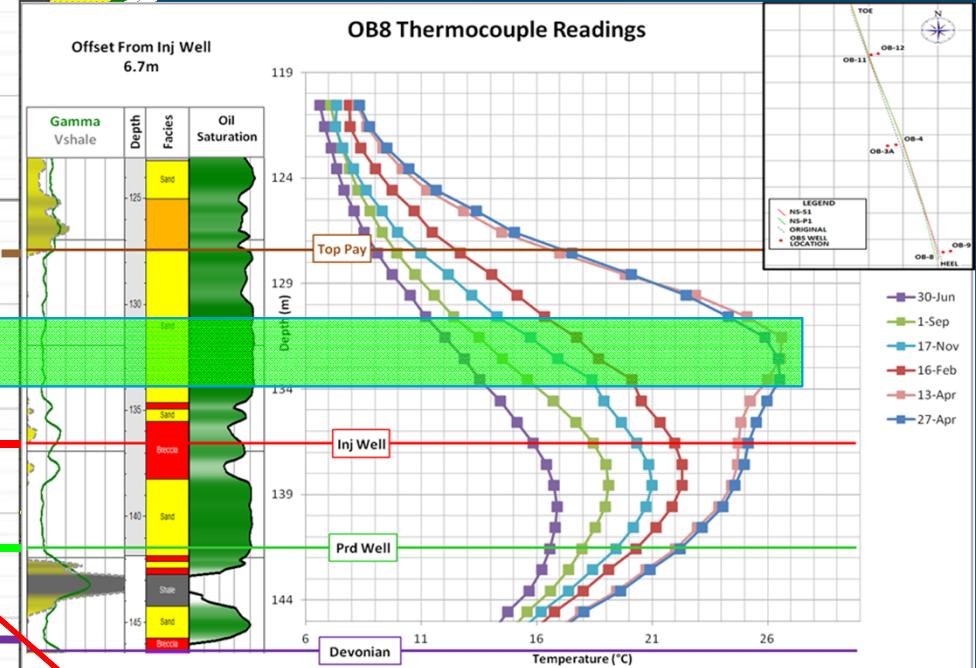
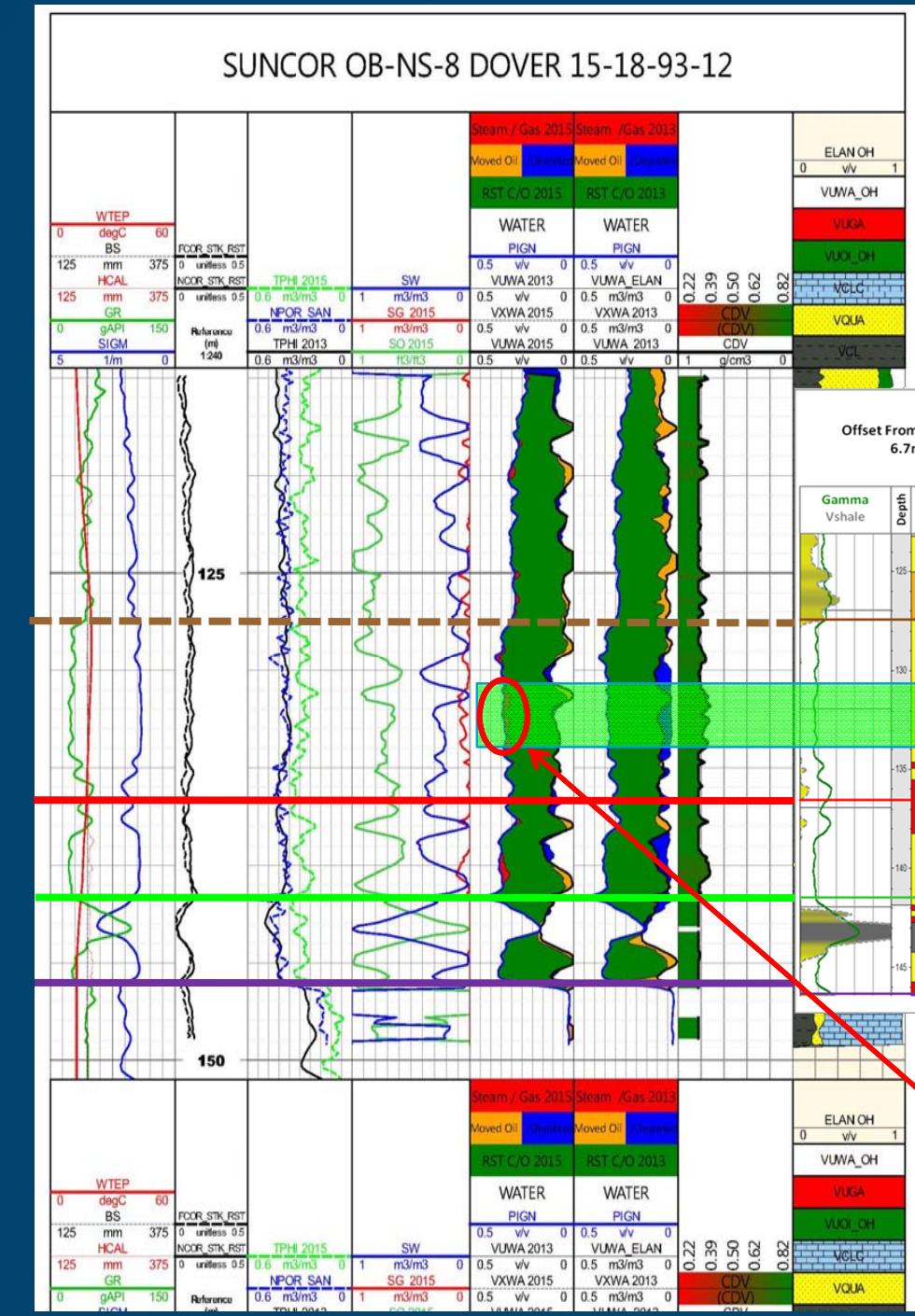
Producer

Devonian





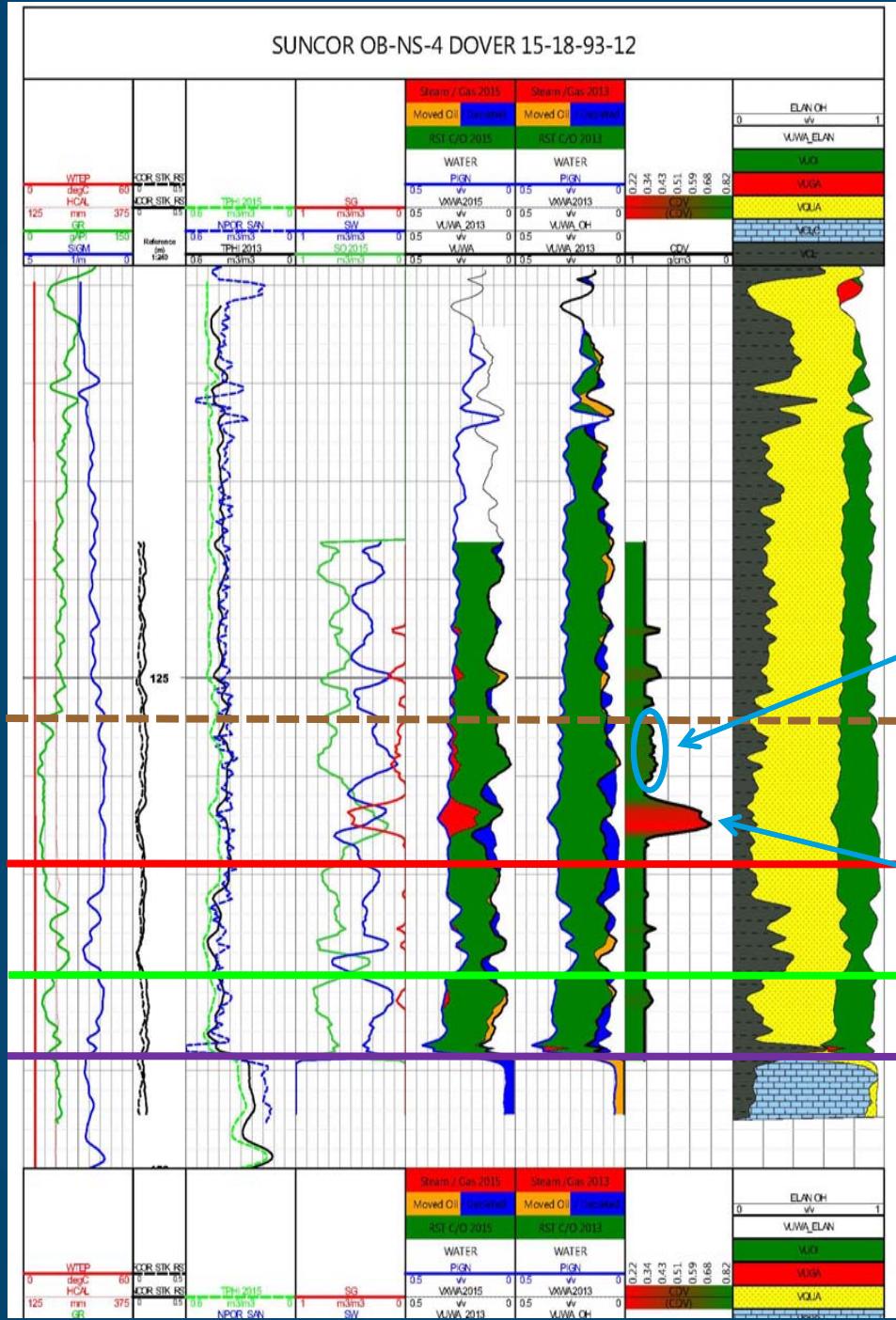
RST & OB-8 Thermocouple Correlation



Interval showing minor gas saturation is associated with the highest temp interval

Reservoir Saturation Tool Log (RST)

Top of Pay
Injector
Producer
Devonian



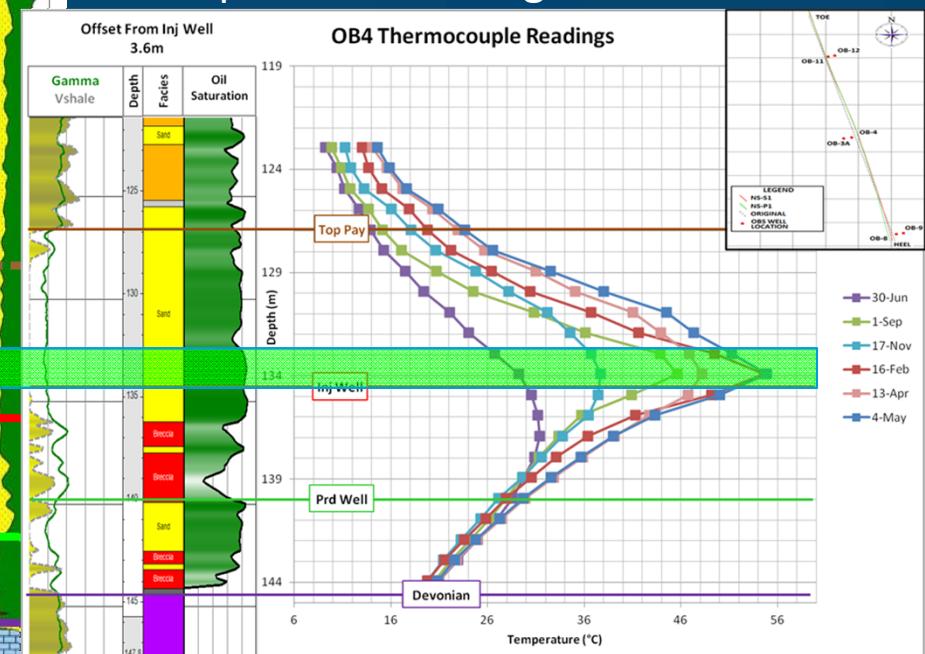
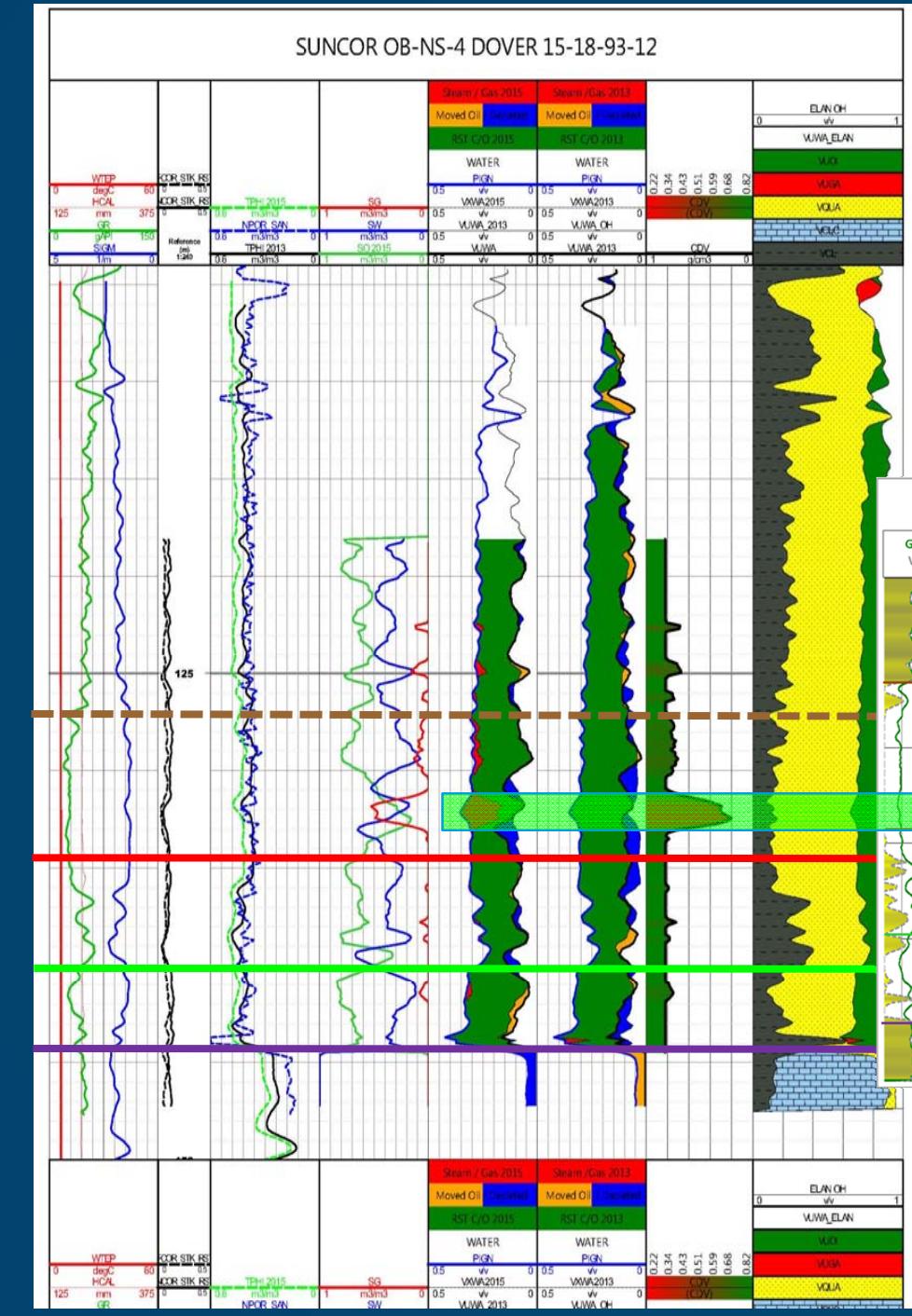
Slight decrease in carbon density indicating some solvent interaction, minor gas showing as well

1.5 to 2m vapor chamber indicated



RST & OB-4 Thermocouple Correlation

Depth does not align ~1.5m offset

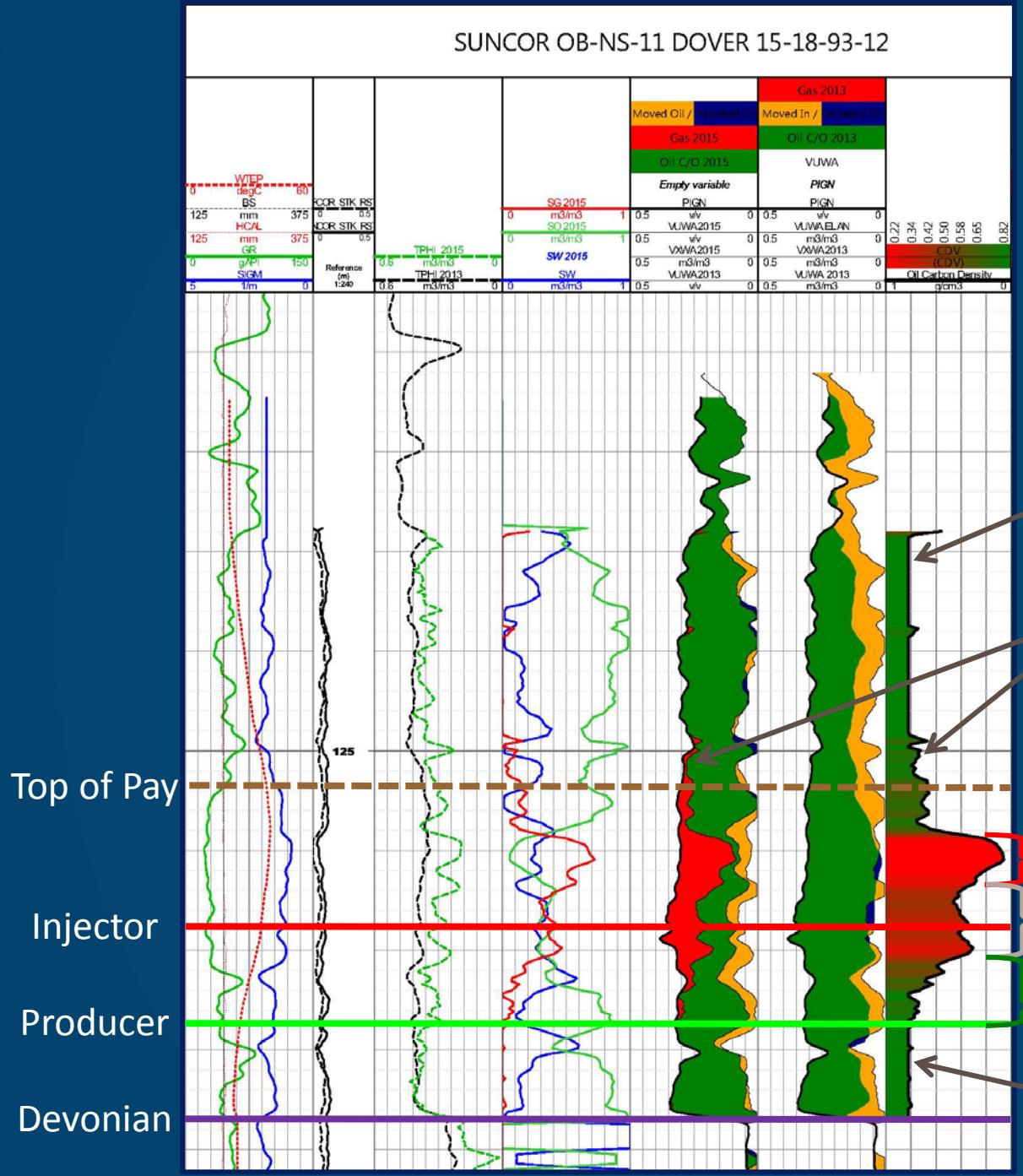


Temperature profile matches RST data.

- T of ~50°C appears to be chamber on rst log.
- Based on temp log chamber was unexpected



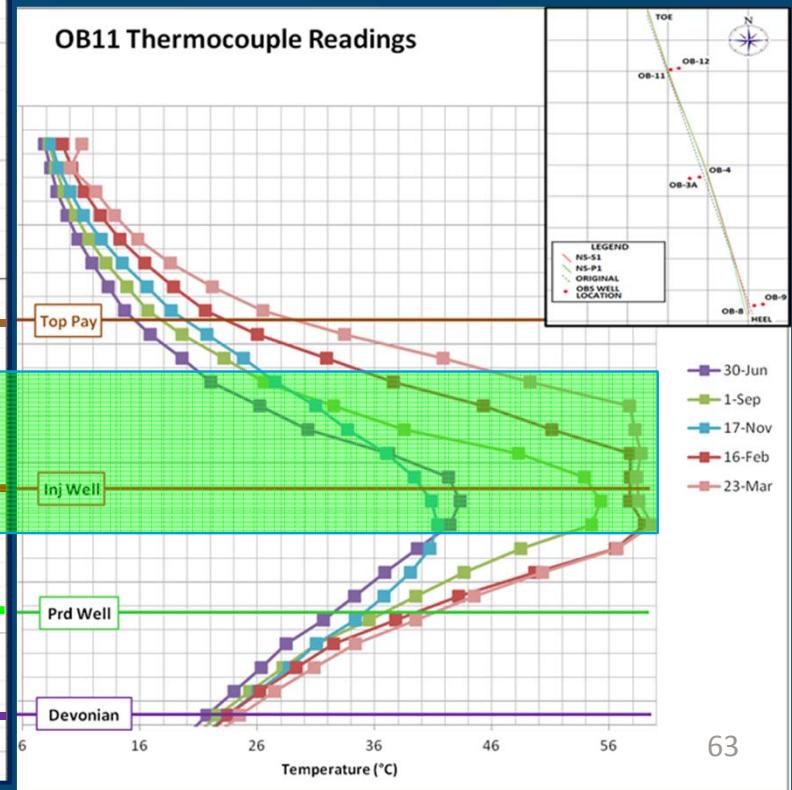
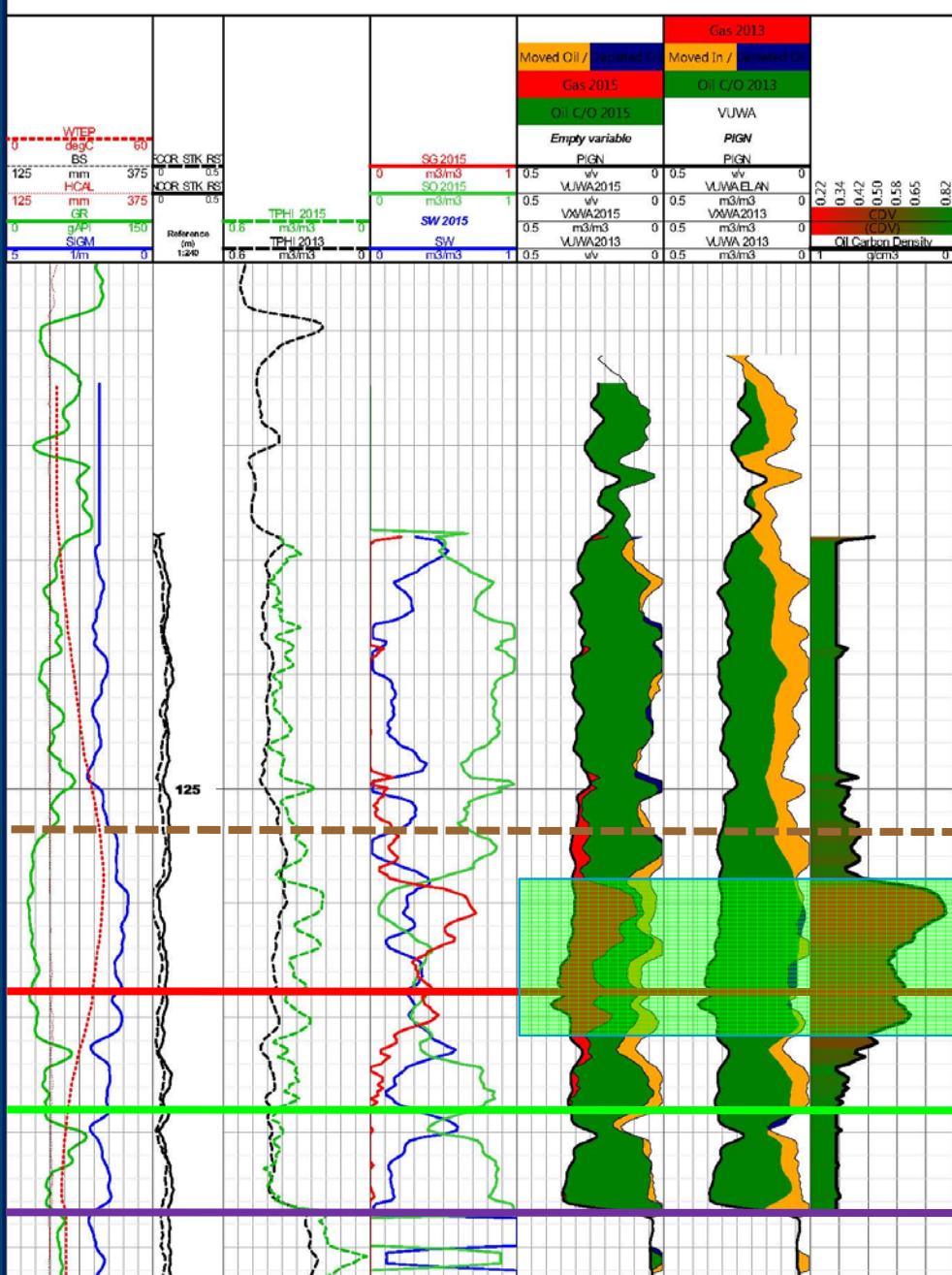
Reservoir Saturation Tool Log (RST)





RST & OB11 Thermocouple Correlation

RST shows top of chamber slightly higher than thermocouple data.

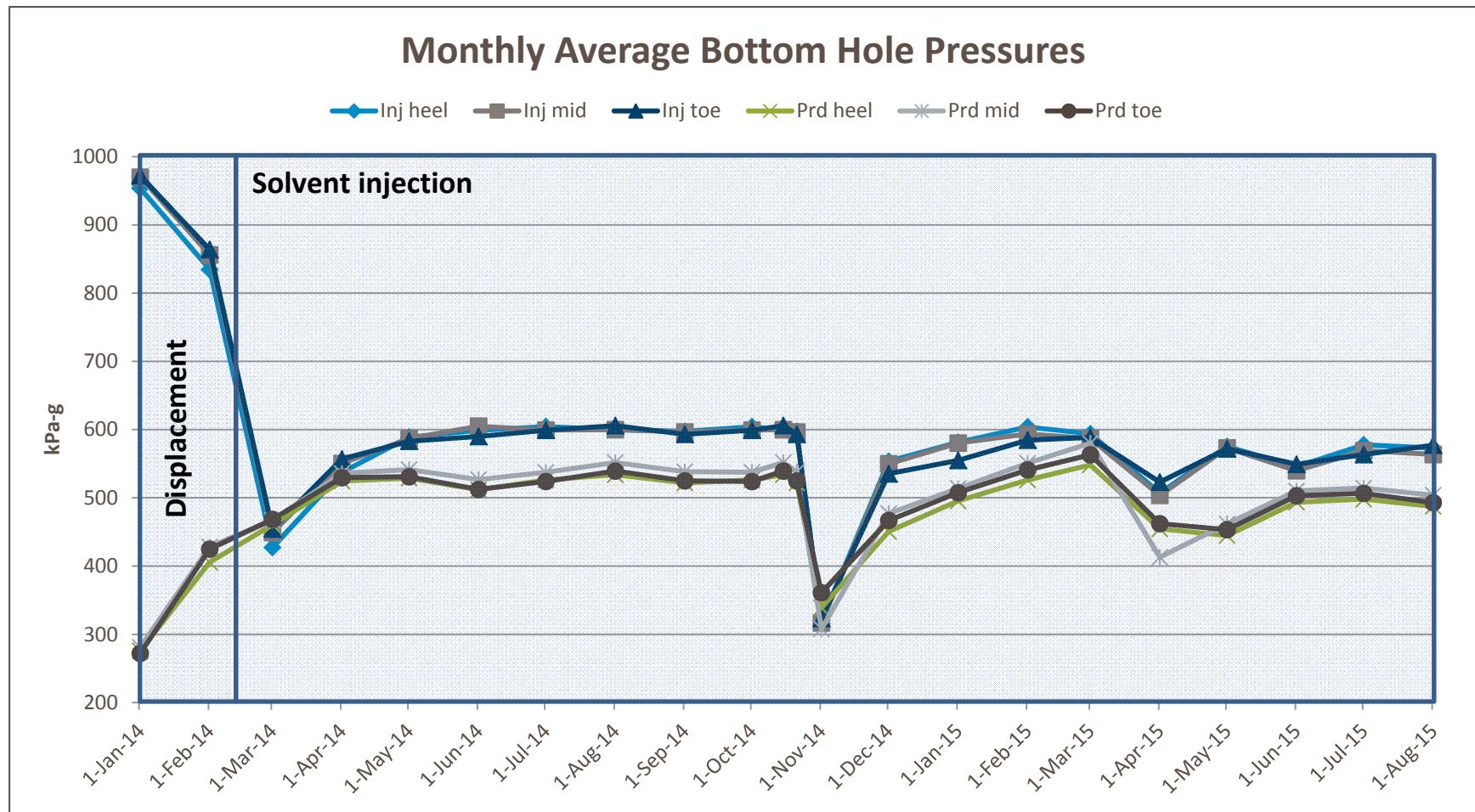


Scheme Performance – Solvent delivery

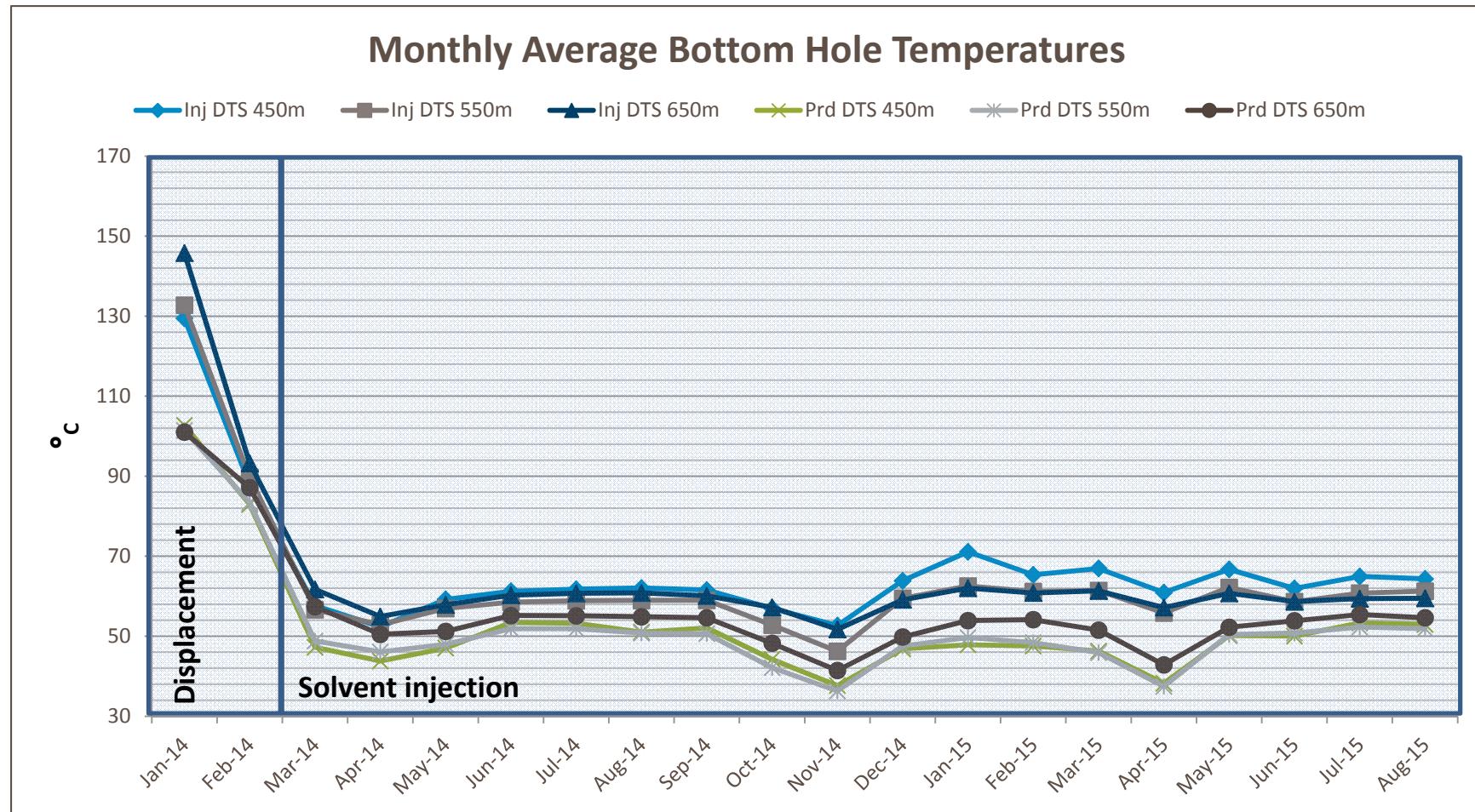


- Currently operating solvent chamber ~570 kPa and 58 deg C
- Solvent vapourizer temperature setpoint is adjusted to target vapour conditions downhole
- Solvent purity, non-condensables (C1 and C2) injection maintained below 0.03 mol %

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 several week outages without issue (even with immature chamber)
- 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 to increase injection and production rates
- 4D seismic
- Potential testing of new surface equipment
- Coring of solvent chamber
- Solvent recovery from chamber at end of life

AER Directive 054 - 2015 Performance Presentation



Section 3.1.2

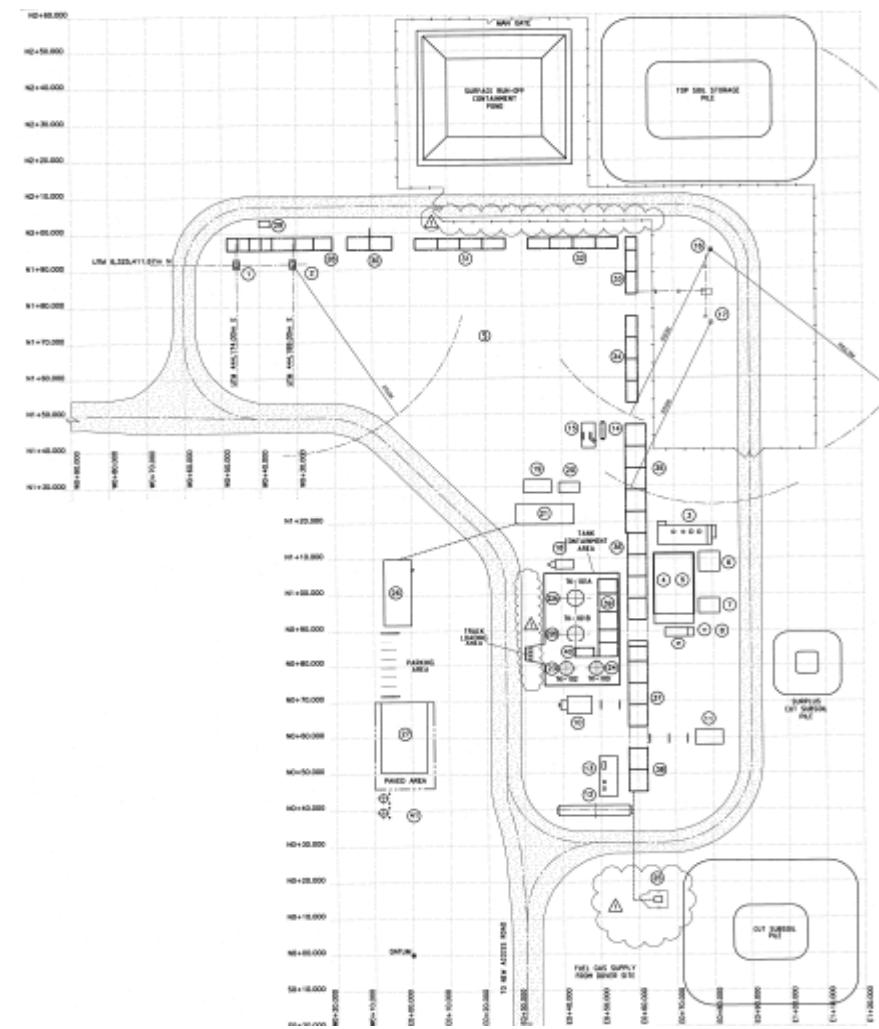
Surface Operations, Compliance, and Issues not related to Resource Evaluation and Recovery



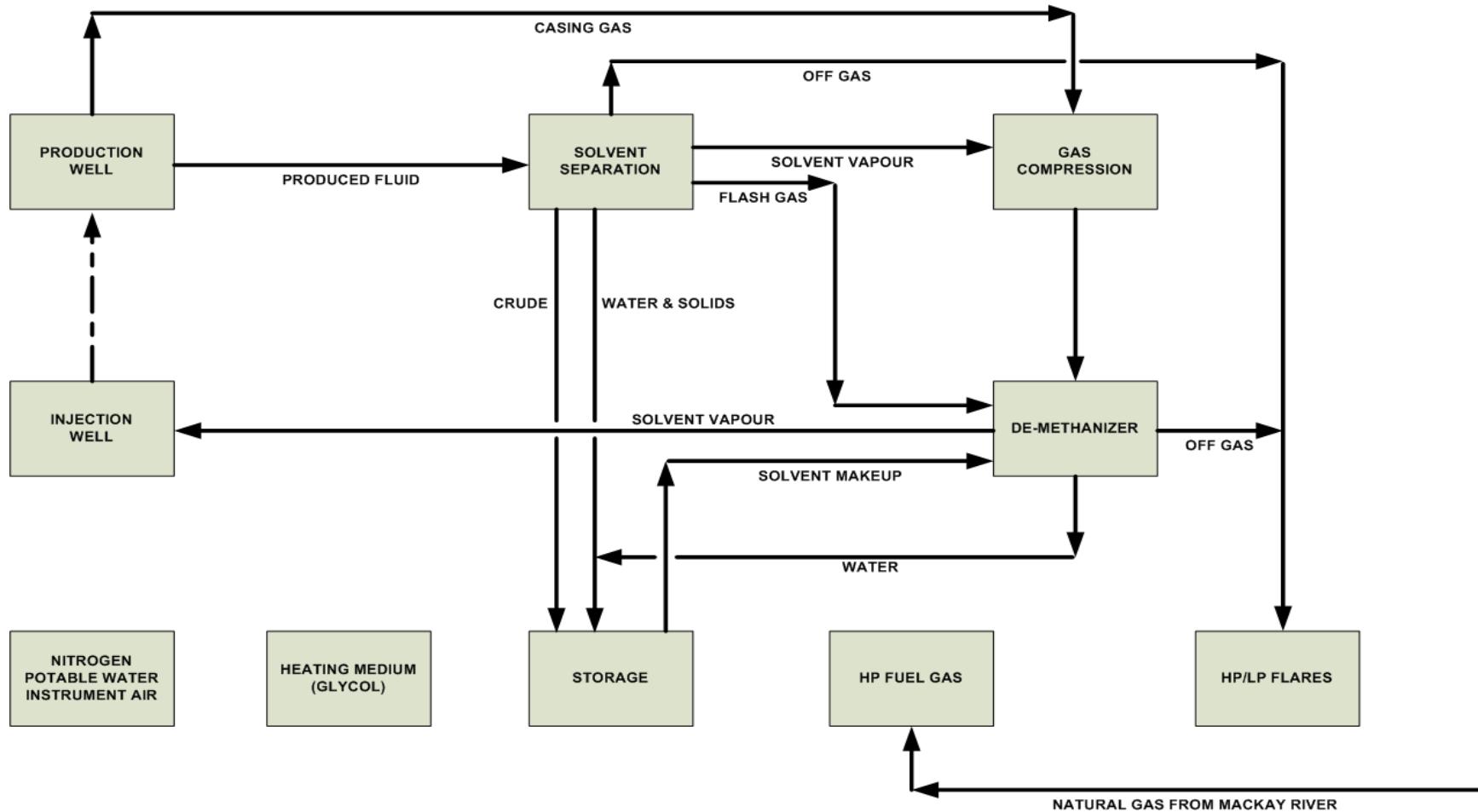
Table of Contents

- 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



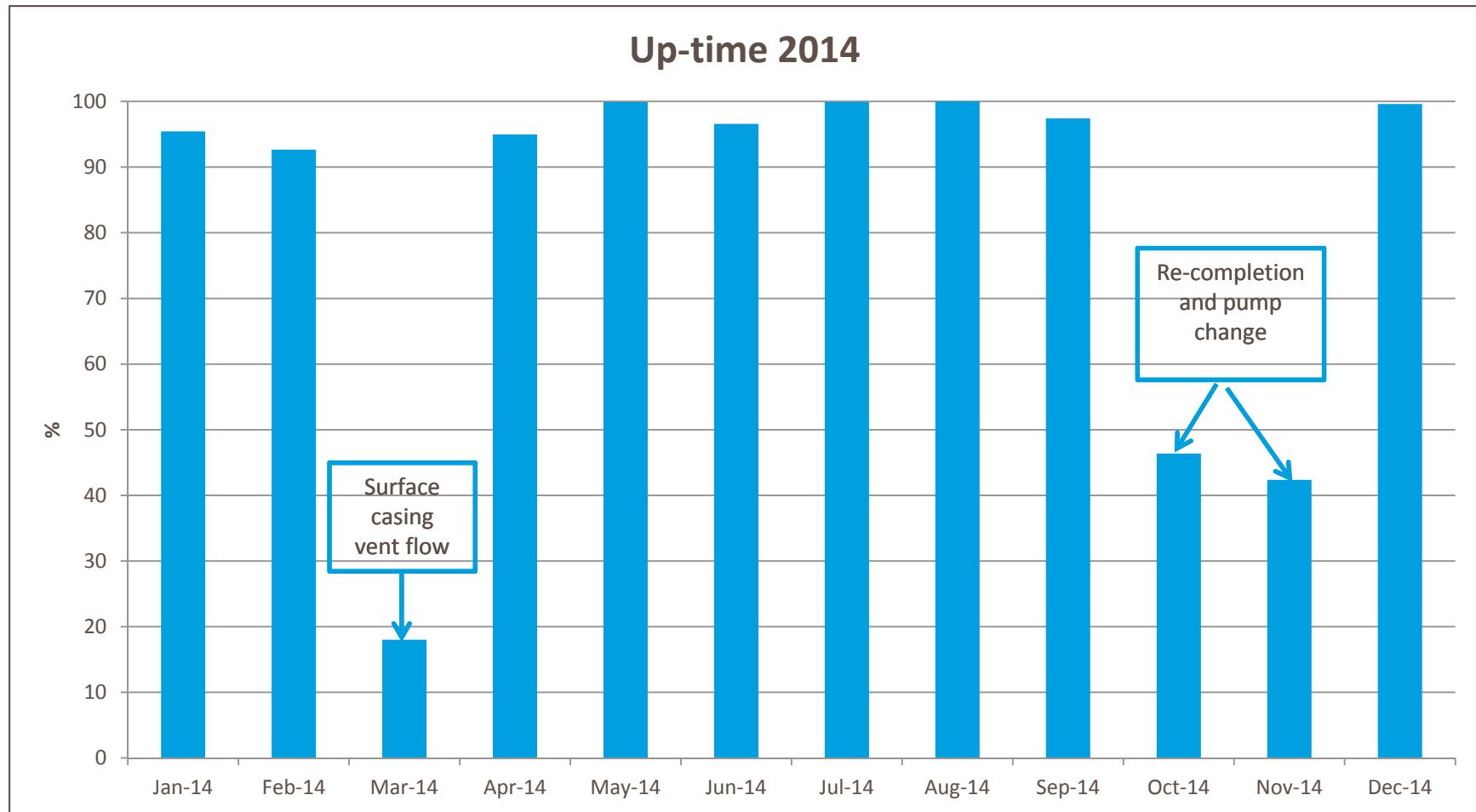
- Installed a surface booster pump
- Removed chemical mixer

CPF Performance

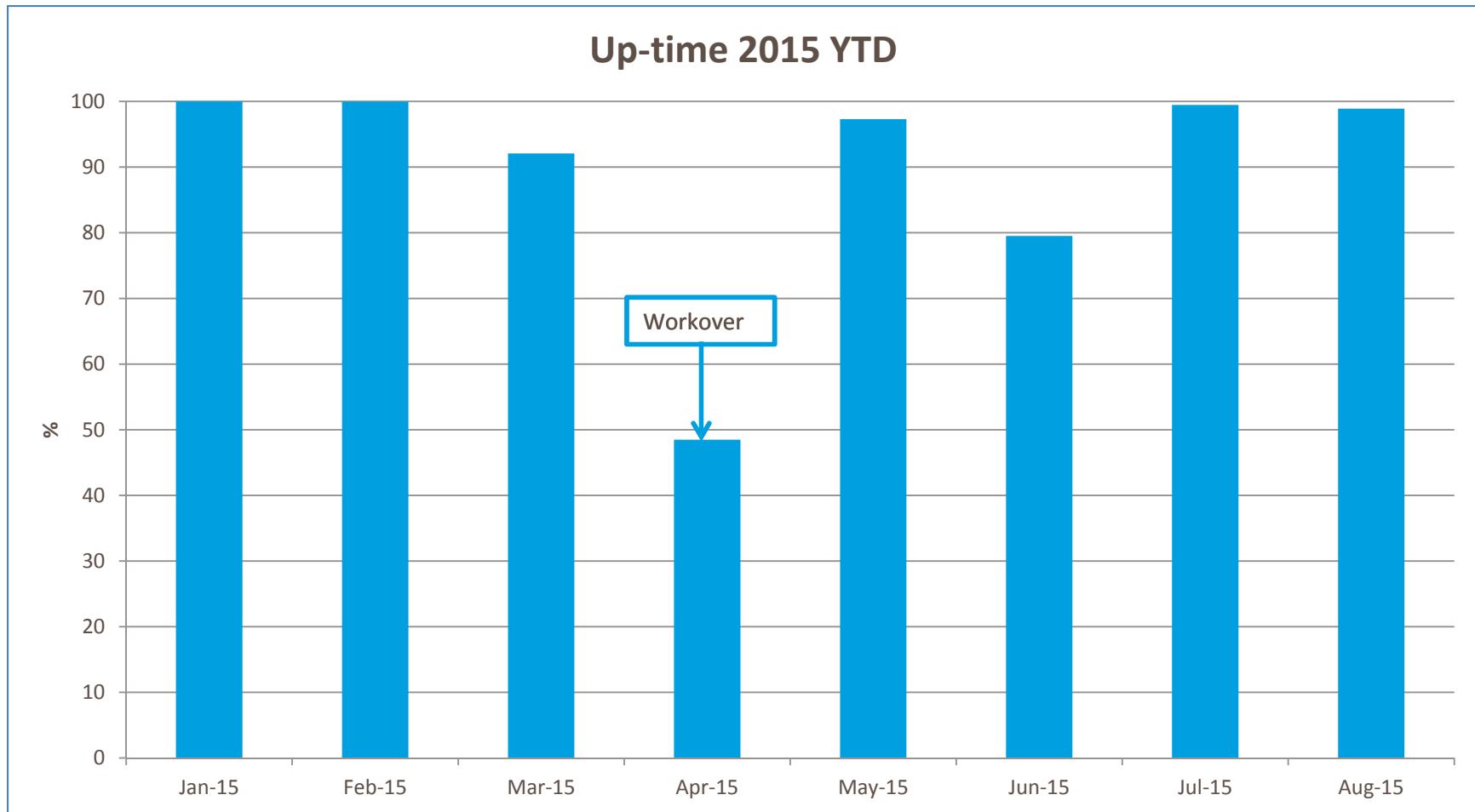


- Facility is operating very well
- Able to maintain an average up-time of 97.1% excluding workovers, despite limited redundancy
- Fluid separation without chemicals
 - Oil with only trace water
 - Very clean produced water
- No issues maintaining solvent purity

CPF Performance



CPF Performance

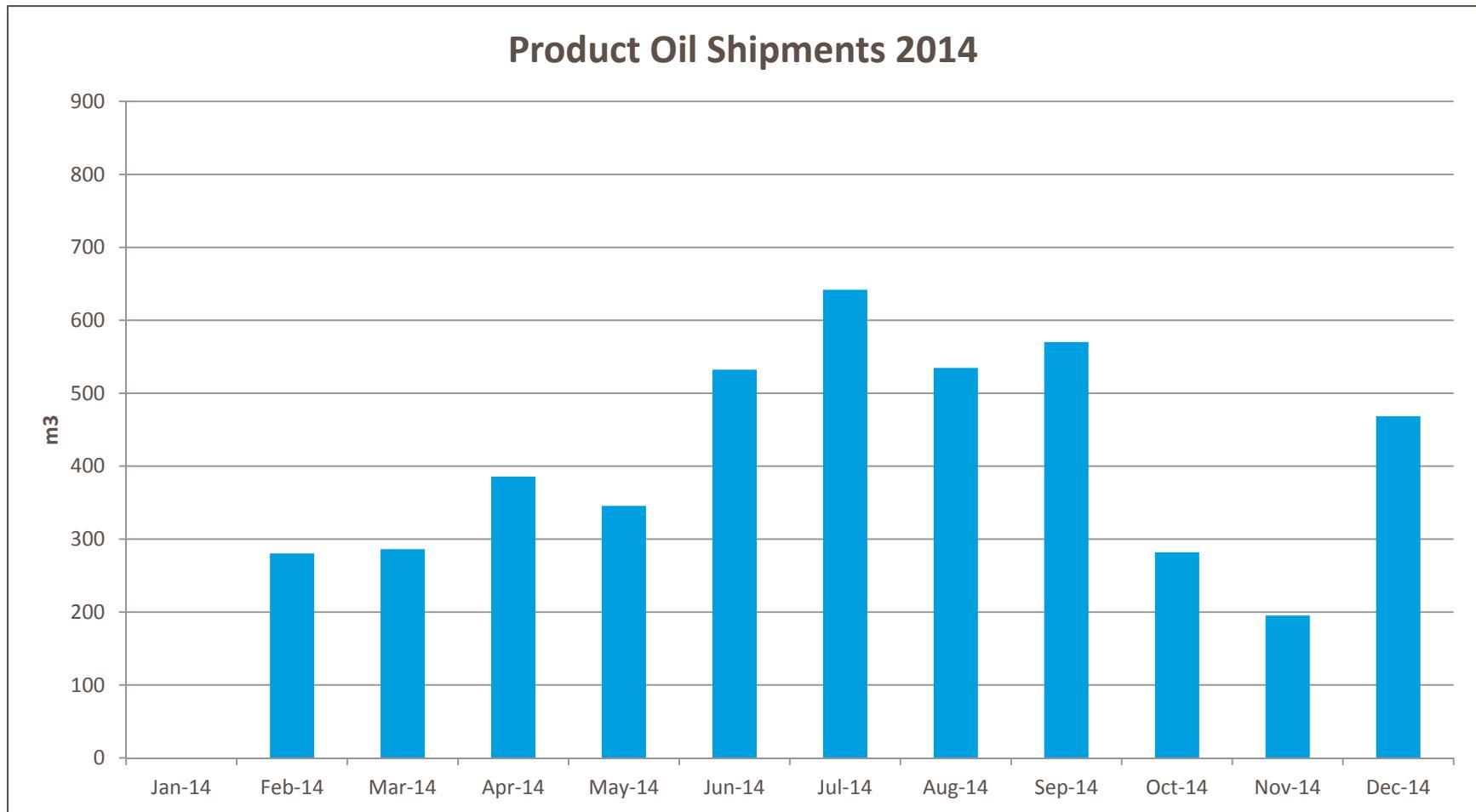


CPF Performance – Bitumen Treatment

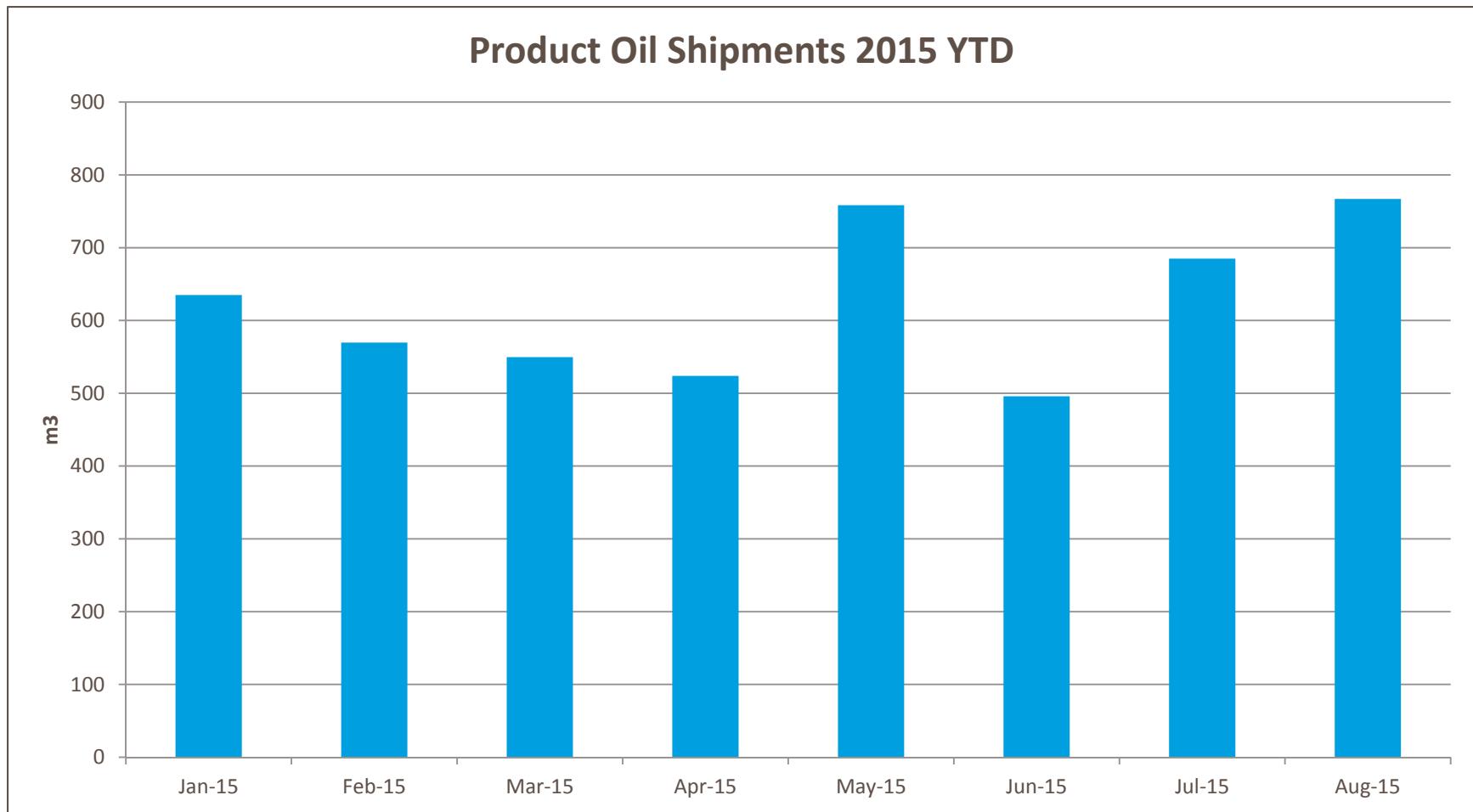


- Able to produce dry oil without use of separation chemicals or diluent

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



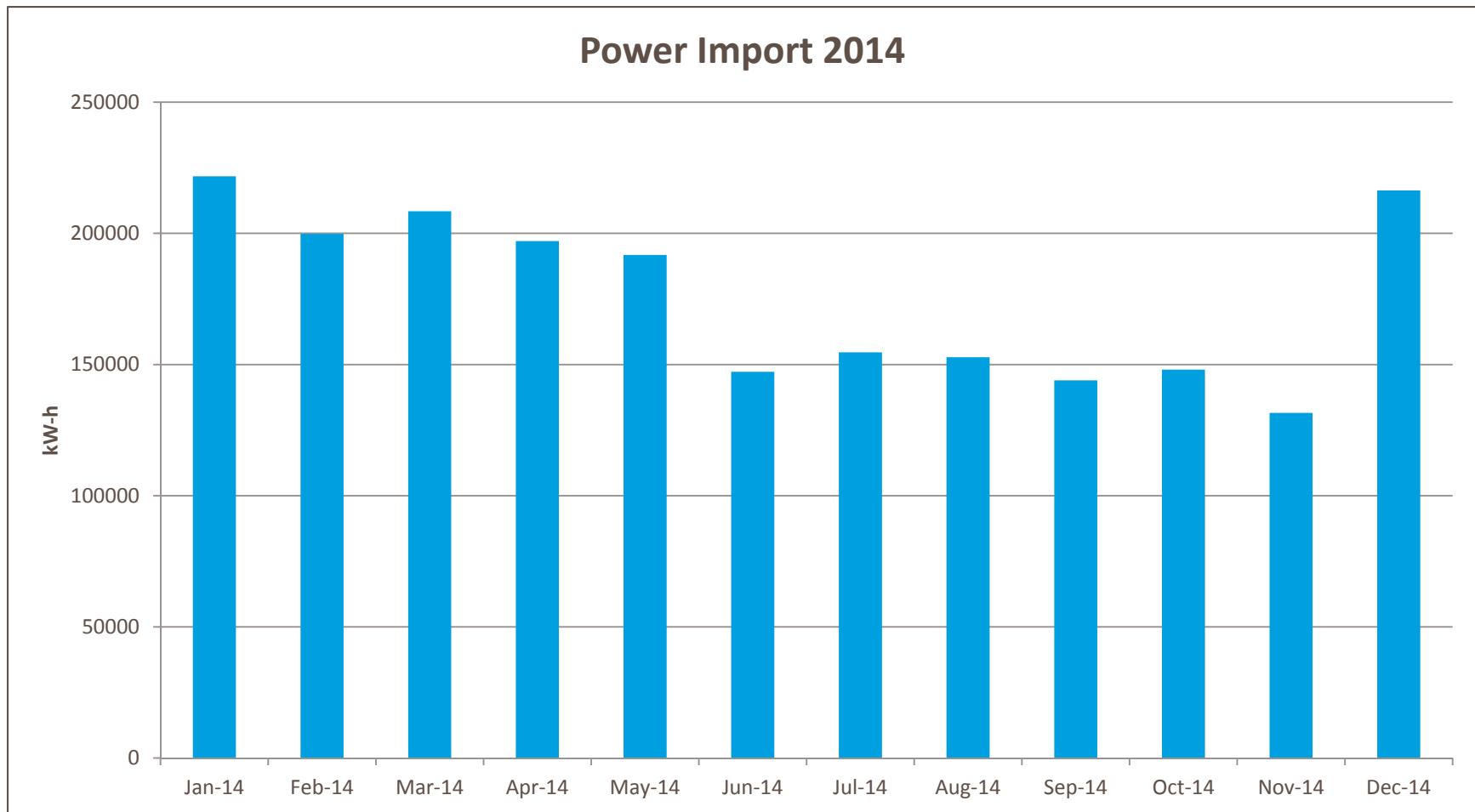
- Solvent purity is critical to the Nsolv process
 - Defined in terms of non-condensables (C1, C2) mol%
 - C3 to C5+ is considered solvent
- Solvent is purified in a distillation column
 - Target non-condensables mol%: < 0.03

CPF Performance – Power

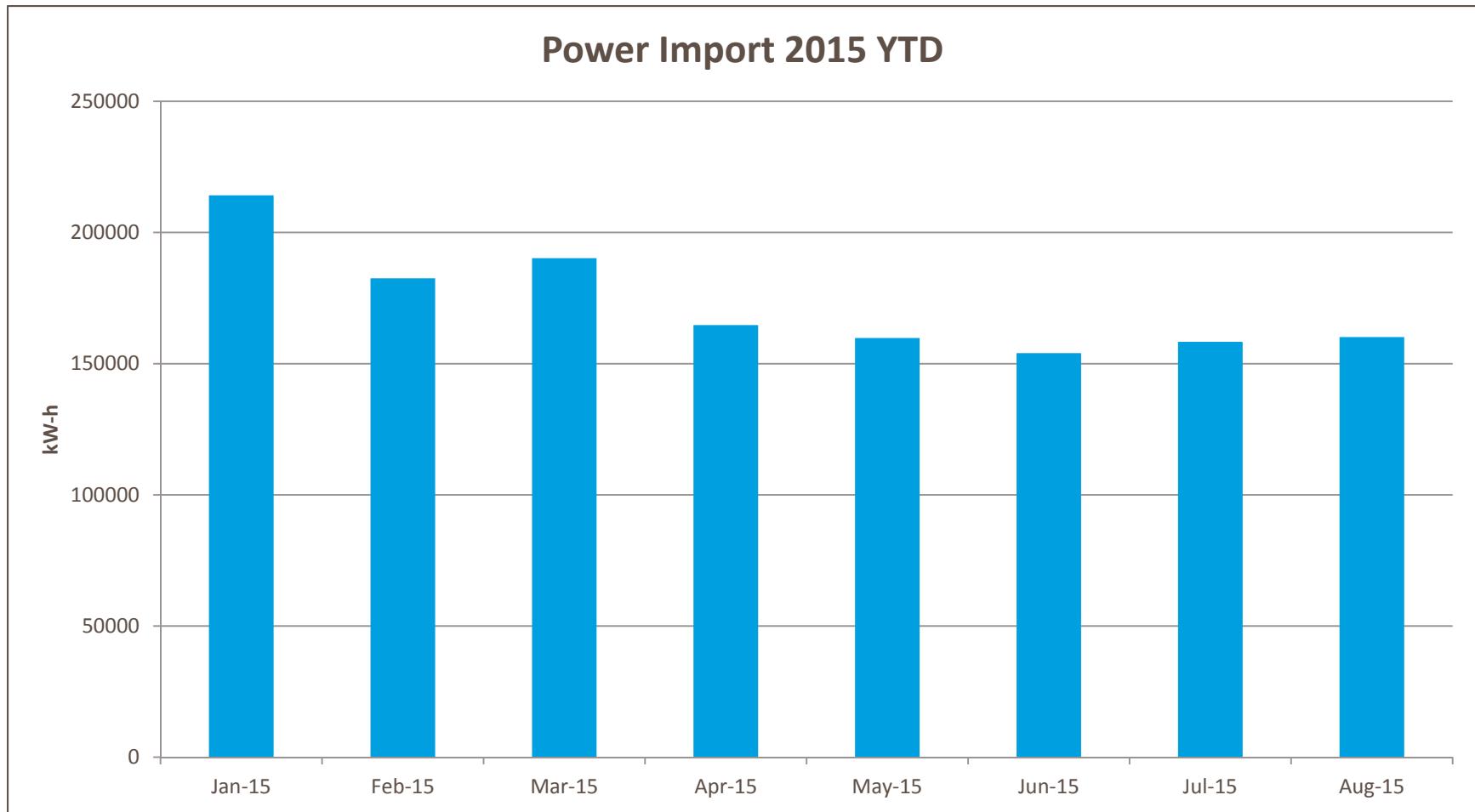


- Power imported from ATCO
- Emergency backup provided by 500 kW generator

CPF Performance – Power



CPF Performance – Power



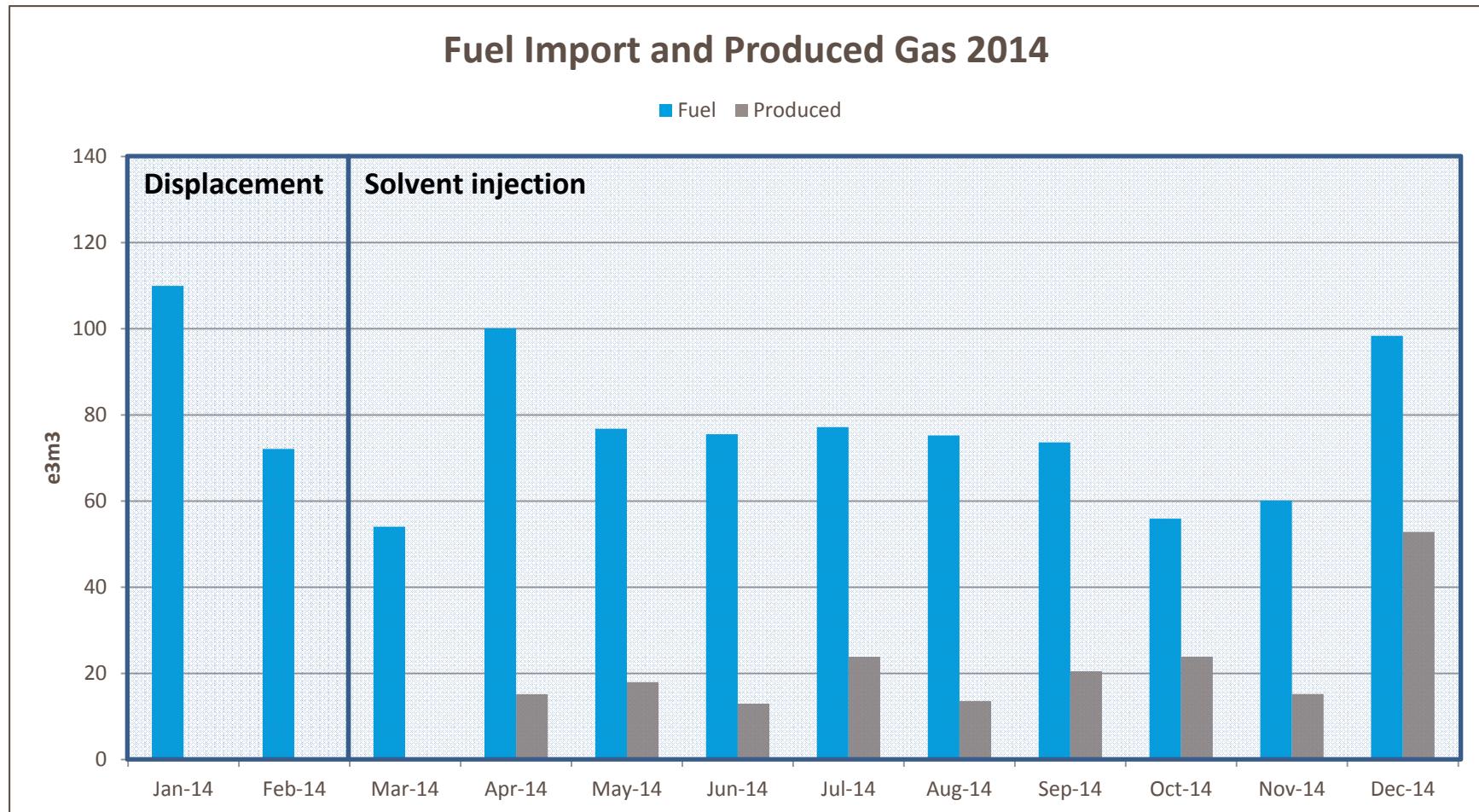


CPF Performance – Gas

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

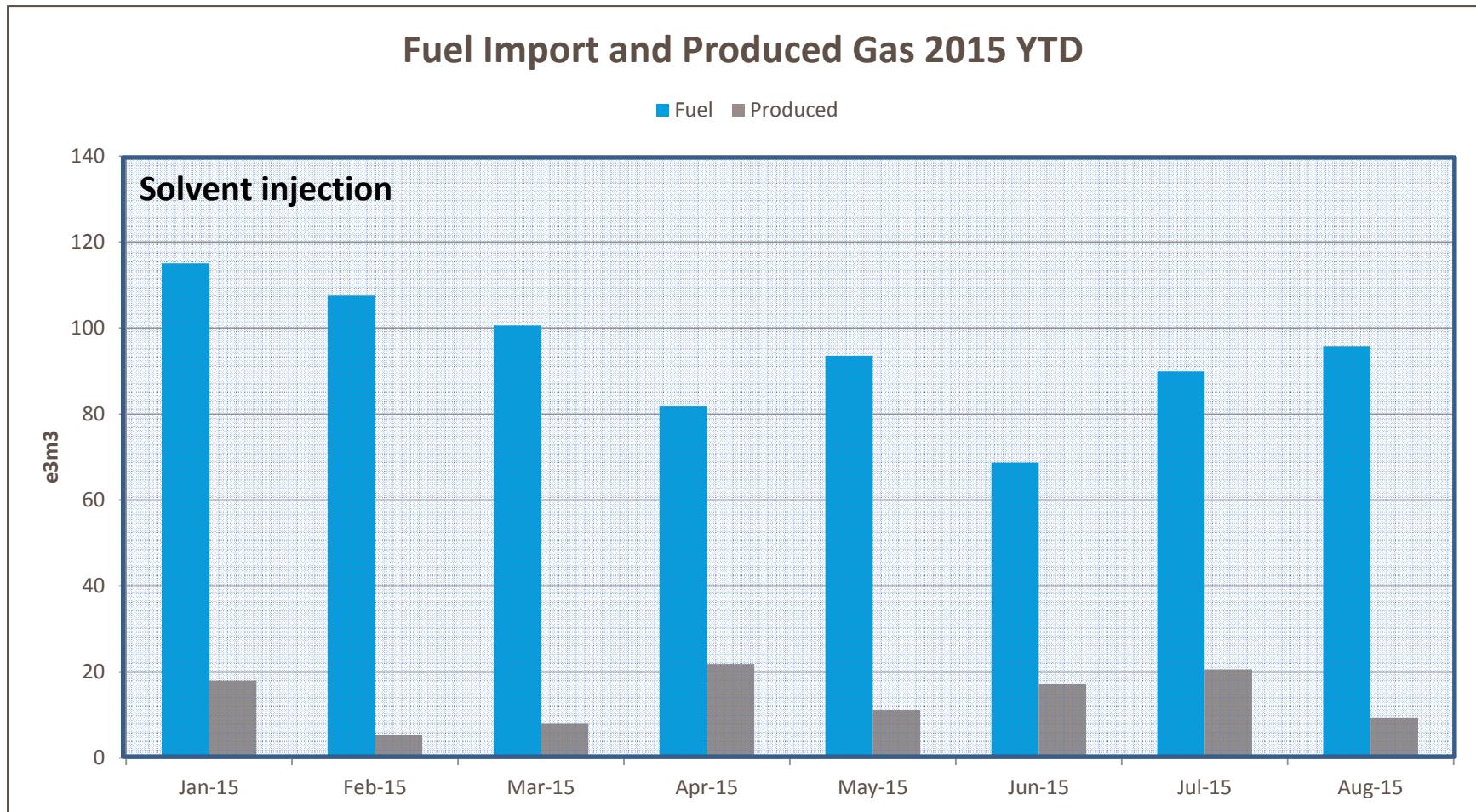


CPF Performance – Gas





CPF Performance – Gas



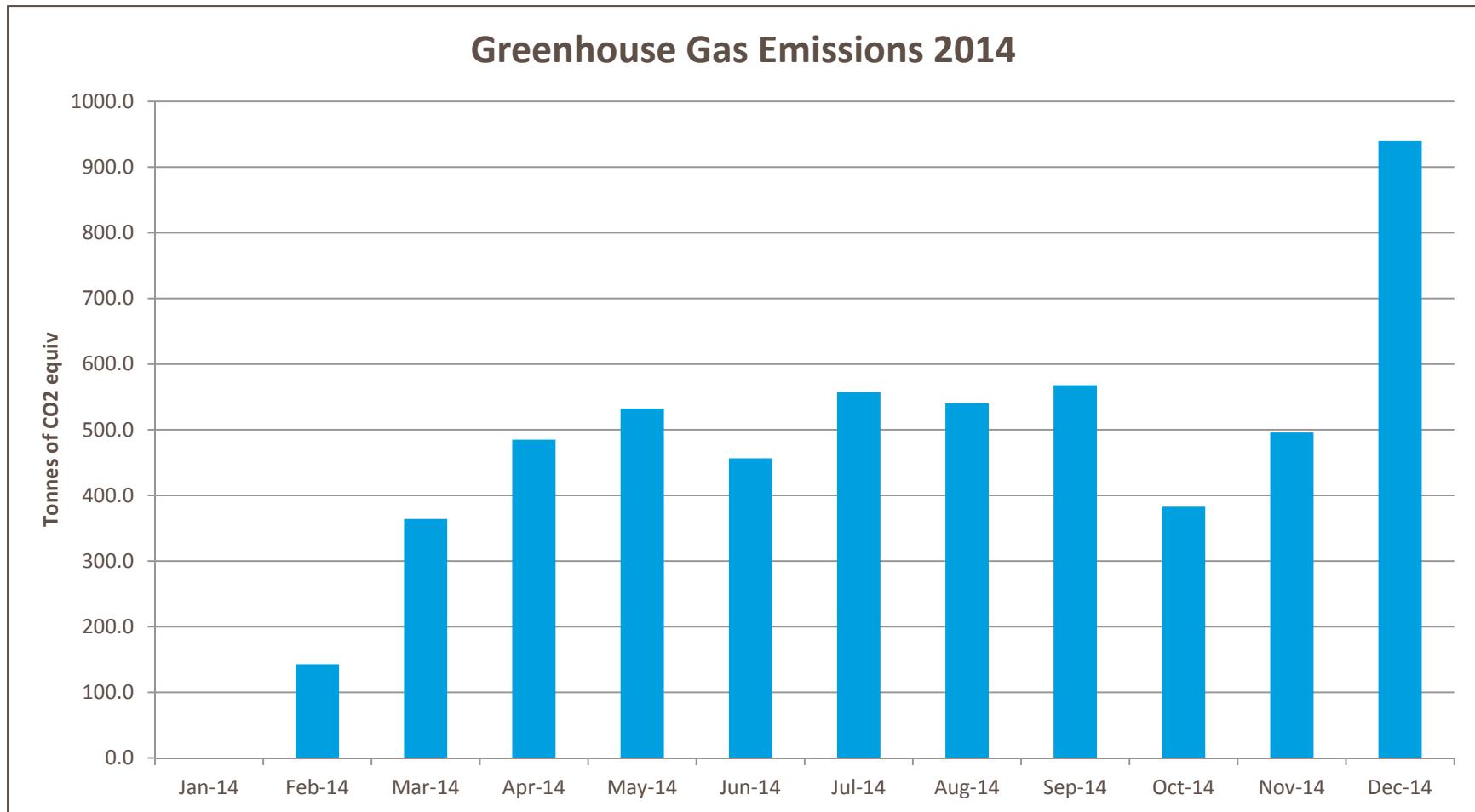
CPF Performance –

Green House Gas Emissions

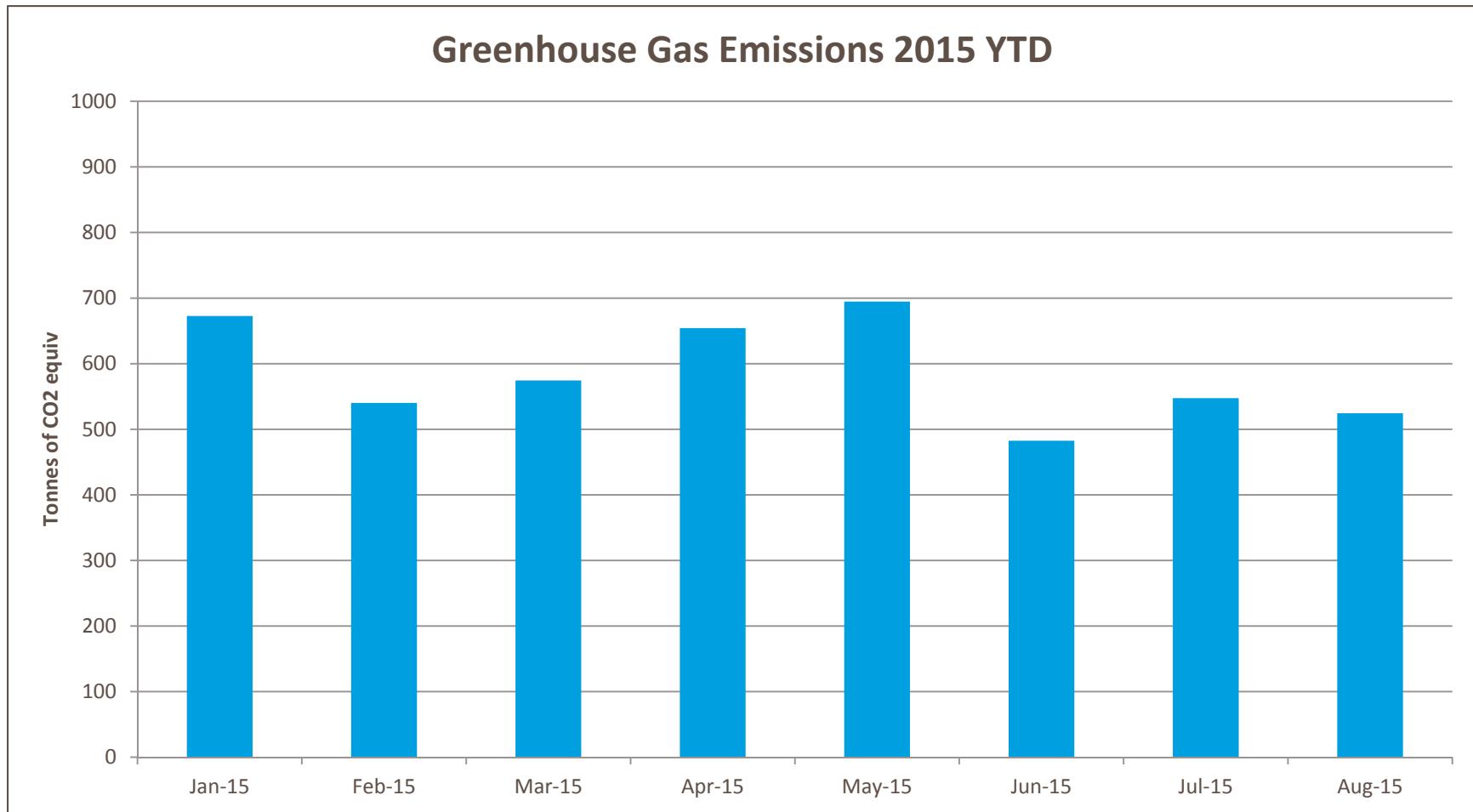


- CO₂ emissions YTD: 4,691 Tonnes CO₂ equiv.
- Total CO₂ emissions: 12,504 Tonnes CO₂ equiv.
- GHG factors:
 - Power: 0.91 kg/kWh
 - Fuel gas: 1.7 kg/m³
 - Solvent trucking: 166 kg/m³
 - Solvent flaring: 1.7 kg/m³

CPF Performance – Green House Gas Emissions



CPF Performance – Green House Gas Emissions



Measurement & Reporting



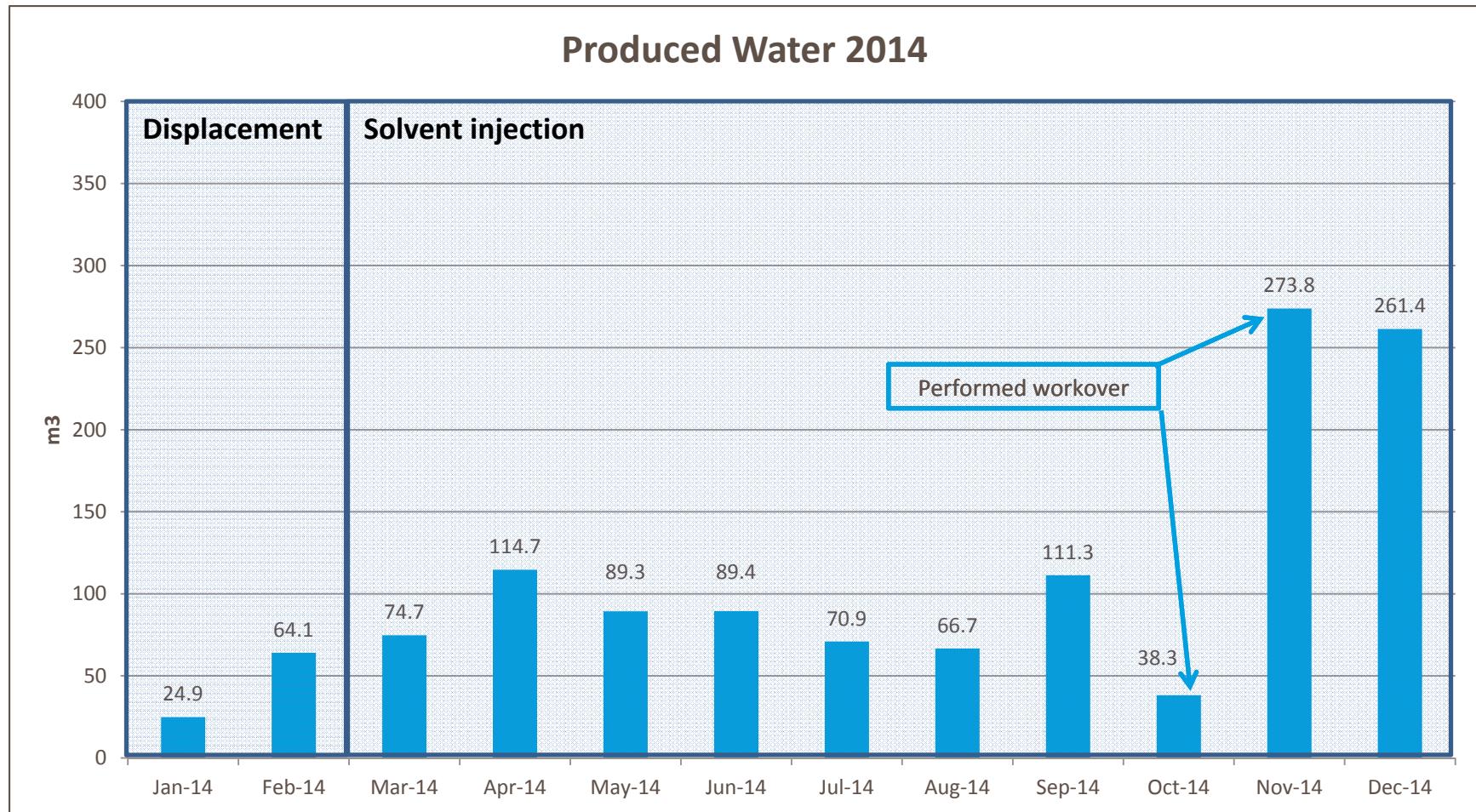
- Single well pair facility:
 - All production attributed to the production well
 - No individual well testing required
- Facility Codes associated with Suncor BEST Approval 11825:
 - AB BT0126919
 - AB IF0126920

Water Production

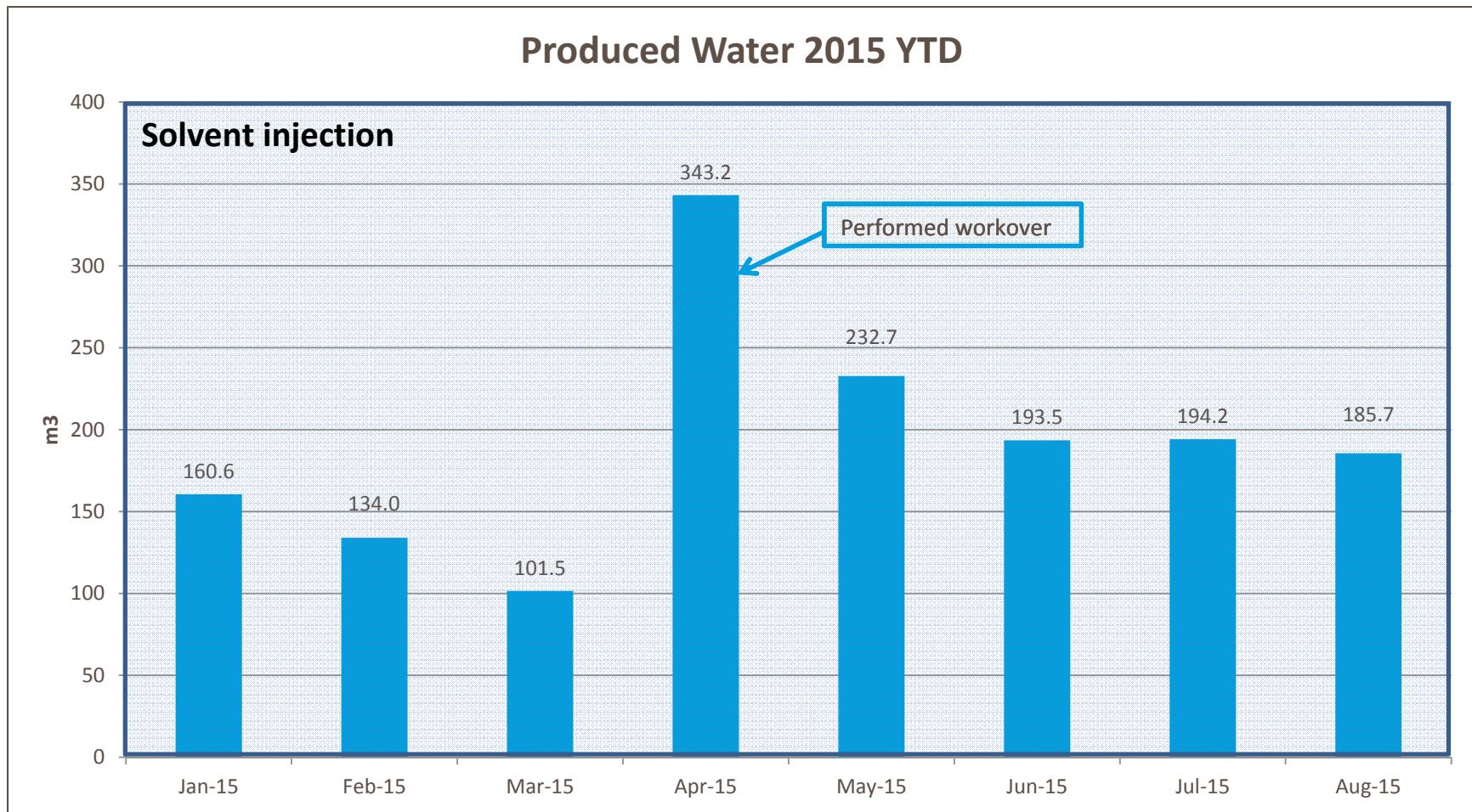


- 21.9% water cut on average
- Water is hauled off-site to disposal facilities operated by Gibsons Environmental Services:
 - ABWP0000556
 - ABCT0076056
 - ABTM0000961
 - ABCT0128757
 - ABTM0128266
 - ABTM 0102339
- Produced water is sampled and analyzed by third party lab:
 - Avg. TDS: 17,309 mg/L
 - Avg. pH: 8.2
 - Avg. Na: 6,663 mg/L
 - Avg. Cl: 9,908 mg/L
 - HCO₃: 1,511 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.