Marginal and Mature Field Development and Operation

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Design, Implementation and Results from a Tracer Surveillance Program to Remotely Monitor Water and Oil Inflow Data in the Deep Water Parque das Conchas (BC-10), Argonauta O-North Field Development Operated by Shell do Brasil Ltd

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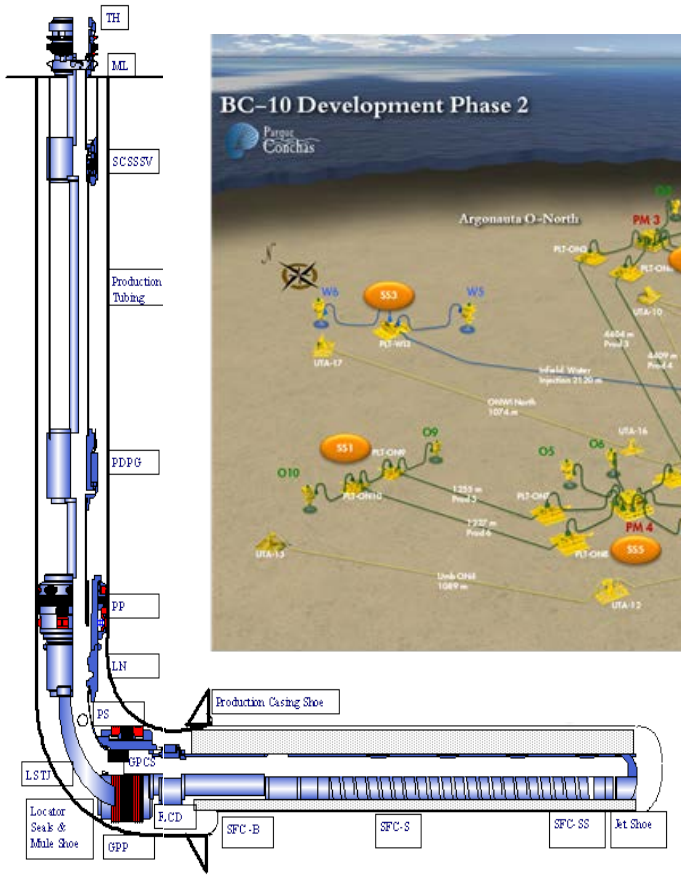
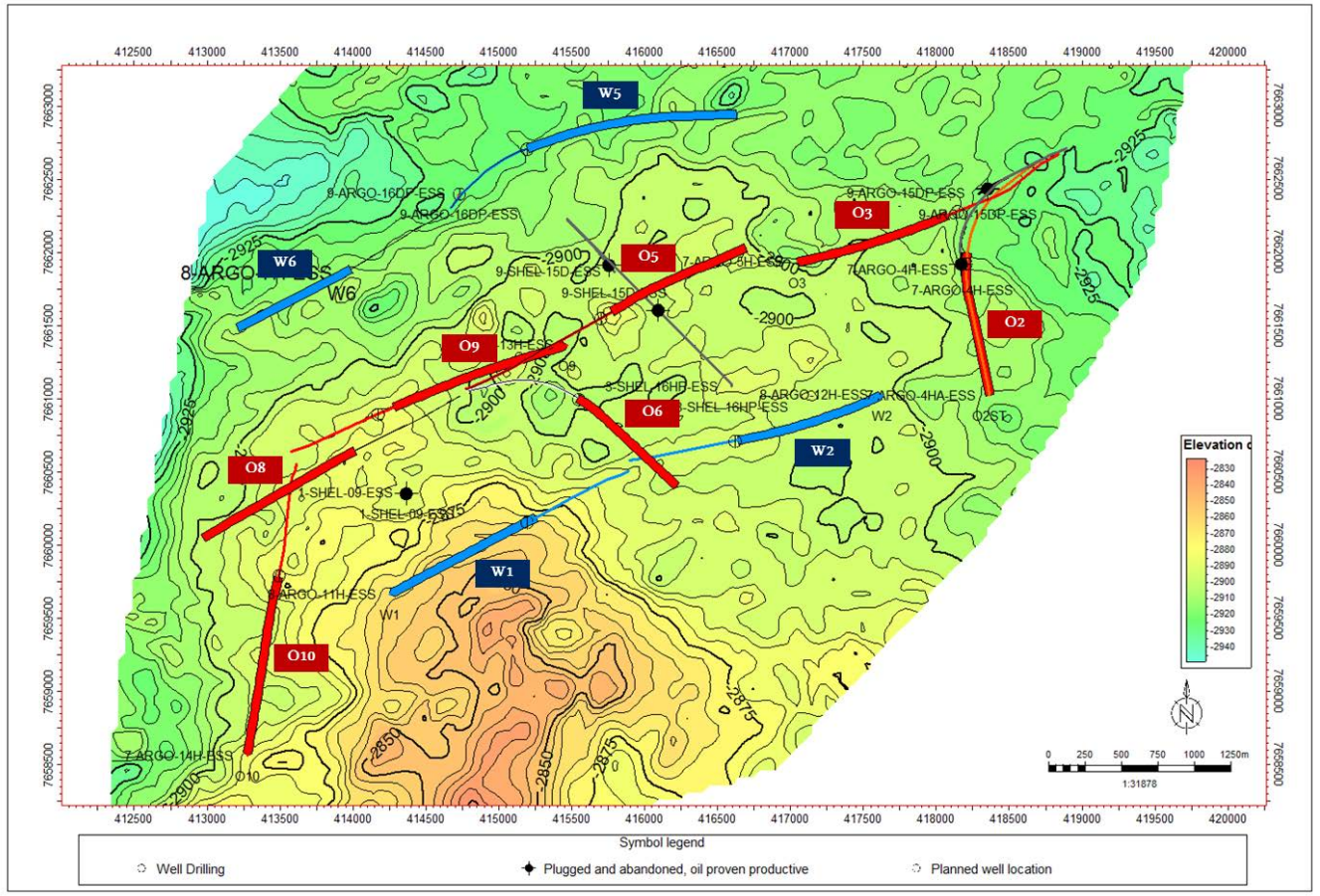
Overview of O-North Field Development

- Argonauta O-North Field – 1 of 5 fields in the Parque das Conchas
- Located in the Campos Basin, offshore Brasil
- Subsea development with 7 production and 4 water injection wells
- Subsea flow lines comingle into 1 production and 1 injection riser at FPSO Espirito Santo
- Lower Completion - OHGP Using 5-1/2” mesh sand screens with average OH length of ~1100 meters



Overview of O-North Field Development

Parameter	Description
Oil	API ~ 16, viscosity ~ 28 cP
Flow rate	Production: 5000 – 10000 bpd per well Injection: Up to 20000 bwpd per well
Water Cut	Model shows 0 to 45% within first 7 years
Wellbore fluid	Completion fluids: brine, breaker
Temperature	~ 57 ° C
Well condition	Temporary Abandonment: 4 – 8 months

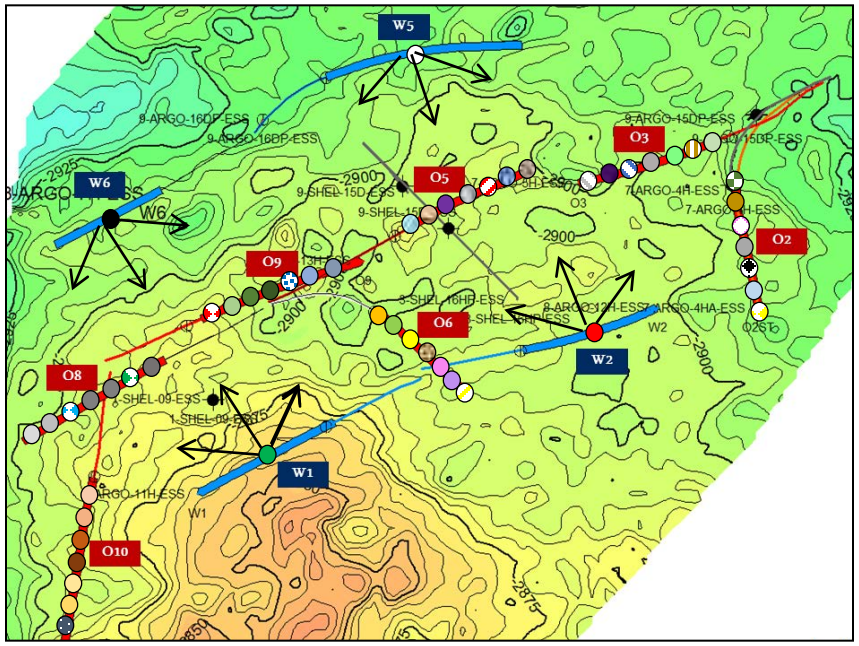


Objectives of Tracer Surveillance Program

- Acquire information on well connectivity and sweep of the reservoir to optimize water injection
- Provide improved interpretation and identification of high permeability channelling between injector and producer wells
- Establish points of water influx into production wellbores
- Provide information regarding oil inflow profile in producers without intervention
- Confirm clean-up in horizontal production wells

Project Design

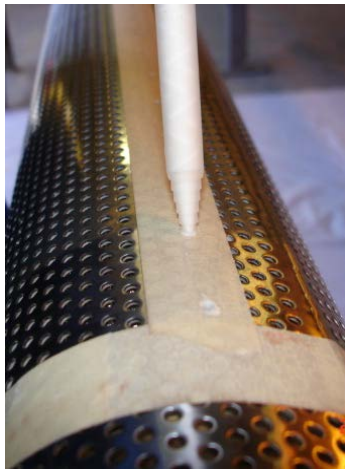
- 60 unique tracers applied;
  - 4 waterflood chemical tracers each injected into 1 of the 4 water injection wells
  - 4 inflow water tracers in each of the 7 production wells – 28 unique tracers in total
  - 3 inflow oil tracers in each of the 7 production wells – 21 unique tracers in total
  - 4 oil and 3 water inflow spare tracers
- Frequent sampling after well shut-in to measure transient tracer flow and quantify zonal oil inflow
- Routine produced water sampling to establish source of produced water and positional inflow within each of the water producing wells



Integration into Sand Screens

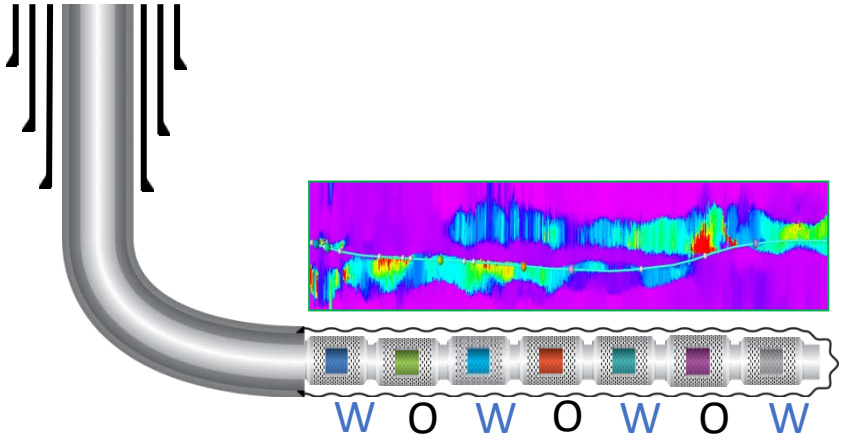
- Normal placement of tracers in sand screen is between base pipe and filter in drainage layer using pre-cast tracer strips before screen end caps are welded
- Sand screen selected had minimal drainage layer and no ribs
- Asymmetry of filter on pipe could not guarantee consistent annular space between outer shroud and filter

- Another option considered – liquid polymer addition between shroud and filter
- Liquid polymer selected due to practicalities of pre-cast strand loading and surface to volume ratio benefits
- Controlled release tracers added to manufactured sand screens by liquid polymer injection through shroud / curing. Work completed at screen vendor factory
- 32 unique water and 24 unique oil tracers manufactured in total



Tracer Deployment – Inflow Application

- Chemical Tracers RIH to specific positions of most interest
- Positions selected based upon geological sampling and logs acquired during drilling



Well	Wellhead	Top Depth of Tracer Screens (m MD)						
Producer	mMD	2800935-7/T-911	2800934-7/T-721	2800935-6/T-190A	2800934-8/T-165A	2800935-2/T-158D	2800934-2/T-715	2800935-20/T-806
O5	1675	3812	3860	4039	4098	4314	4398	4541
		2800935/3-T158B	2800934/6-T718	2800935/12-T158A	2800934/1-T729	2800935/18-T809	2800935/19-T804	2800934/5-T720
O8	1672	3550	3598	3765	3921	3981	4242	4278
		2800935/3 T-910	2800934/13 T-722	2800935/8 T-821	2800934/15 T-160D	2800935/1 T-194A	2800935/5 T-176A	2800934/21 T-169B
O3	1725	3532	3555	3782	3950	4046	4417	4465
		2800935-4/T-918	2800934-3/T-165F	2800935-8/T-176C	2800934-4/T-723	2800935-17/T-803	2800934-9/T-167D	2800935-11/T-158E
O6	1673	3499	3559	3726	3918	3978	4146	4170
		2800936/2 T-912	2800934/18 T-728	2800935/15 T-922	2800934/24 T-731	2800935/13 T-801	2800936/4 T-920	2800934/20 T-726
O10	1661	*3454*	*3489*	*3856*	*3987*	*4083*	*4261*	*4392*
		2800936/1 T-811	2800934/10 T-701	2800935/16 T-923	2800934/14 T-169C	2800936/5 T-914	2800934/23 T-730	2800935/9 T-193
O9	1663	*3355*	*3407*	*3680*	*3758*	*4084*	*4165*	*4410*
		2800934/17 T-741	2800935/10 T-158F	2800934/12 T-716	2800936/10 T-90B	2800934/16 T-706	2800936A/16 T-925	2800936/12 T-820
O2	1663	*3777*	*3789*	*3916*	*3928*	*4069*	*4081*	*4232*

Sample Strategy

- Hot stabilized oil used during initial flow to eliminate wax issues
- Sampling strategy used produced volume through subsea flow line to initiate sample collection
- Producer wells started sequentially with standard step rate testing / well shut-in pressure build-up testing
- Frequent fluid sampling during well start up to capture oil tracer time of arrival at surface

O2 & O3 Strategy

Time After Well Start-Up based upon 15,000 bbl/day total flow (hours)	Combined Volume Flow Past Sample Point After Well Start-Up (bbl)	Sampling Frequency
2 – 10	1200-6300	Every 5 minutes
10 –16.7	6300-10500	Every 15 minutes
16.7 - 31.5	10500-19700	Every 30 minutes
31.5 – 38	19700-23900	Every 1 hour
38 – 61	23900-38000	Every 2 hours
61 – 85	38000-53000	Every 3 hours
(*) 3.5 – 6.5 days	(*) 53000-98000	Every 6 hours
(*) 6.5 – 20.5 days	(*) 98000-308000	Every 12 hours
(*) 21 – 28 days	(*) 308000 – 420000	Every 3 days
(*) 28+ days	420000+	Every 7 days
(*) 56+ days	-	Every 14 days

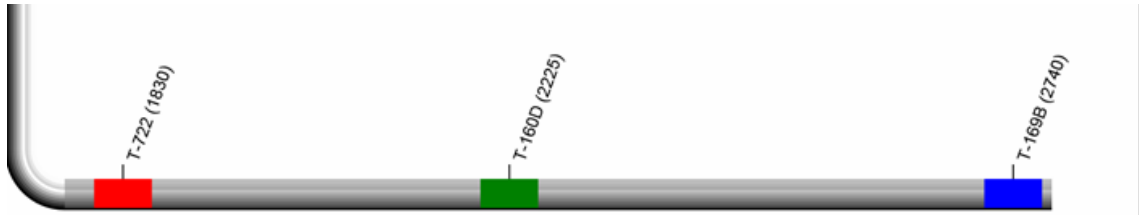
O5, O6, O8, O9 & O10 Strategy

Time After Well Start-Up based upon 15,000 bbl/day total flow (hours)	Combined Volume Flow Past Sample Point After Well Start-Up (bbl)	Sampling Frequency
3.3 – 10	2100-6300	Every 5 minutes
10 –16.7	6300-10500	Every 15 minutes
16.7 - 31.5	10500-19700	Every 30 minutes
31.5 – 38	19700-23900	Every 1 hour
38 – 61	23900-38000	Every 2 hours
61 – 85	38000-53000	Every 3 hours
(*) 3.5 – 6.5 days	(*) 53000-98000	Every 6 hours
(*) 6.5 – 20.5 days	(*) 98000-308000	Every 12 hours
(*) 21 – 28 days	(*) 308000 – 420000	Every 3 days
(*) 28+ days	420000+	Every 7 days
(*) 56+ days	-	Every 14 days

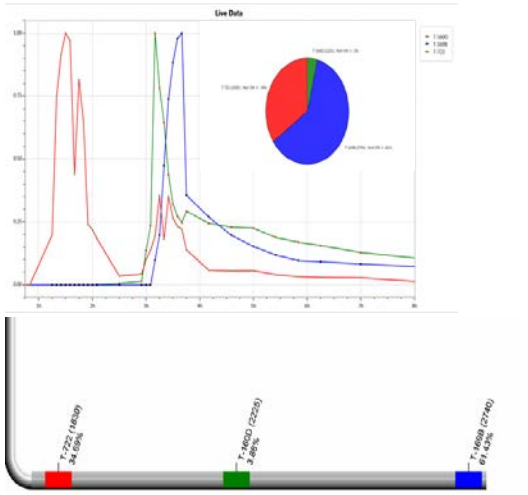
Production Well Results – ON3

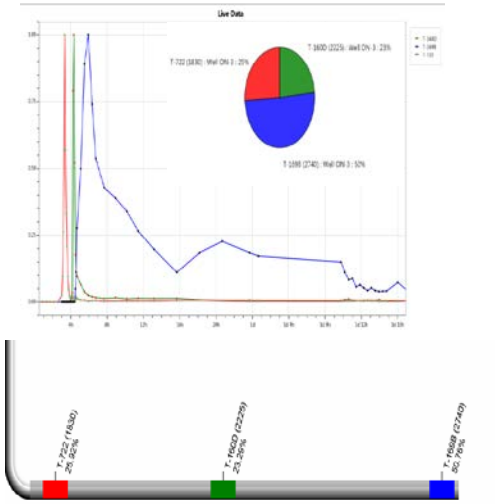
Well ON3

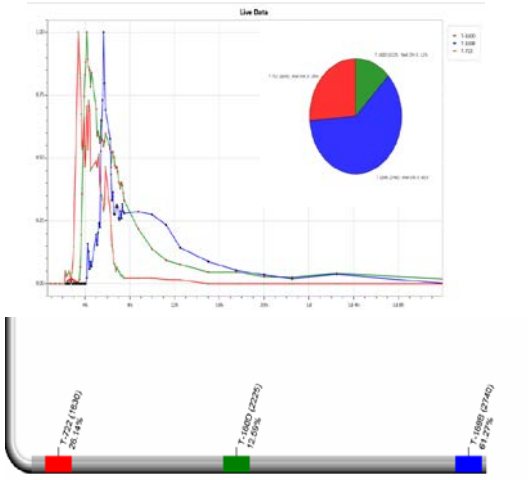
Lower Completion Run May 2013

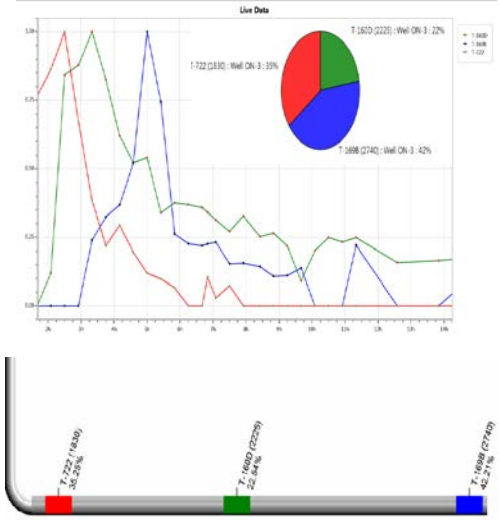


Test Number	Well Start-up	Well Start-Up Correction For Subsea Flow Line Volume	Well Shutdown
1	15:45hrs Oct 9 2013	19:05hrs Oct 9 2013	00:30hrs Oct 18 2013
2	22:15hrs Oct 21 2013	00:20hrs Oct 22 2013	06:50hrs Oct 27 2013
3	17:00hrs Nov 22 2013	20:05hrs Nov 22 2013	09:10hrs Dec 4 2013
4	22:40hrs Dec 14 2013	01:20hrs Dec 15 2013	13:08hrs Jan 16 2014



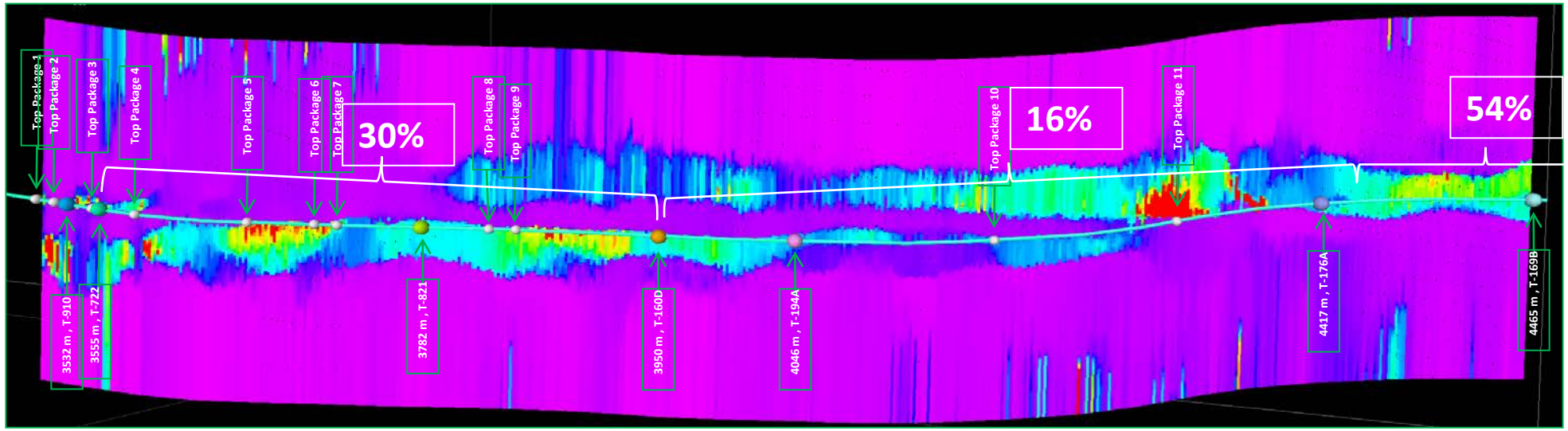






Production Well Results – ON3

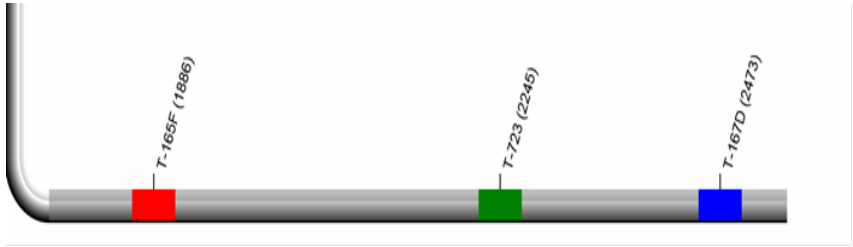
- Reviewing all data reveals an average flow contribution across well is split:
  - Heel 30%
  - Mid 16%
  - Toe 54%
- With higher quality sands in the first third and last third of the well providing preferential oil flow



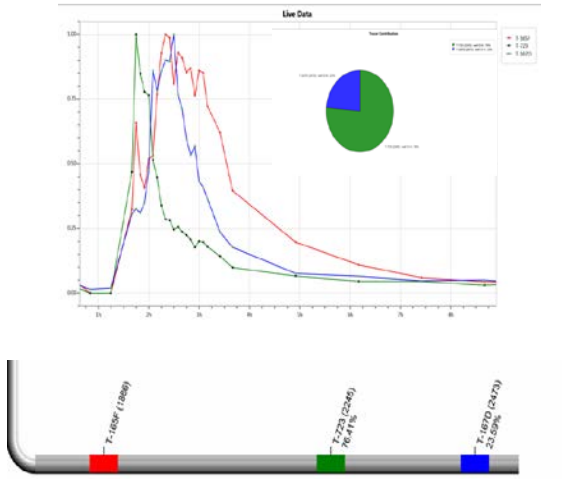
Production Well Results – ON6

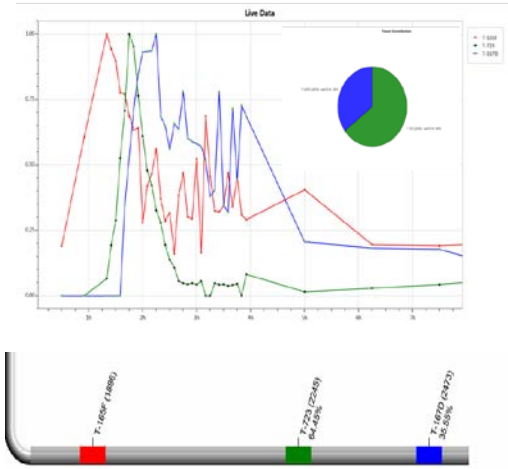
Well ON6

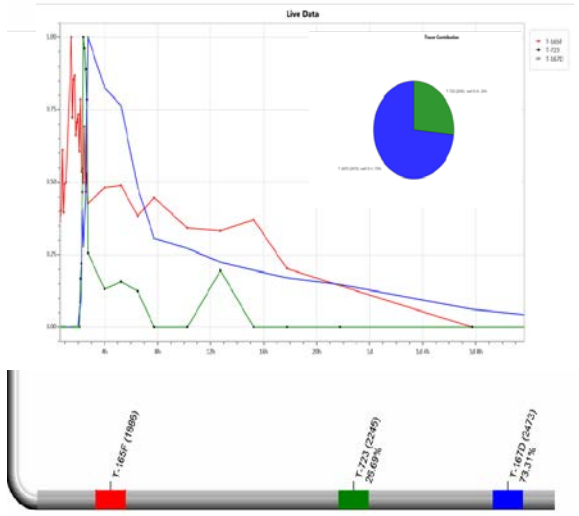
Lower Completion Run April 2013

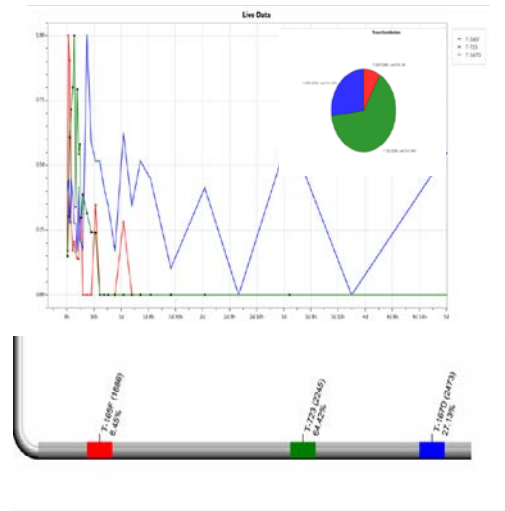


Test Number	Well Start-up	Well Start-Up Correction For Subsea Flow Line Volume	Well Shutdown
1	11:40hrs Oct 1 2013	16:30hrs Oct 1 2013	20:02hrs Oct 8 2013
2	19:30hrs Oct 11 2013	23:50hrs Oct 11 2013	00:30hrs Oct 18 2013
3	18:15hrs Nov 22 2013	00:25hrs Nov 23 2013	09:10hrs Dec 4 2013
4	17:50hrs Dec 14 2013	01:00hrs Dec 15 2013	16:00hrs Jan 6 2014



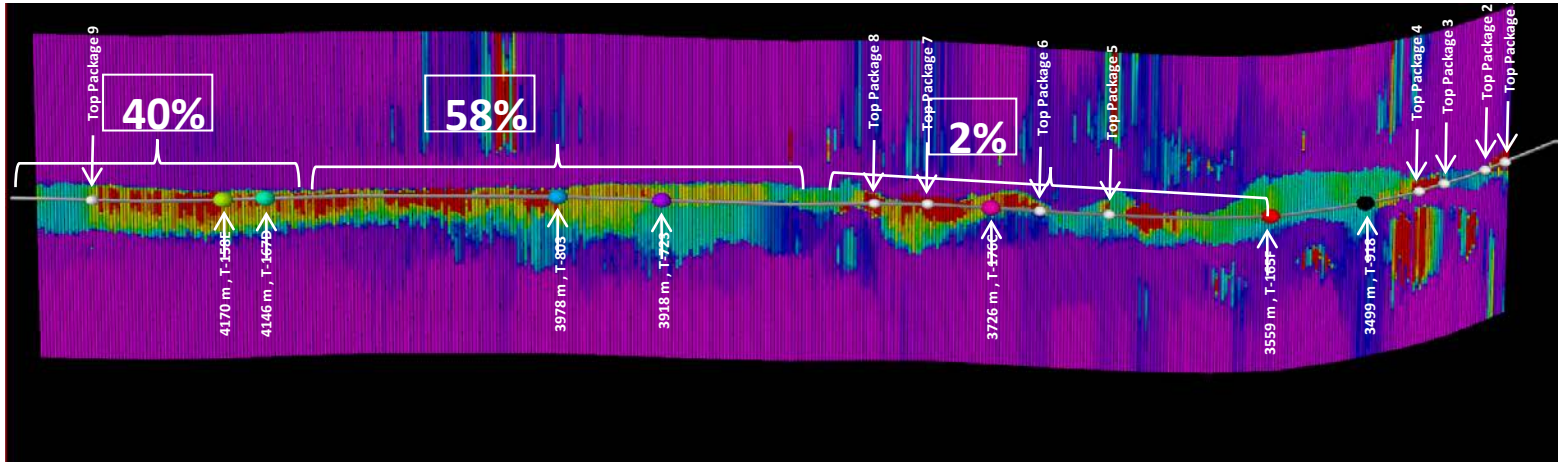






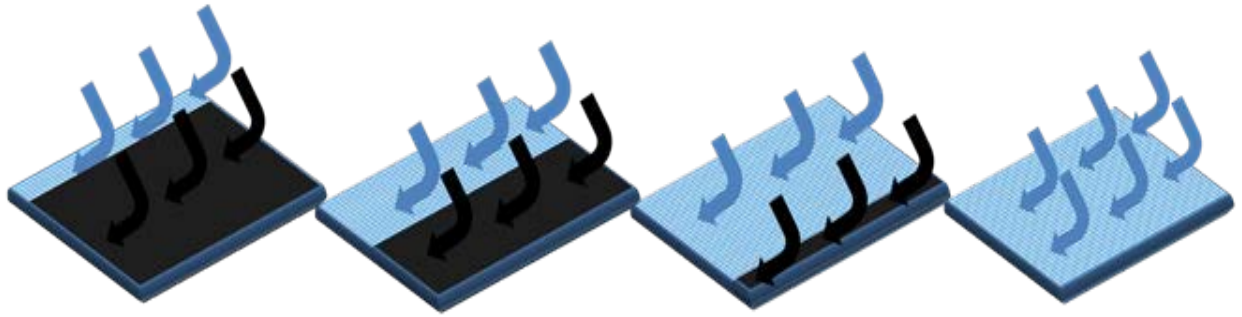
Production Well Results – ON6

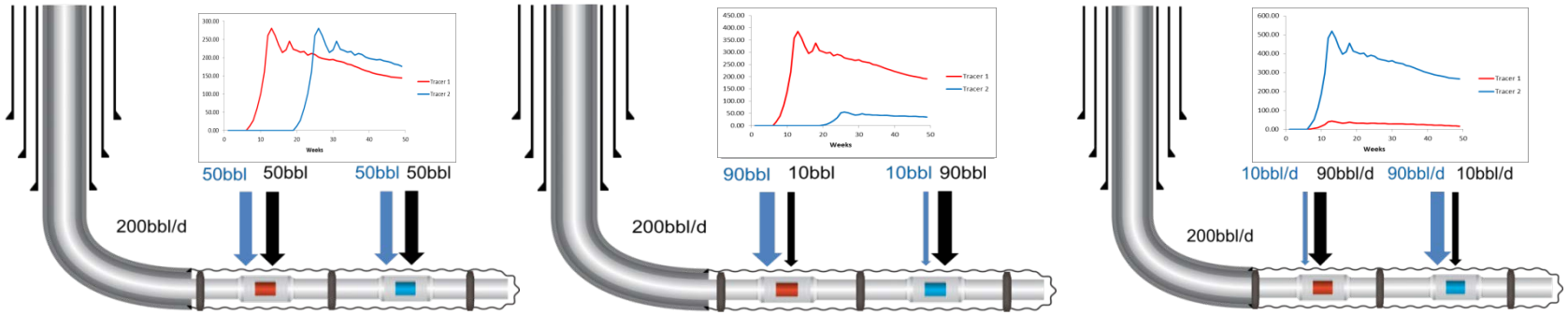
- Reviewing all data reveals average flow contribution across well is:
  - Heel 2%
  - Mid 58%
  - Toe 40%
- Significant amounts of shale found to exist in the heel section and quality sands in the middle and last third of the well
- Mid section tracer produced before heel during first clean out with contribution from the heel after significant flow suggesting in addition to geological issues inadequate initial clean out



Produced Water Data Analysis

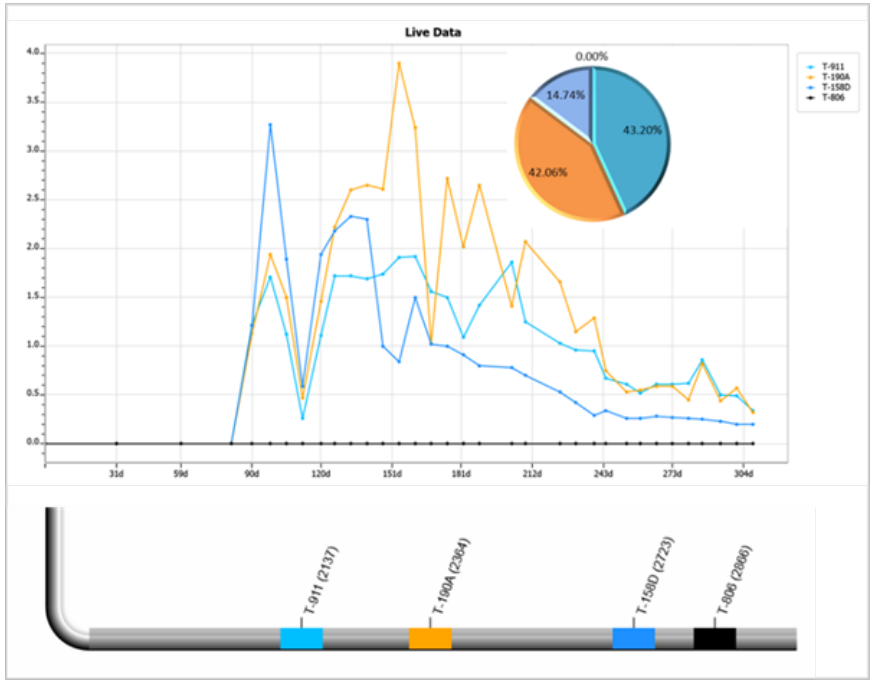
- The larger the surface area exposed to target fluid the more tracer will release and hence its concentration will be higher in produced fluids for a specific overall flow rate





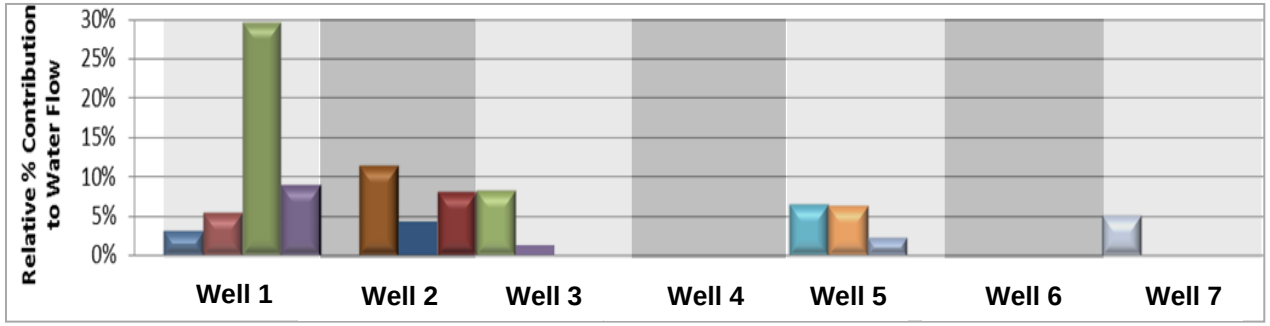
Produced Water Data Analysis

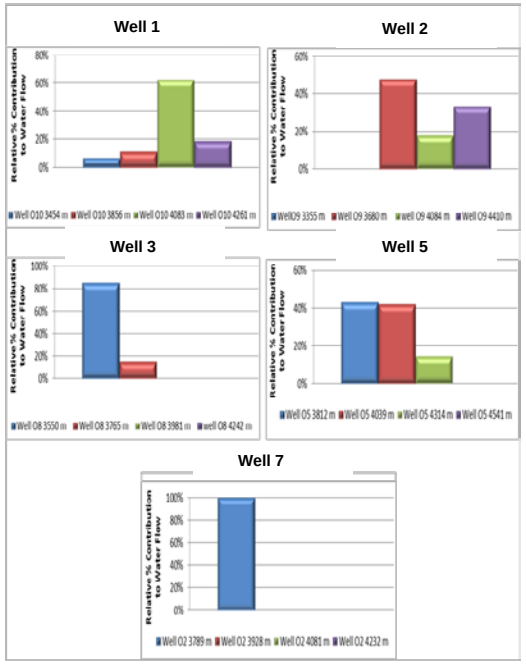
- Source of water determined by identification of individual water tracers in produced fluid in commingled production riser
- To date 1 seawater injection well has broken through and 5 producer wells are producing formation water
- Mass of Inflow tracer calculated integrating concentration of each tracer over time with volume of water flow through sample location
- Tracer responses corrected for surface area variation and differences in release rate

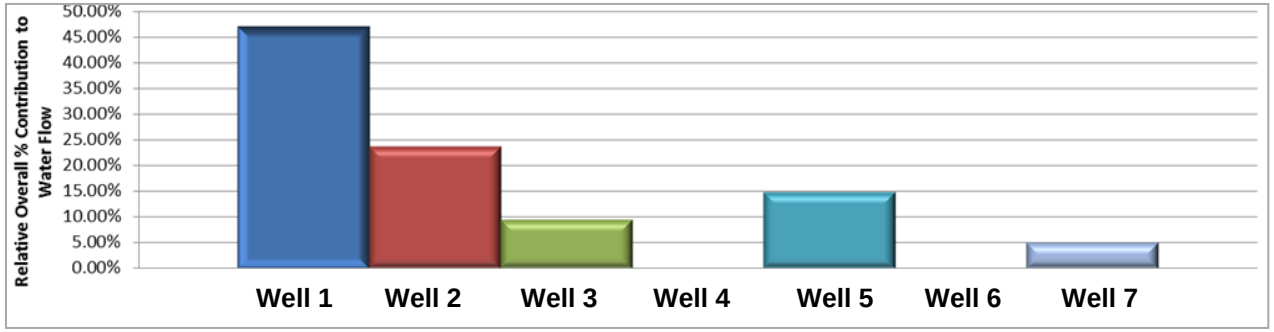


Produced Water Data Analysis

- Tracer release normalised against each other to calculate % contribution from each position and each well
- The 5 wells showing water tracers in varying amounts tie in with MPFM measurement







Summary

- The use of tracers has provided the following information:
  - Confirmed long OHGP horizontal well clean out has been achieved in all production wells
  - Provided quantitative data on oil inflow in each of the 7 wells that can be used alongside geological data to refine reservoir simulation models and predict future fluid inflow
  - Determined 5 wells have started to produce water after detection of water in oil at the common flow line
  - Confirmed positions along each producer at which water is flowing into each well
  - Confirmed 1 seawater injection well breakthrough. Optimized water injection.

- Sampling and tracer analysis continuing allowing confirmation of further produced water source and injection water breakthrough. Analysis of the waterflood tracer curves will allow channelling and sweep efficiency to be established once additional data is generated