Integrating Production and XPT Analysis for Field Development in a Complicated Carbonate Reservoir, Bahrain Field*

Omar Matar[1] and Khamis Al Abdali[1]

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[1]Subsurface, Tatweer Petroleum, Sukhair, Bahrain (omar_matar@tatweerpetroleum.com)

Abstract

For mature oil fields with complicated reservoir architecture, reservoir surveillance is a key to track the reservoir performance. The reservoir surveillance may include various monitoring tools from complicated horizontal production logging tools down to regular well tests. One of the key surveillance techniques is running formation pressure measurement tools such a PressureXpress (XPT) or as historically known to the industry, RFT. This article describes the use of this important tool, integrated with production data to understand the reservoir production and depletion behavior and hence support the field development plan. This article describes a study done on the Ostracod and Magwa reservoirs, which are complicated carbonate reservoirs in Bahrain Field.

The Ostracod Zone is a sequence of interbedded limestones and shales in the Upper Rumaila Formation of the Middle Cretaceous Wasia Group. It is over 200 feet thick and consists of three main units: B0, B1 and B2. The Magwa reservoir is the lower member of the Rumaila Formation. It is 120 feet thick and conformably underlies the Ostracod reservoir. It consists of three main units: M1, M2 and M3. This study had four main objectives: (1) Evaluating the pressure depletion from the initial reservoir pressure for each unit in both reservoirs. This defined the existence of flow barriers in this inter-bedded complicated carbonate, (2) Evaluating the relationship between pressure depletion in each unit and the spacing between offset wells to XPT location, (3) Evaluating the Ostracod/Magwa pressure depletion per unit with time, and (4) Linking the pressure depletion to the cumulative production from the area offseting the XPT data. The results of this study helped define the depletion risk of the future infill opportunities in such complicated reservoirs. It also helped on locating the highly depleted units and determining the optimal locations for the new infill wells.

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Integrating Production and XPT analysis for field development in Complicated Carbonate Reservoir

Omar Matar –Associate Reservoir Engineer
Khamis AlAbdali –SRMT head

GEO 2016

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Outline

- Objective
- Reservoirs Overview.
- OST/MAG XPTs data Overview.
- Well by Well XPT analysis
- Units XPTs with spacing analysis.
- XPT with time
- XPTs pressure vs. Production Cumulative
- Conclusion
- Recommendation

Objective

This study had four main objectives:

1) Evaluating the pressure depletion from the initial reservoir pressure for each unit in both reservoirs.

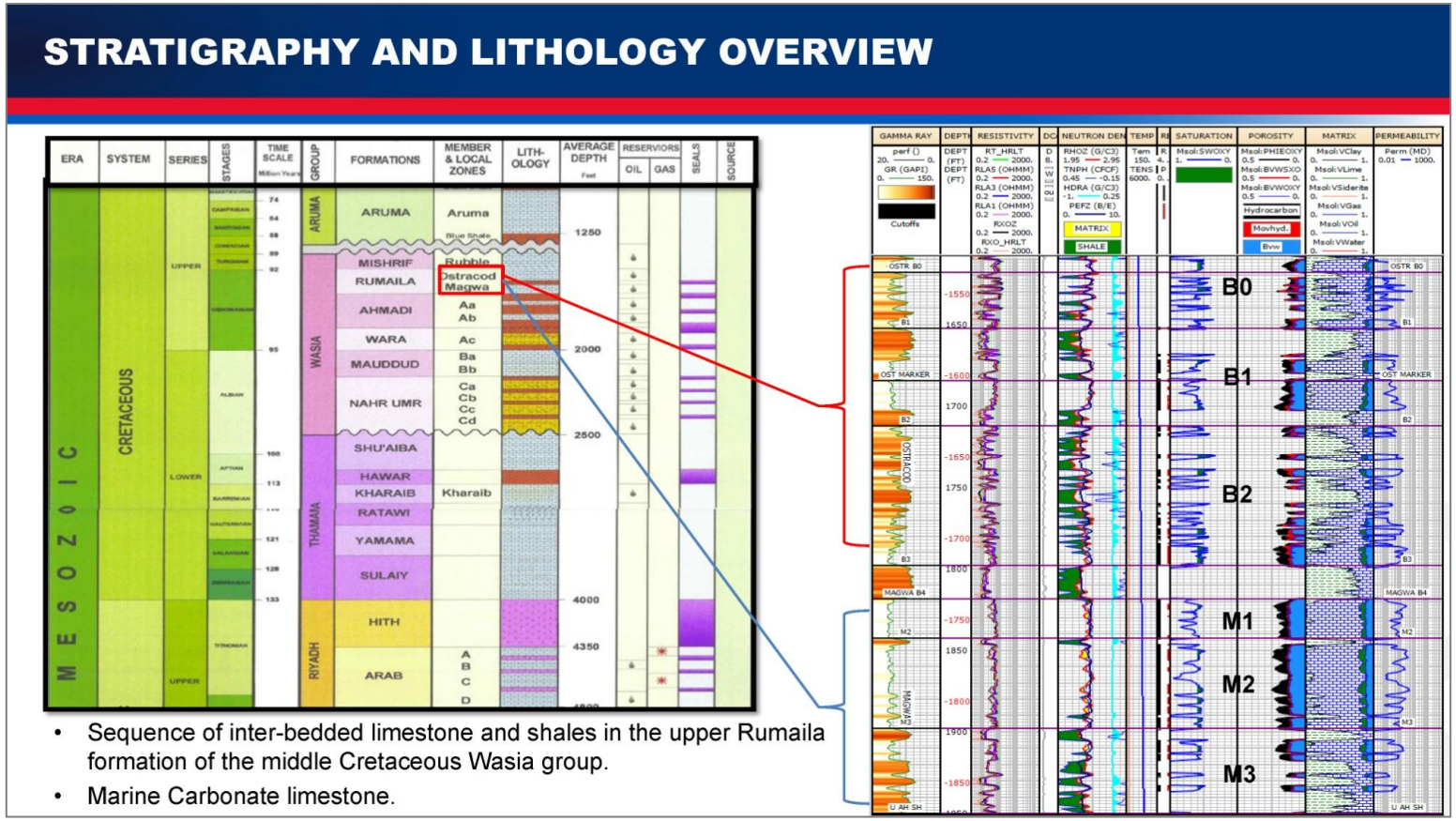
2) Evaluating the relationship between pressure depletion in each unit and the spacing between offset wells to XPT location.

3) Evaluating the Ostracod / Magwa pressure depletion per unit with time:

4) Linking the pressure depletion to the cumulative production from the area wells to the XPT data.

The results of this study should help defining:

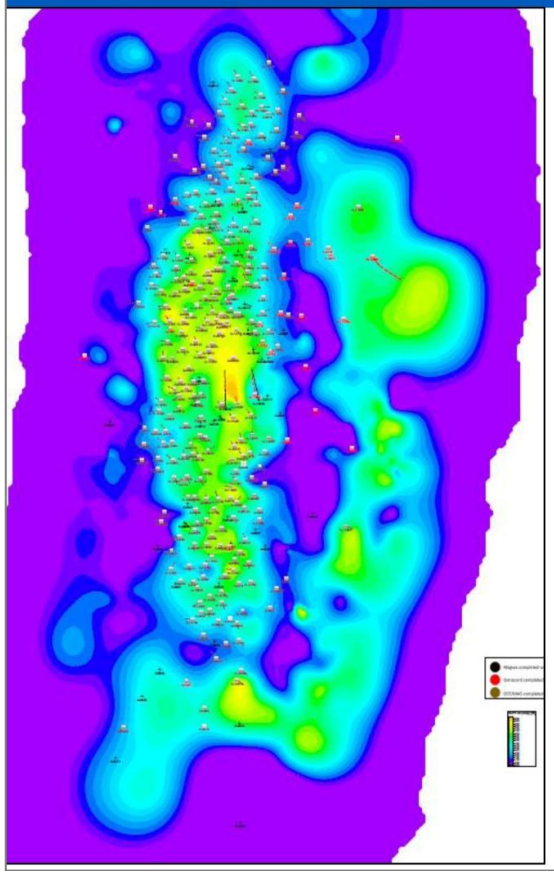
1) **The depletion risk on the future infill opportunities in such complicated reservoirs.**
2) **Locating the highly depleted units and determining the optimal locations for the new infill wells.**



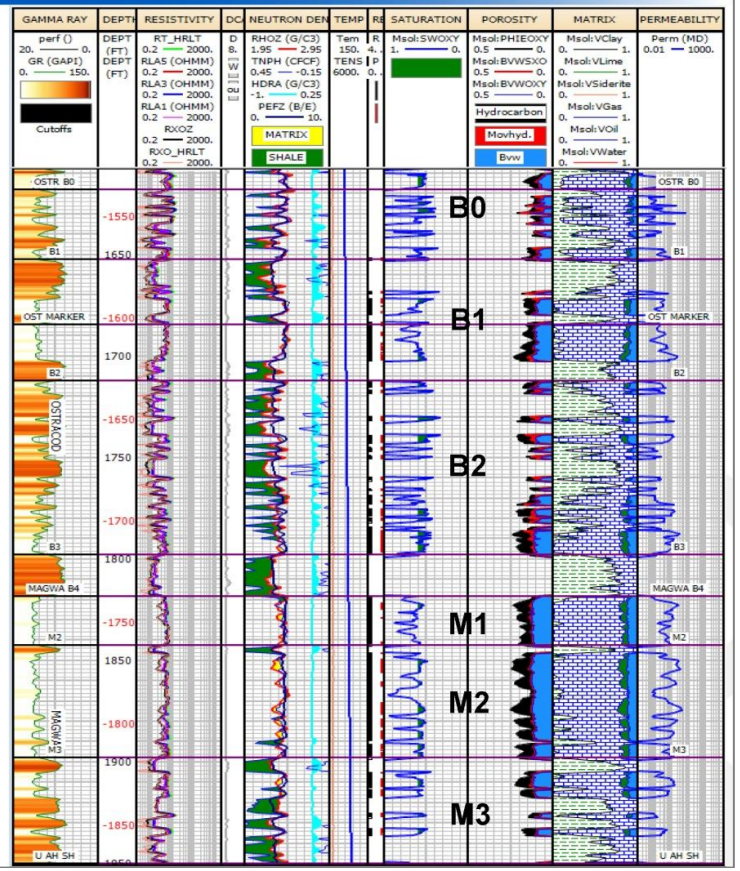
Presenter's notes:

- Ostracod and Magwa reservoirs are complicated carbonate reservoirs in the Bahain Field. Ostracod Zone is a sequence of interbedded limestone and shales in the Upper Rumaila Formation of the Middle Cretaceous Wasia Group. It is over 200 feet thick and consists of three main units B0, B1 and B2. Magwa reservoir is the lower member of the Rumaila Formation. It is 120 feet thick conformably underlies the Ostracod reservoir. It consists of three main units M1, M2 and M3.
- The Ostracod and Magwa reservoir is the Upper Member of the Rumaila Formation in the Bahrain Field. The Ostracod was deposited in a passive margin setting. Subsequent uplift and erosion associated with Late Cretaceous compressional tectonics has removed the entire Rubble zone and the upper portion of the Ostracod reservoir from the crest of the Bahrain Anticline
- The Ostracod/Magwa reservoir consists of interbedded limestone and shale that underlie the Rubble Reservoir on the flanks of the Bahrain structure, and directly underlie the Blue Shale on the crest of the structure where the Rubble and the upper portion of the Ostracod have been eroded

RESERVOIR PROPERTIES



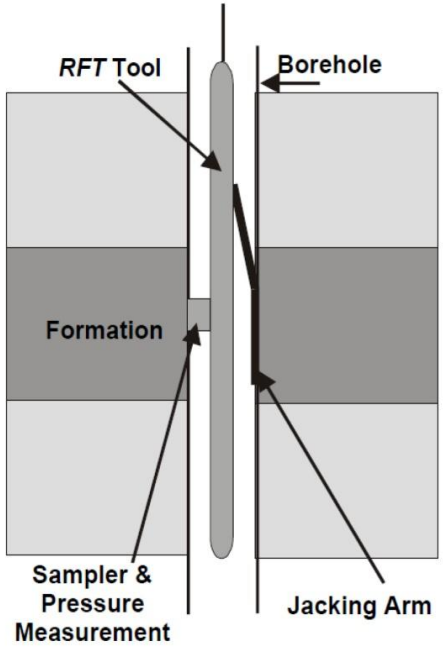
Ostracod	
Thickness	Gross 160 ft, Net 48 ft
Porosity	14-20%
Average K	0.1-2 md
Initial Sw	45%-55%
Datum	1450 ft
Initial pressure at datum	790 psi
Magwa	
Thickness	Gross 130 ft, Net 46 ft
Porosity	16-20%
Average K	0.2-3 md
Initial Sw	40%-50%
Datum	1688 ft
Initial pressure at datum	900 psi

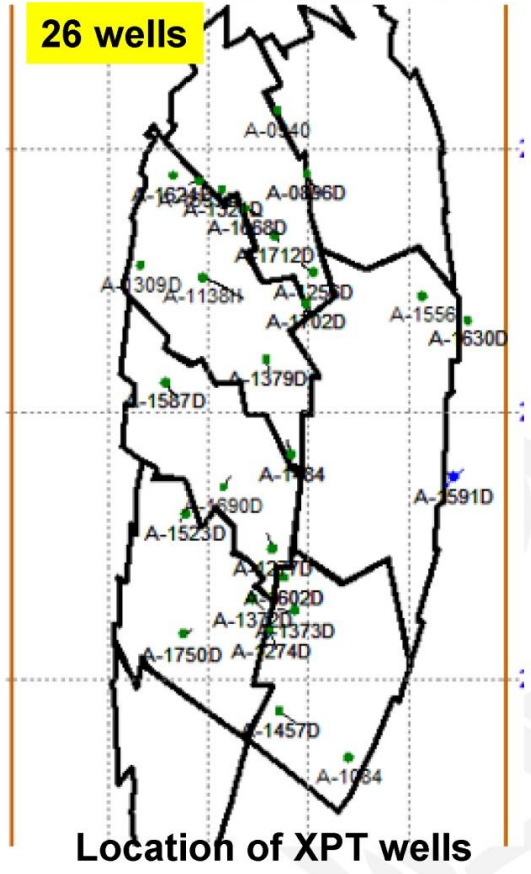


Presenter's notes:
Ostracod and Magwa have similar reservoir quality, with slightly better properties in Magwa. The thickness of the reservoir is 200 ft and 130 ft for Ostracod and Magwa respectively. Ostracod and Magwa are both divided into six main layers. However, each of these six main layers can also be divided into sub-reservoirs due to the existence of interbedded shales. The porosity of Ostracod ranges between 14%-20%, as compare to Magwa which ranges around 16%-20%. Core permeability was found to be 0.25 mD in Ostracod, and 0.41 in Magwa and this reflects the matrix permeability. The effective permeability is enhanced in most areas by natural fractures.

OST/MAG XPTs data Overview

- XPT (SLB) : Wireline formation testing (*RFT*).
- XPT Pressure data from 26 wells scattered over the field.
- Wells completed in OST/MAG located mainly in the center.
- Low confidence data such as Tight Test, Not stabilized, Not fully Stabilized, No Seal, Supercharged and Dry Test were eliminated from the data used in this study.





Location of XPT wells

Presenter's notes:

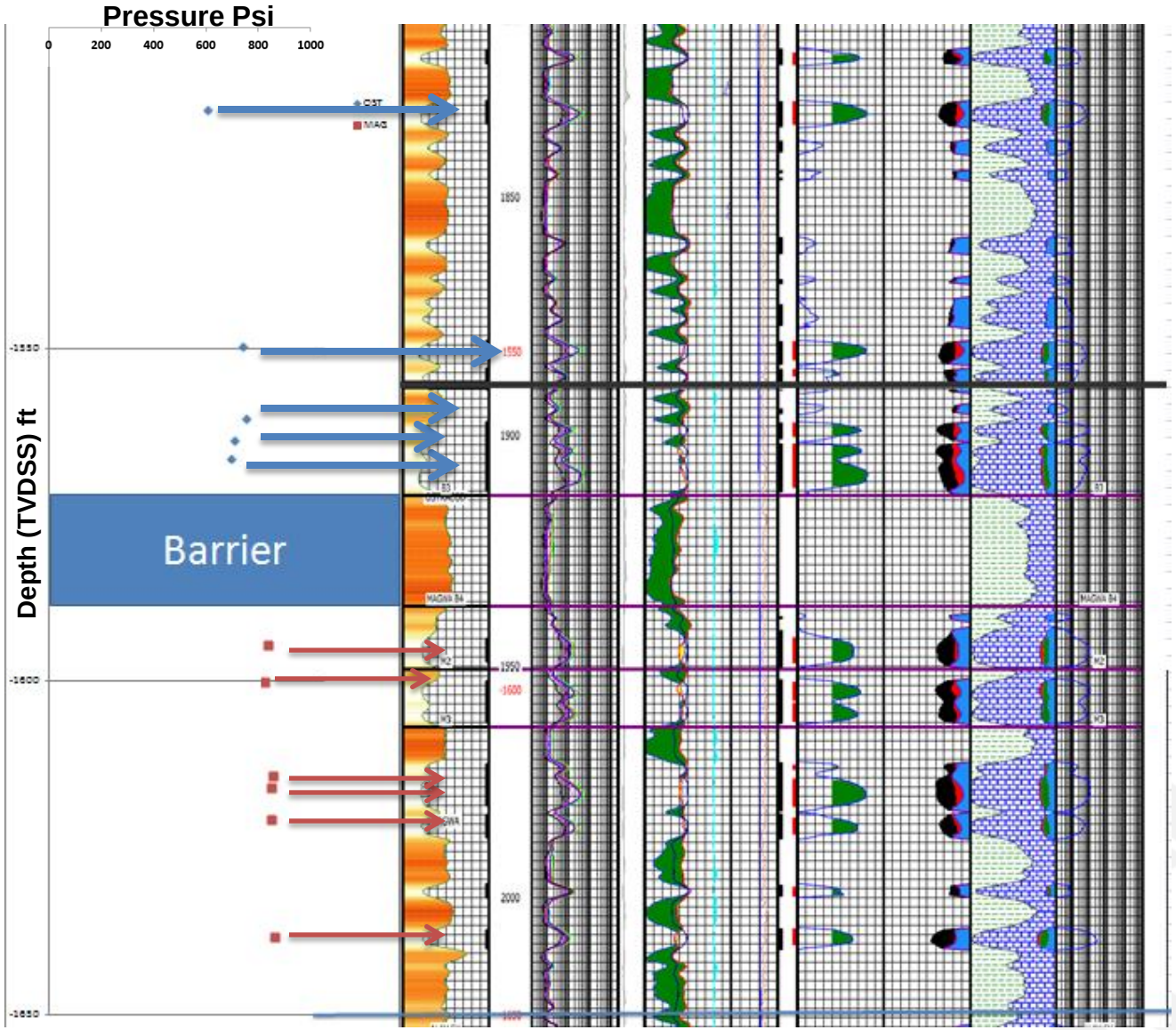
- This operation is carried out in an open hole during wireline logging operations. The wireline tool is lowered down the uncased hole to the point of interest. It is then jacked and sealed against the borehole wall. fluid pressures are then taken.
- Wells completed in Ostracod Magwa with XPT have XPT points covering all units compared to other wells

Well by Well XPT analysis (e.g. A-1372D)

Compared the Pressure Vs. TVDSS Plot with the well logs to identify the correct zone:
OST :B0,B1,B2
MAG: M1(B4),M2,M3) .
This is done for all wells

Main Conclusion:

XPT shows different reservoir units have different depletion –presence of flow Barriers between the units



Well by Well XPT analysis (e.g. A-1372D)

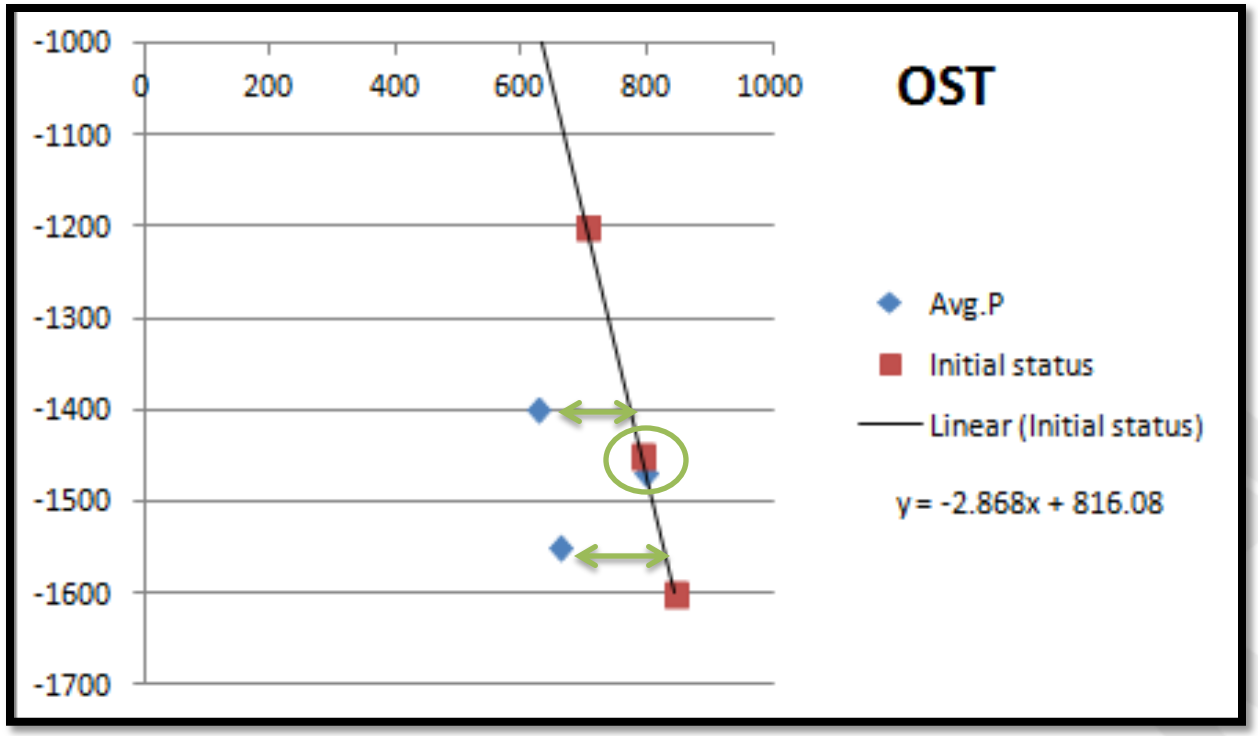
Objective:

To determine the depletion per units

Procedures:

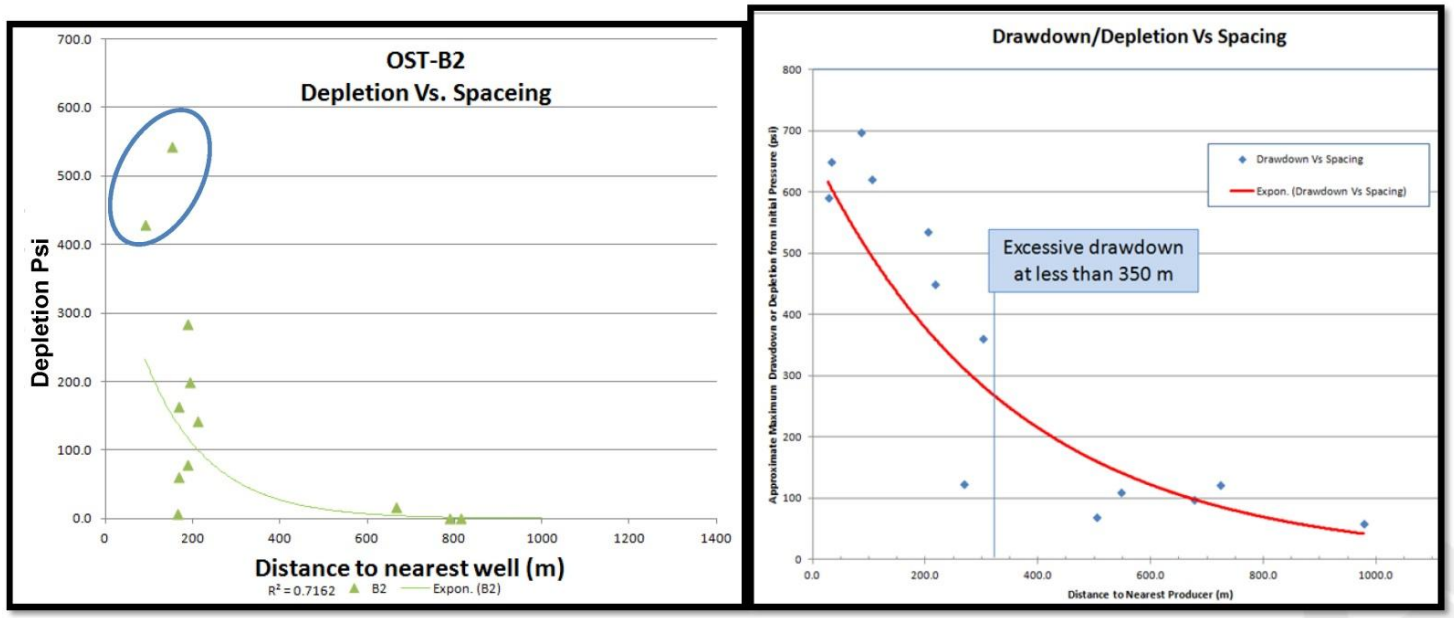
- **The average pressure and TVDSS for each zone was calculated .**
- **The initial pressure for each certain TVDSS was calculated**
- **The depletion at each zone was then determined**

Unit	avg.TVDSS	average P	initial P at TVDSS	Depletion
B0	-1400.28	624	773	149
B1	-1469.245	797	797	0
B2	-1550.85	660	825	165
M1	-1594.19	790	867	78
M2	-1599.85	781	869	88
M3	-1622.03	808	877	69



Units XPTs with spacing analysis

OST (B2) Depleted pressure Vs. Spacing Plot:

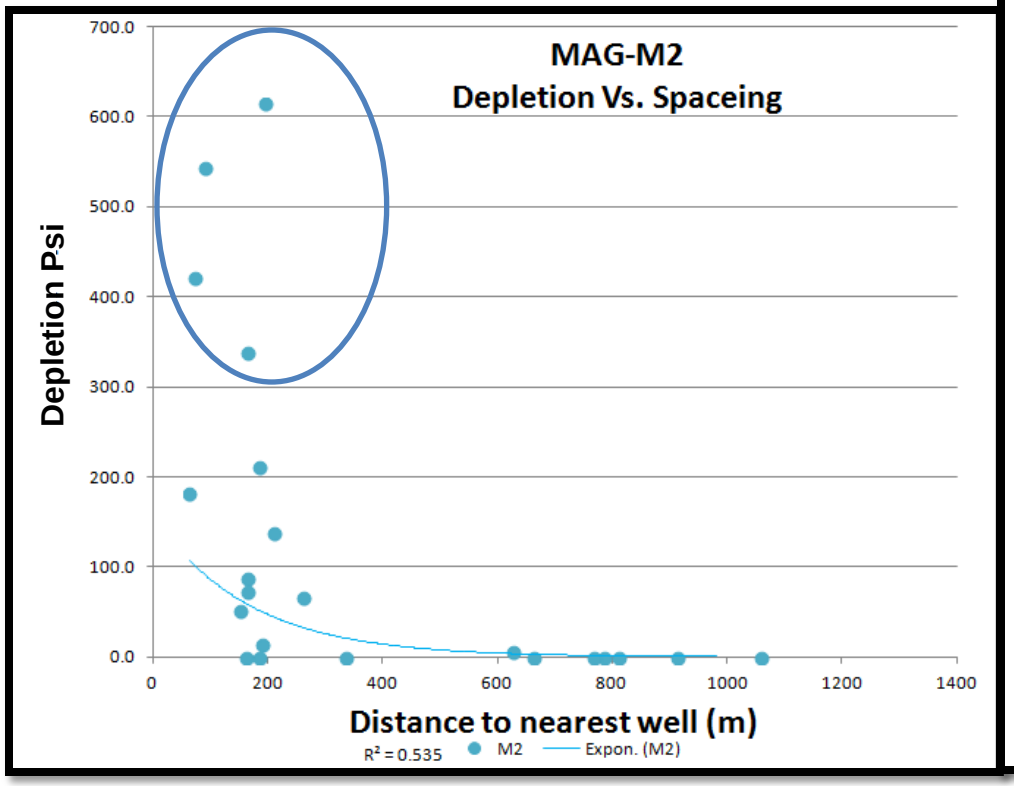


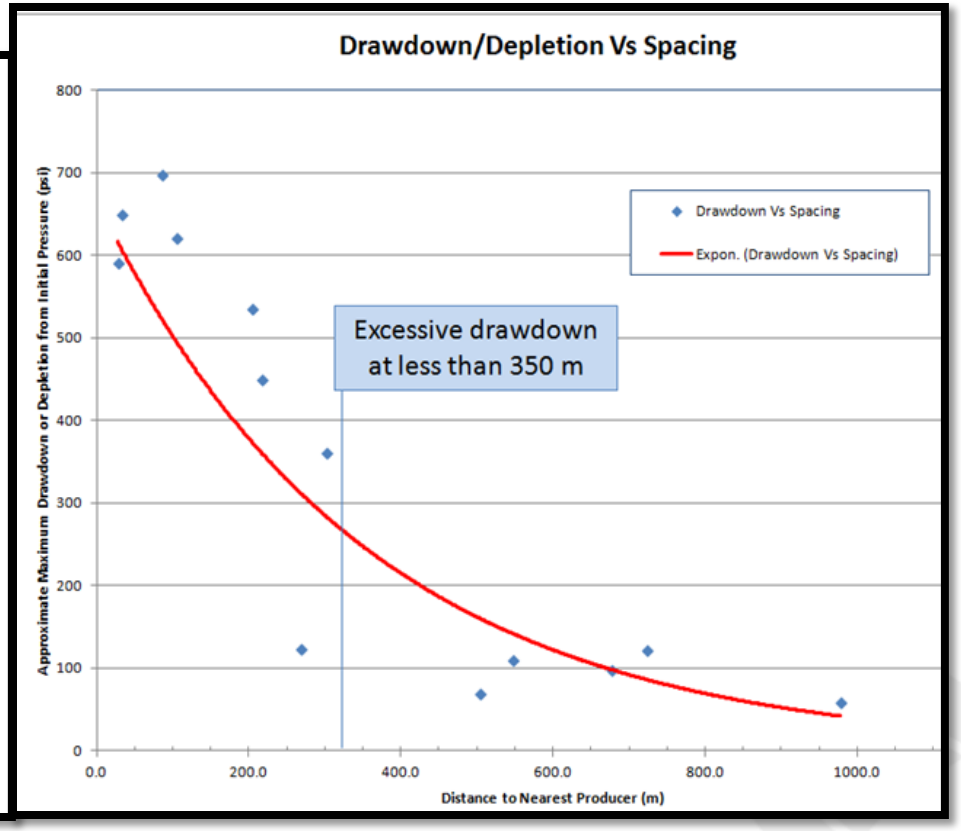
1. 2 out of 15 points has depletion > 300psia
2. Strong variation on depletion at same distance (22% depleted > 300psia at less than 200m spacing)

Presenter's notes: The IRT plot (plot in the right) is based on the average pressure of all units for both reservoirs and it shows that the depletion pf pressure increased significantly when the distance to the nearest offset well exceeds 350 m, but the picture was not the same when we zoom into individual units.

Unit per Unit XPT analysis

MAG (M2) Depleted pressure Vs. Spacing Plot:

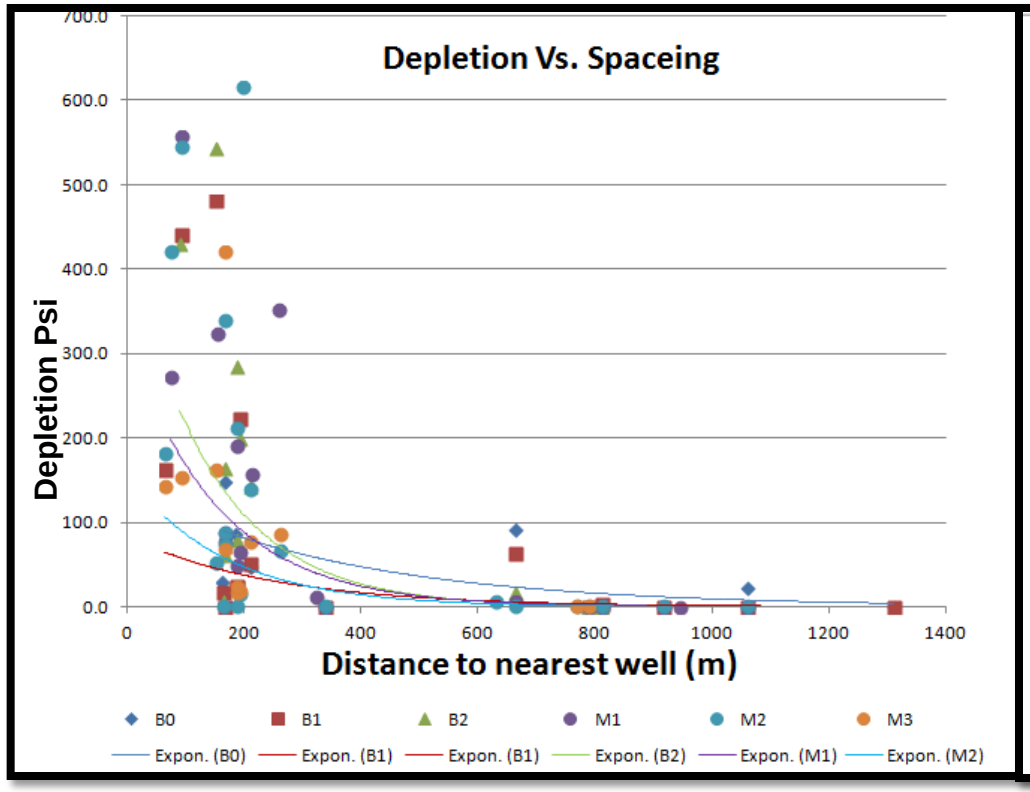


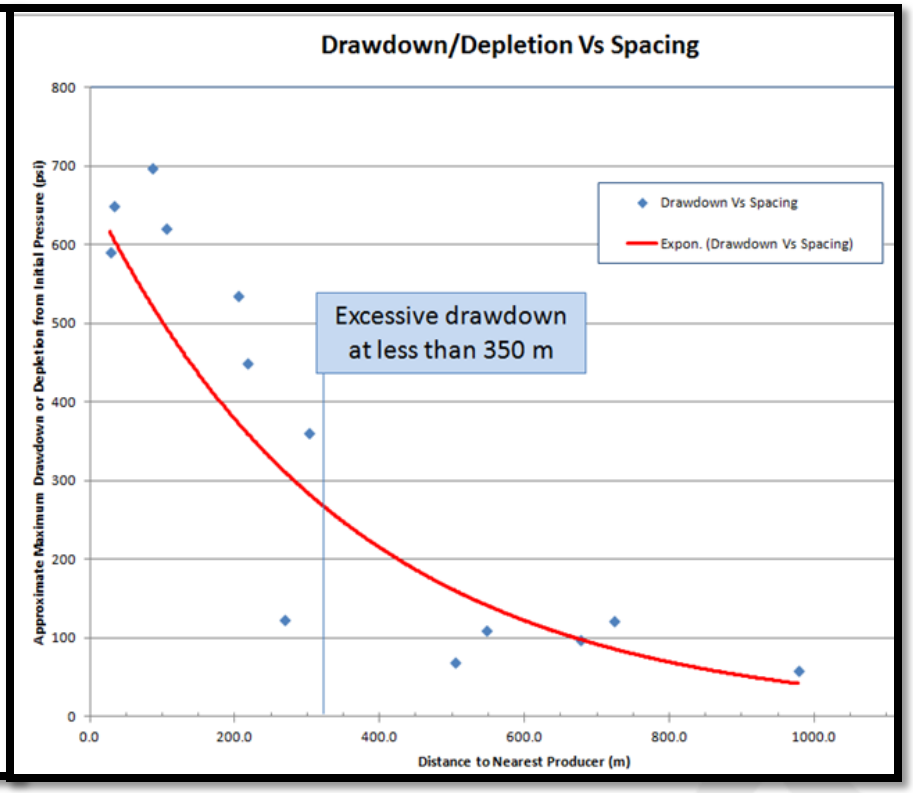


1. 4 out of 18 points has depletion > 300psia
2. Strong variation on depletion at same distance (30% depleted > 300psia at less than 200m spacing)

Unit per Unit XPT analysis

Combined zones plot :





Observation

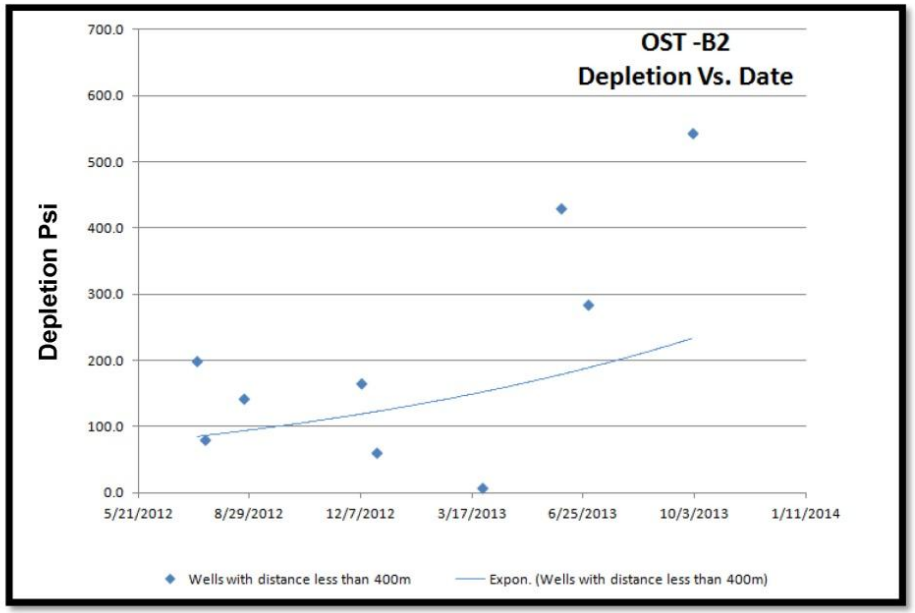
1. 14 out of 84 points has depletion > 300psia (17%)
2. 22% depleted > 300psia at less than 200m spacing

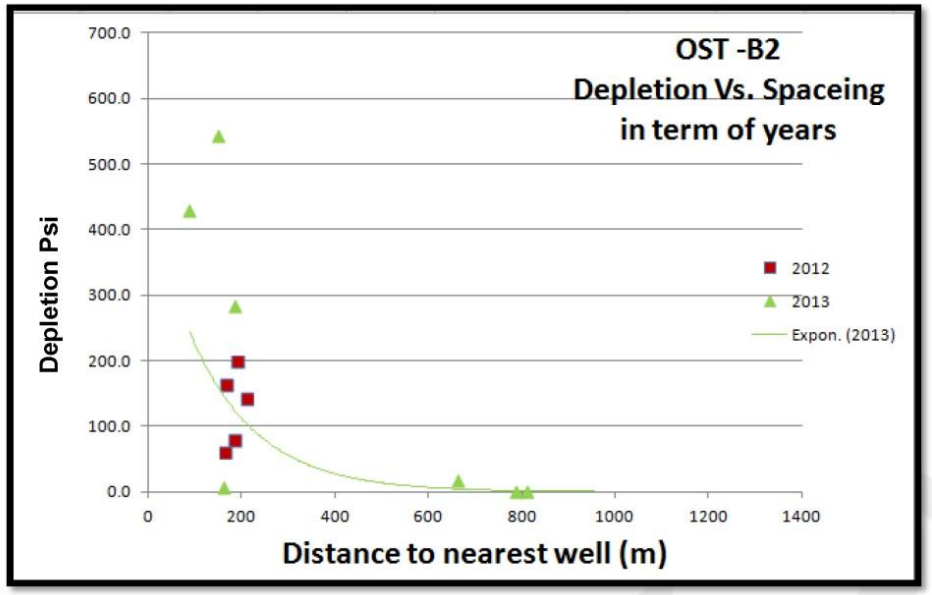
Conclusion:

1. Different units shows different depletions
2. It is difficult to conclude optimum spacing from the depletion vs. spacing plot

XPTs with time

- Obvious trend with time

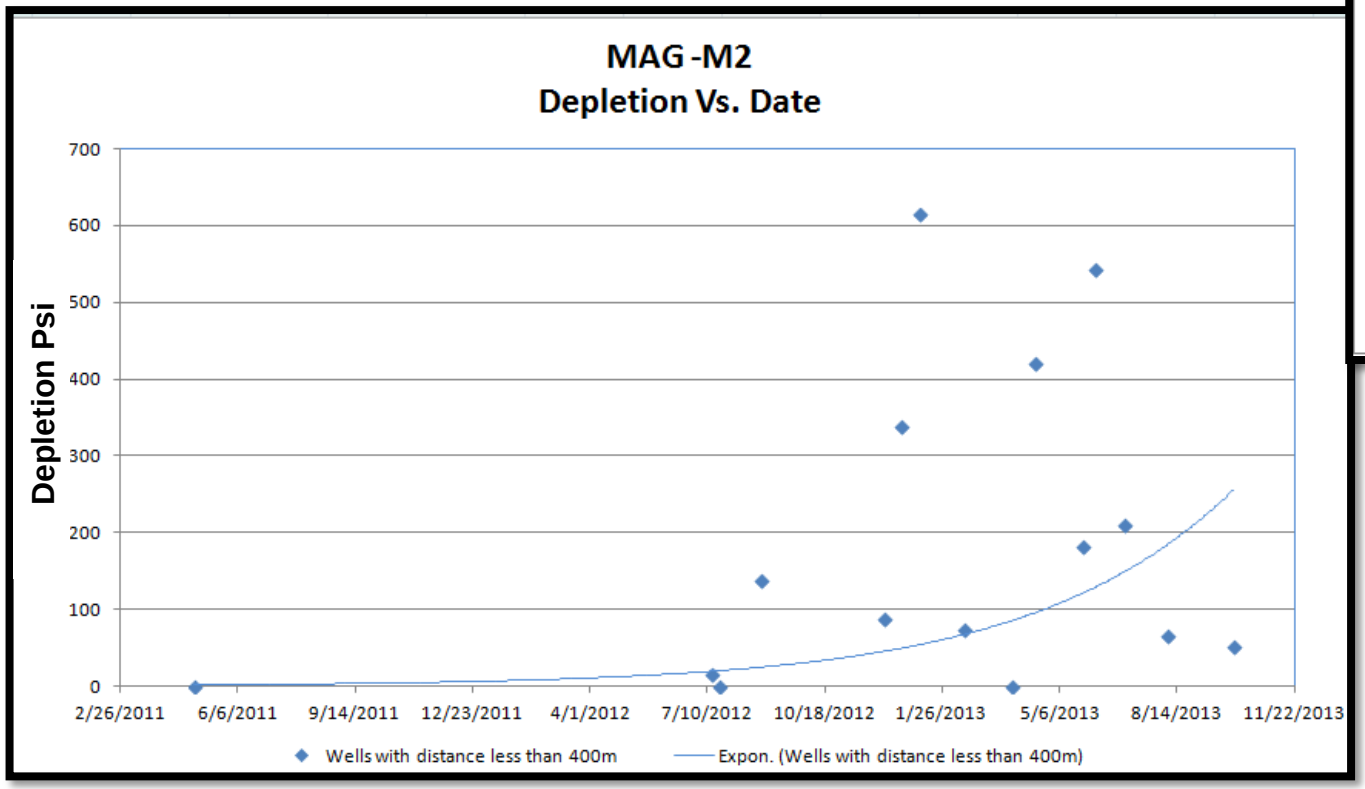


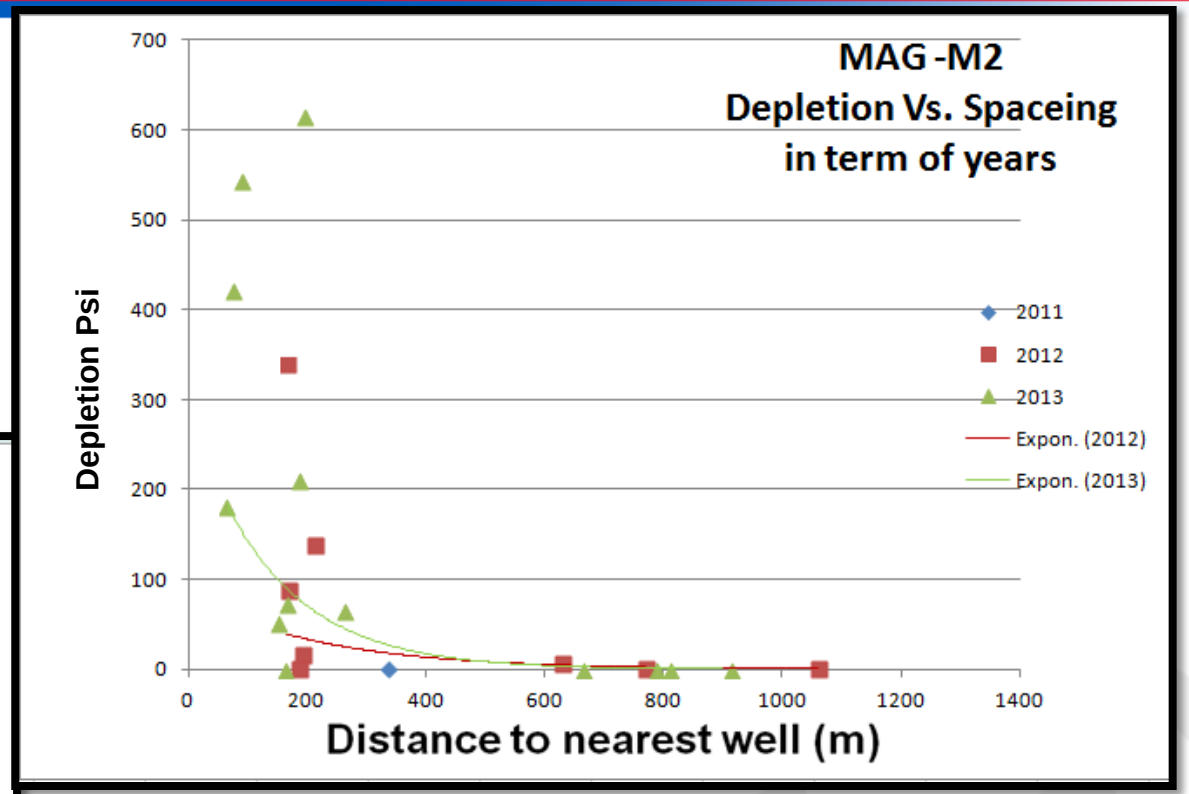


Presenter's notes: Other unit in OST showed same trends

XPTs with time

- M2 has big variation on depletion in 2013 (from 0 psia to 600psia)
- Not necessarily related to well location, therefore, well by well analysis was done to understand the reason for each well

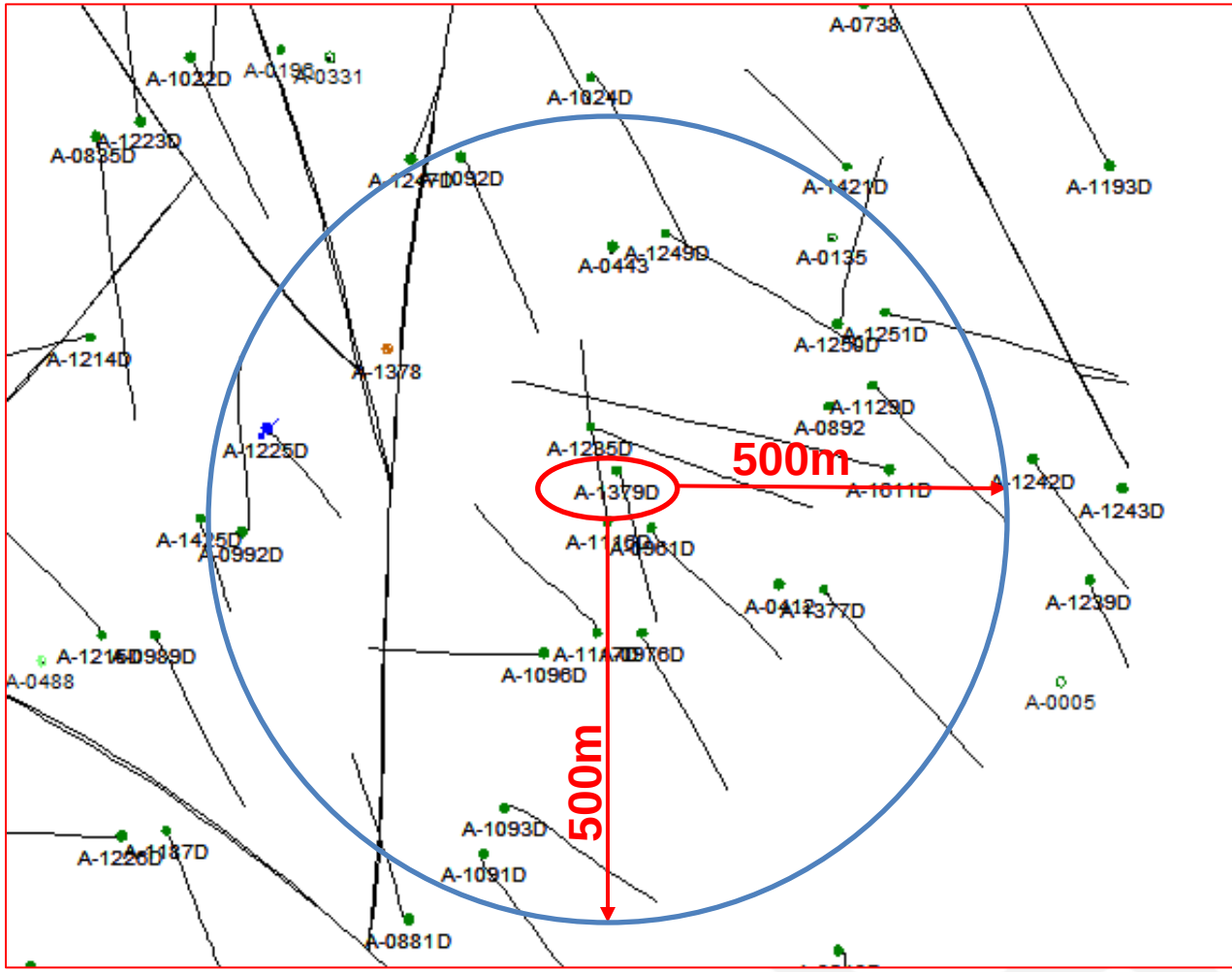




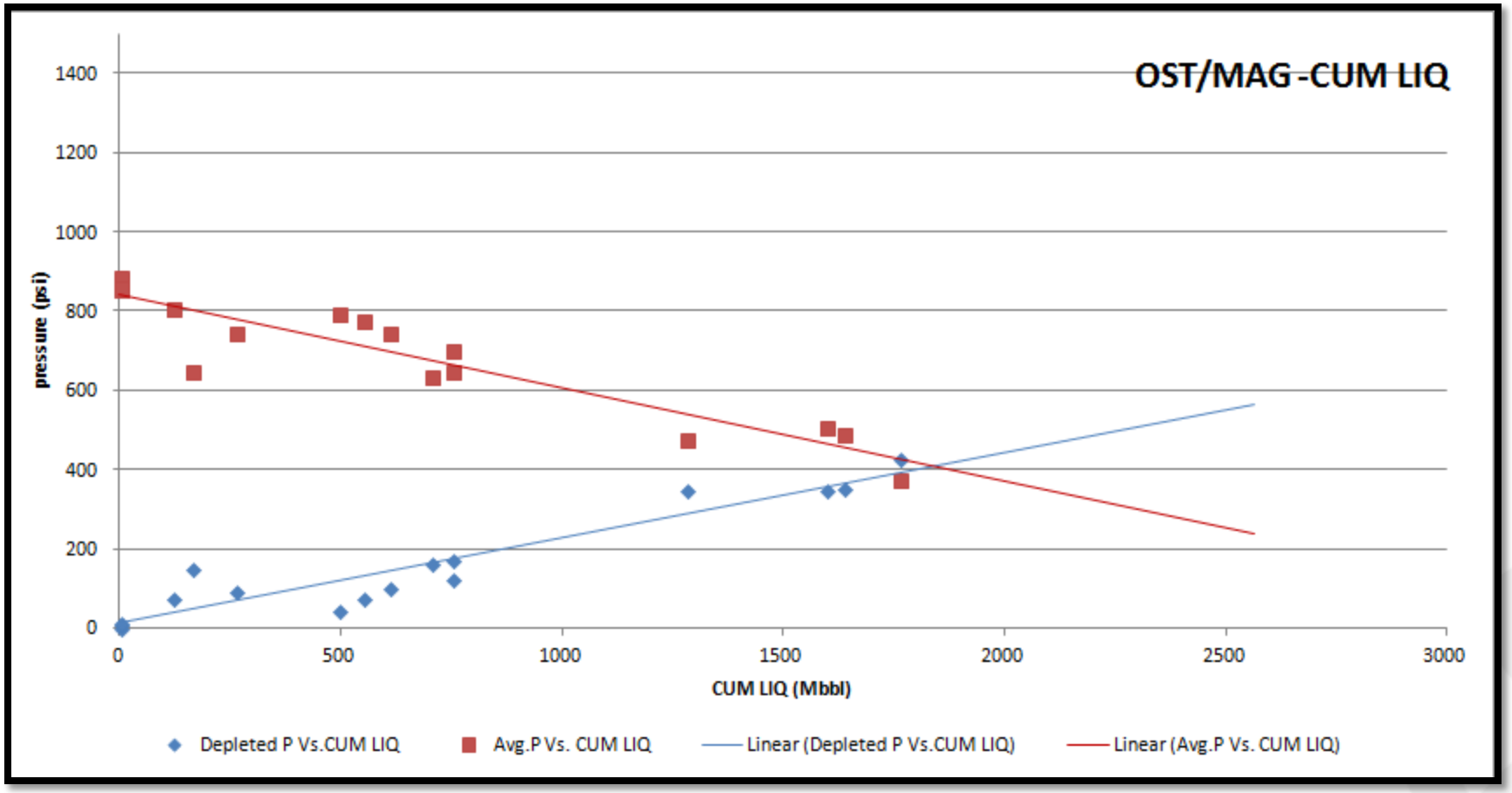
XPTs pressure vs. Production Cumulative Study

Assumptions:

- Cumulative production were taken for about 500 m radius from each well at the time XPT was taken
- Average XPT Pressure in Ostracod and Magwa was used
- Allocated Production for Ostracod & Magwa from OFM was considered separately
- Odd Points in trend (High depletion / Low Cum or Low Depletion / High Cum was revised in details
- The analysis was done for liquid, oil, water & gas.

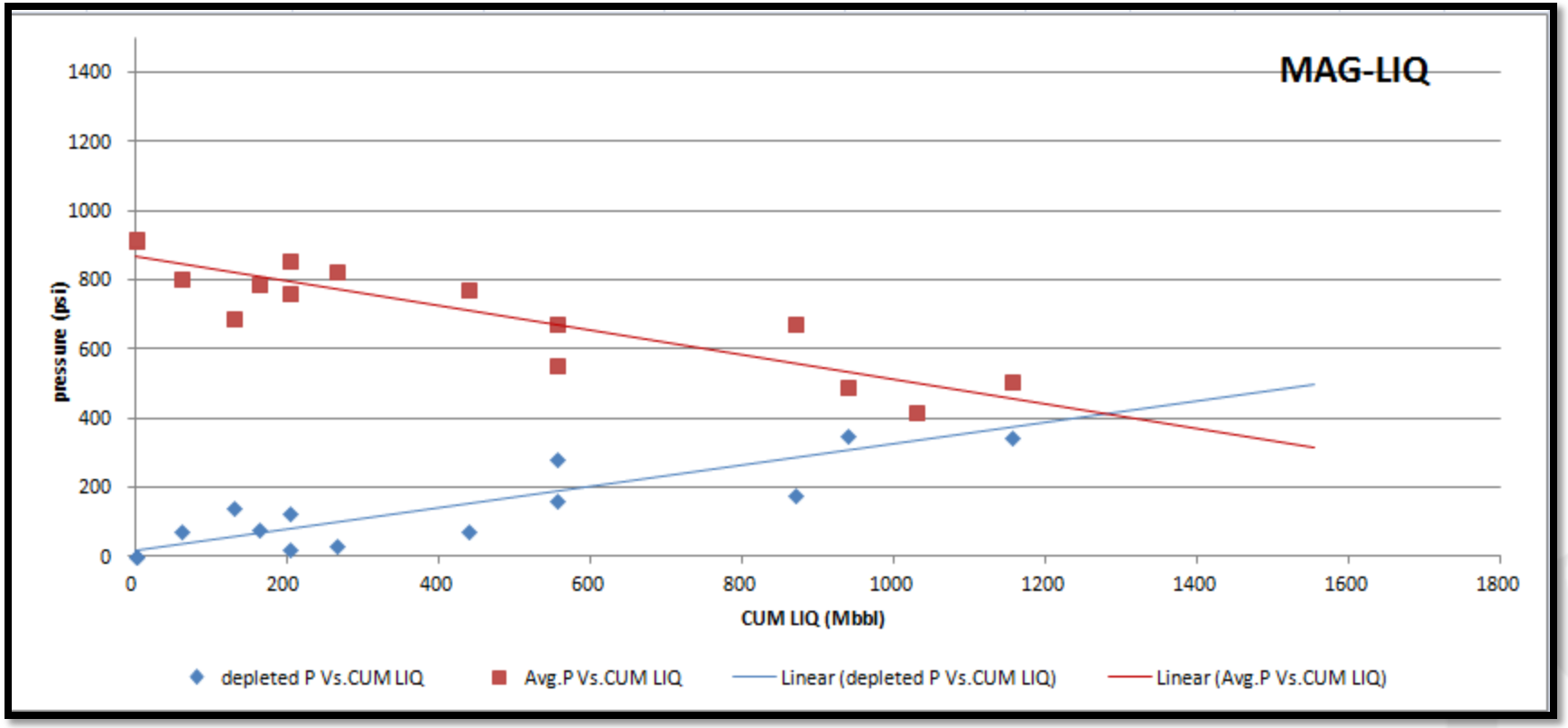


XPTs pressure vs. Production Cumulative Study



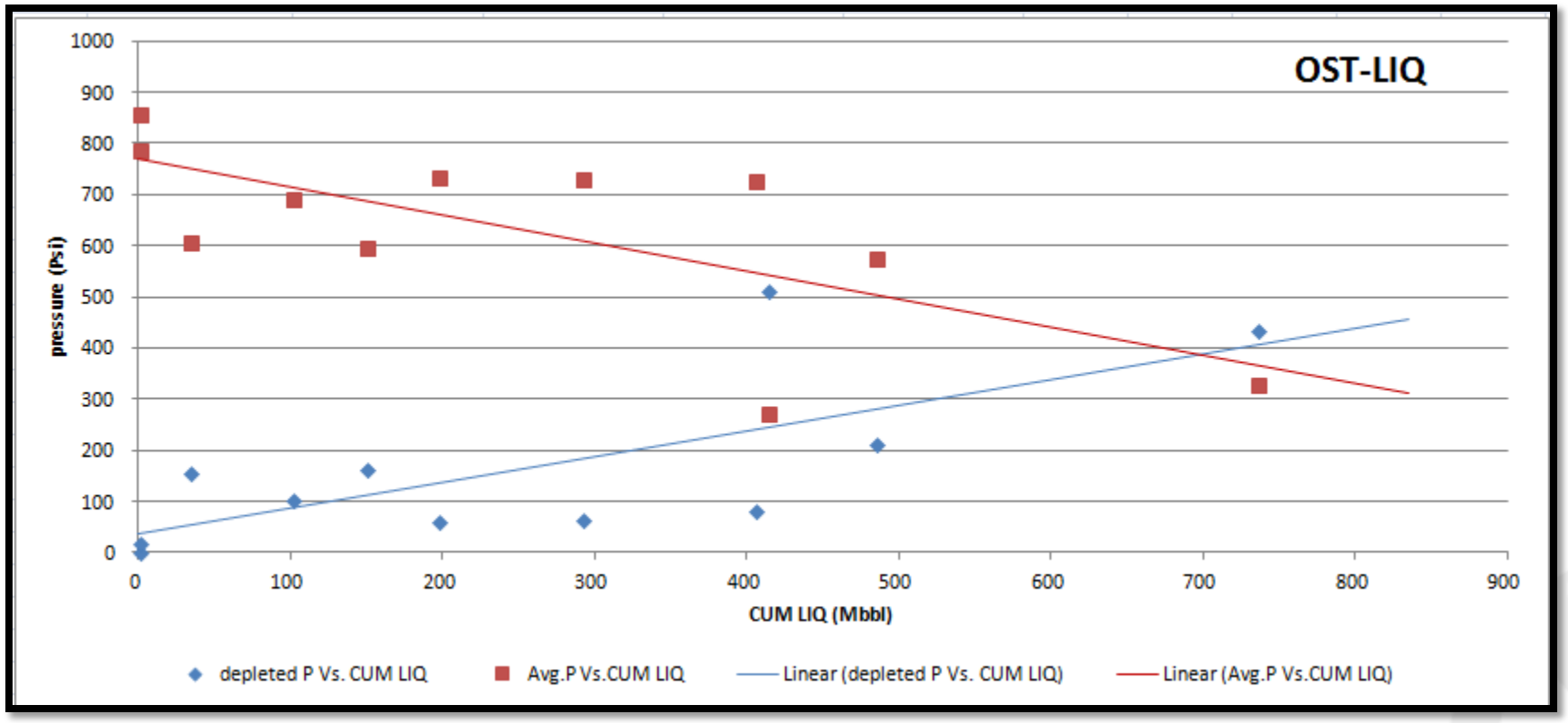
❑ Strong correlation can be seen between average XPT pressure & cumulative production

XPTs pressure vs. Production Cumulative Study



❑ Strong correlation can be seen between average XPT pressure & Magwa cumulative production

XPTs pressure vs. Production Cumulative Study

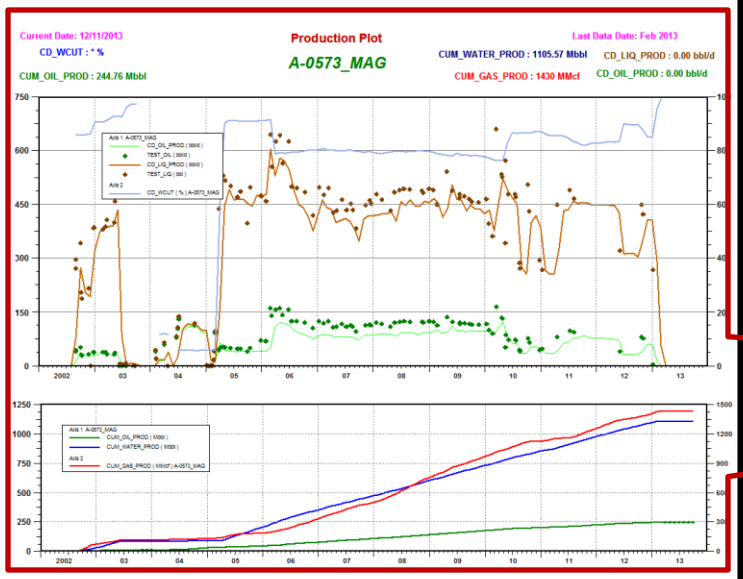


❑ Good correlation can be seen between average XPT pressure & Ostracod cumulative production

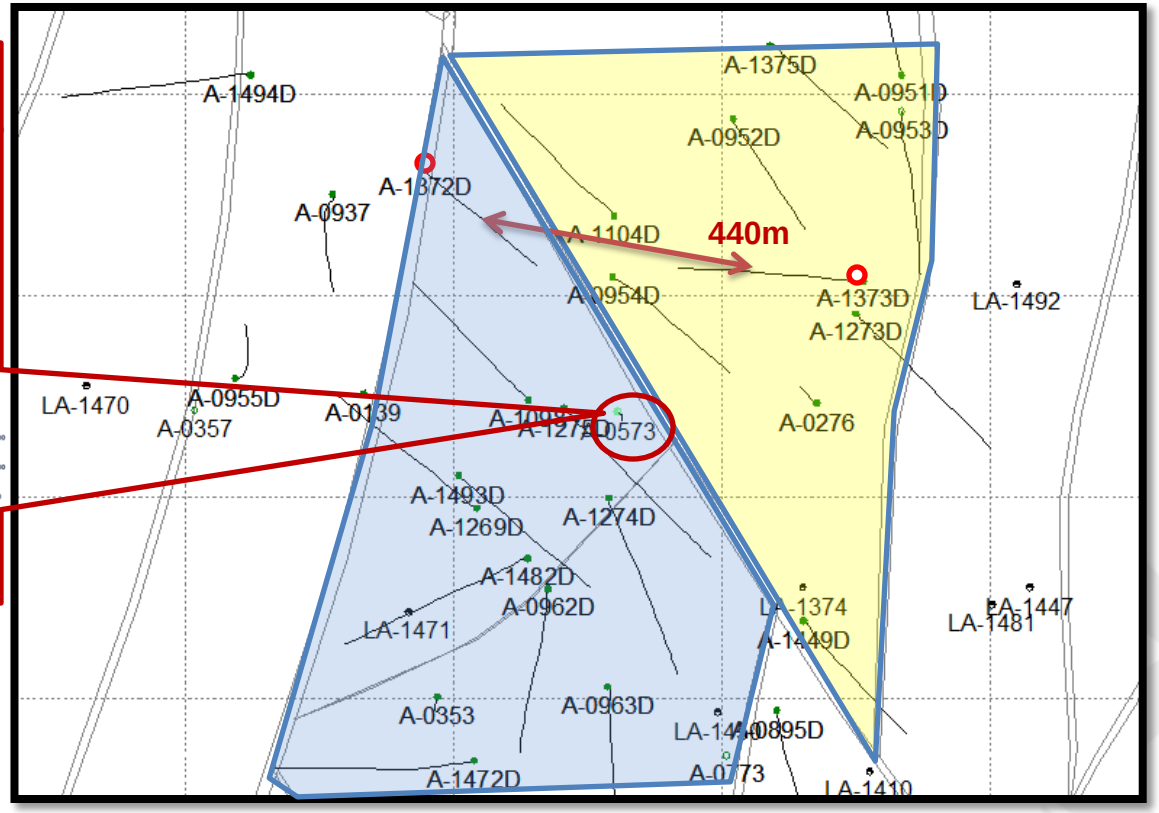
Odd Points Review (e.g. 1372D & A-1373D)

		OST/MAG		OST/MAG	
Well	XPT Date	CUM LIQ (Mbbl)		Average Pressure (psi)	Average Depletion (psi)
A-1372D	7-Dec-2012	2058.4		743.3	91.65
A-1373D	10-Jan-2013	2172.07		474.3	346.6

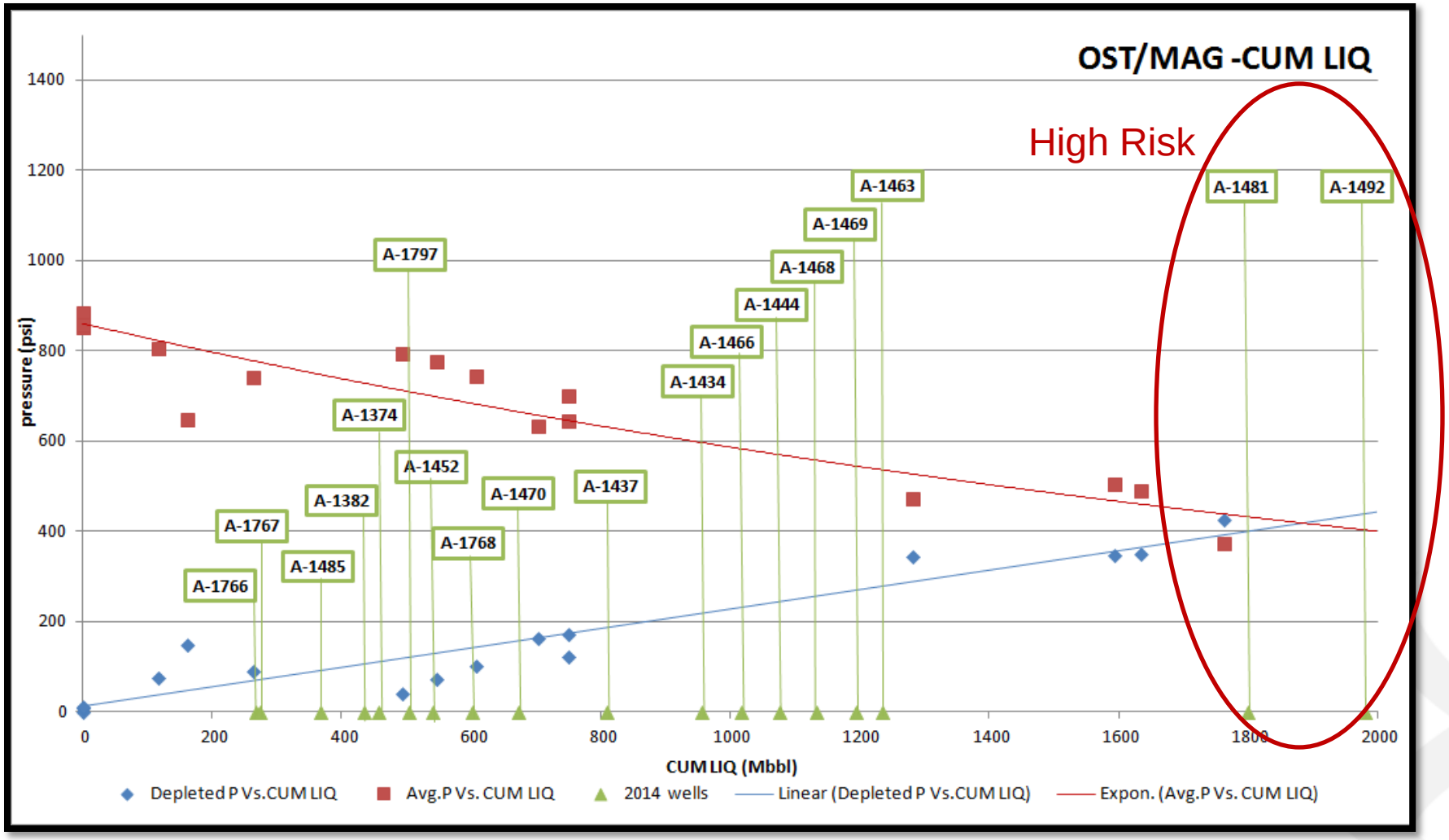
			OST/MAG	OST/MAG	
	Well	XPT Date	CUM LIQ (Mbbl)	Average Pressure (psi)	Average Depletion (psi)
10	A-1372D	7-Dec-2012	262.39	743.3	91.65
11	A-1373D	10-Jan-2013	1281.05	474.3	346.6



A-1138H
A-1277D
A-1379D
A-1602D
A-1712D



2014 planned wells



Conclusions:

- XPT shows different depletion in different reservoir units – confirm presence of flow barriers between the units
- It was difficult to conclude optimum well spacing using XPT pressures since there was strong variation on pressure depletion per unit & per distance to offset wells
- There was strong correlation between cumulative liquid production and pressure depletion in both Ostracod & Magwa reservoirs

Recommendations:

- Use Pressure depletion vs. spacing per unit to focus development on least depleted units / areas ,M2 Frac for example.
- **Use Cumulative Production vs. datum pressure or/and pressure depletion to determine reservoir pressure in the future target areas and include in the risk analysis of the future drilling opportunities .**
- To keep this work updated for the future, It is a key to acquire XPT pressures in future Ostracod Magwa wells

Presenter's notes: Focus development on M2, where the pressure is relatively high to perform a hydraulic fracture job.

Acknowledgment

- Special thanks to Khamis Al Abdali ,the co-auther of this study.
- OST/MAG RMT for their continuous help and support.
- TATWEER Management for supporting the submission of this study at GEO2016.

Thank You

Odd points review : e.g. A-1373 & A-1372

			Ostracod				Magwa				OST/MAG		Ostracod		Magwa		OST/MAG	
	Well	XPT Date	Oil CUM (Mbbl)	Water Cum (Mbbl)	Gas CUM (MMscf)	CUM LIQ (Mbbl)	Oil CUM (Mbbl)	Water Cum (Mbbl)	Gas CUM (MMscf)	CUM LIQ (Mbbl)	CUM LIQ (Mbbl)		Average Pressure (psi)	Average Depletion (psi)	Average Pressure (psi)	Average Depletion (psi)	Average Pressure (psi)	Average Depletion (psi)
10	A-1372D	7-Dec-2012	271.22	101.76	1192	372.98	464.54	1220.88	2419	1685.42	2058.4		693.82	105	792.77	78.3	743.3	91.65
11	A-1373D	10-Jan-2013	279.94	63.3	1129	343.24	643.15	1185.68	3068	1828.83	2172.07		272.477	512.5	676.2	180.7	474.3	346.6

• Both wells are completed in OST/MAG ,the CUM LIQ is similar. big deference in the pressure depletion even though the XPTs were taken at almost the same time.
•The pressure depletion is high in both A-1602D & A-1373D ,both located in the same fault block . and low in A-1372D & A-1274D .
•The fault might be acting as a seal ,isolating the two fault blocks (?)

This is true for M3 but not the other zones.