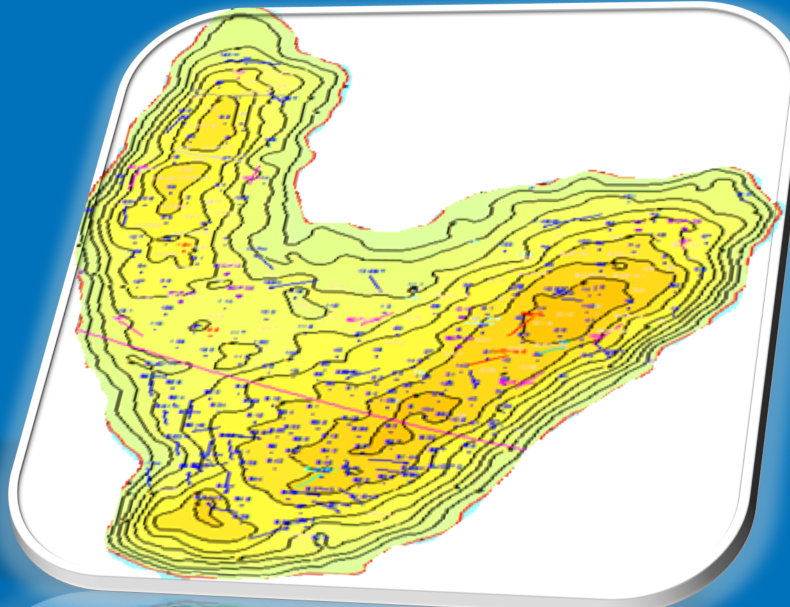
Integrated Live Well & Surface Network Model



Tool for Production Optimization

Fields Development (West Kuwait – UG) - Information Solutions - Exploration & Production Team

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Monaco

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Kuwait Oil Company
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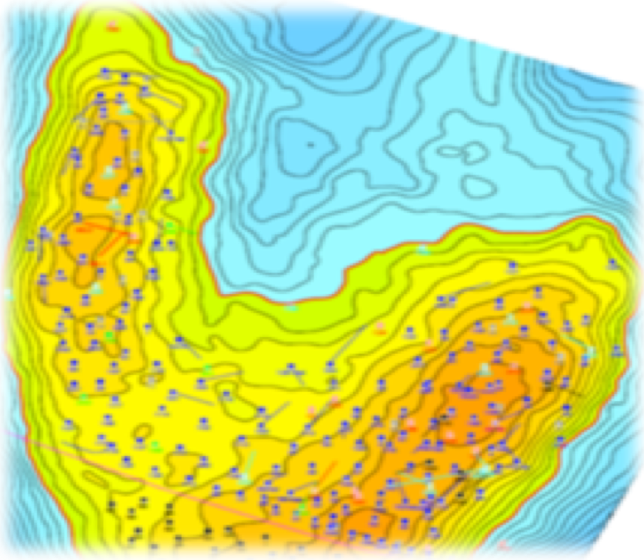
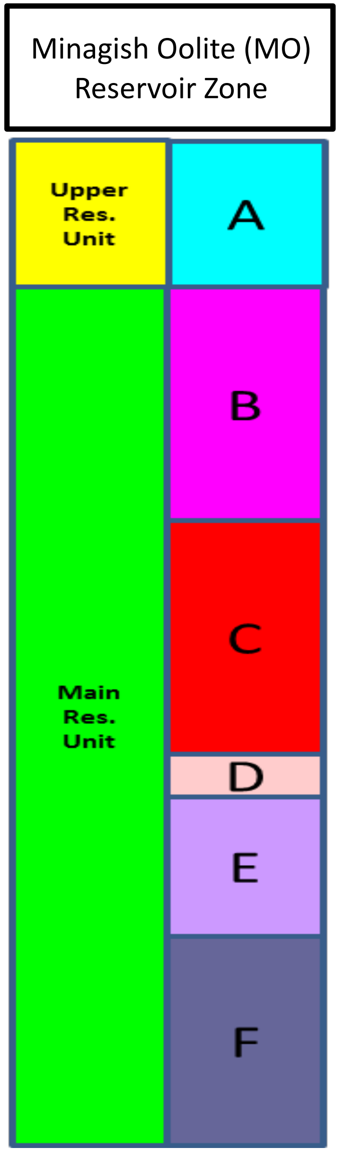
Umm-Gudair Field Introduction

- UG Field located in Kuwait
- Field Discovered in 1962
- Oil Formation : Carbonate
- 100% wells were producing with ESP's
- Wells are flowing to two Gathering Centers



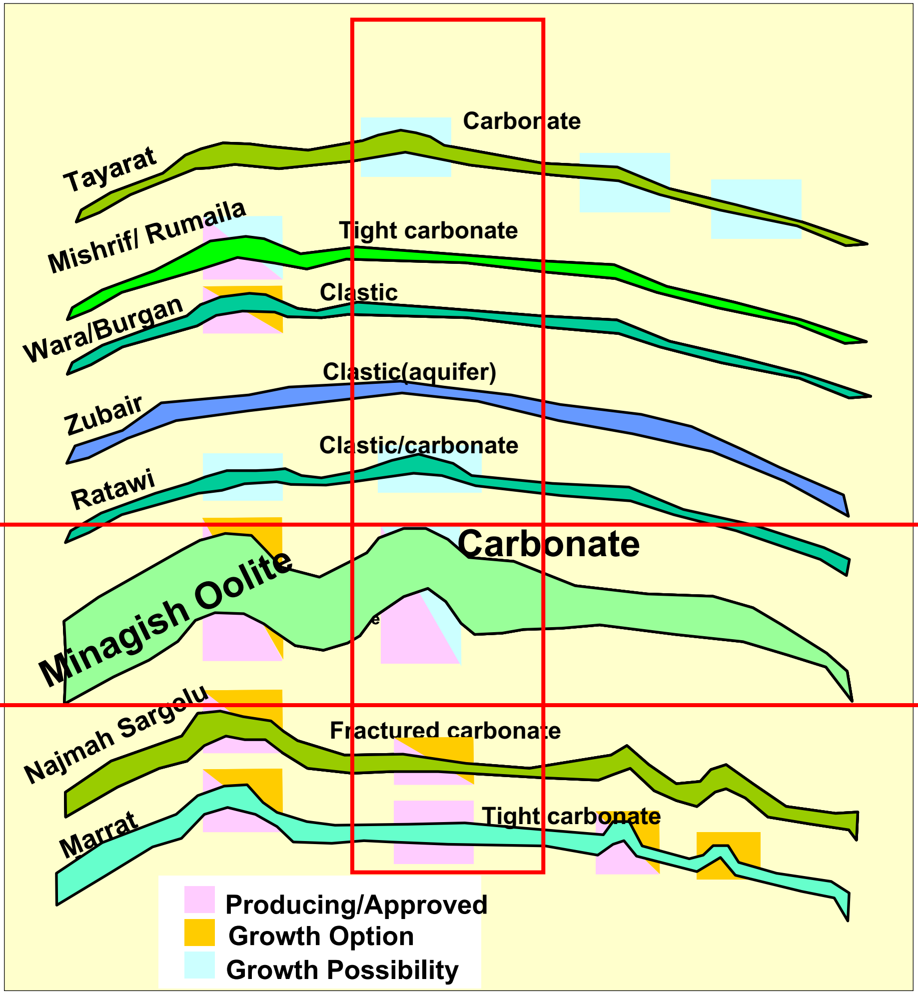
UG (MO) Reservoir Characteristics

- Carbonate reservoir with bottom water drive
- Upper layers with lower Permeability
- Good Communication between layers
- No faults , No fracture



UG (MO) Reservoir Characteristics

- Porosity 20 -23 %
- Permeability 50 – 500 md
- 450 ft Average Res, Thickness
- Reservoir pressure 1800 - 2800 psi
- Reservoir Temperature 175 F



Umm-Gudair Field Challenges

- **Maintain Field production target .**
- **Minimize ESP failures and workovers**
- **Address High water cut issues .**

Objectives

Field Production Management

Production Tracking	Production Optimization	Workovers

Well & Reservoir Performance

Well Test	Pressure Survey	Pres. Gauges & Sensors

Optimum Filed Production

100% Surface & Sub-Surface efficiency	Integrated Asset Modeling

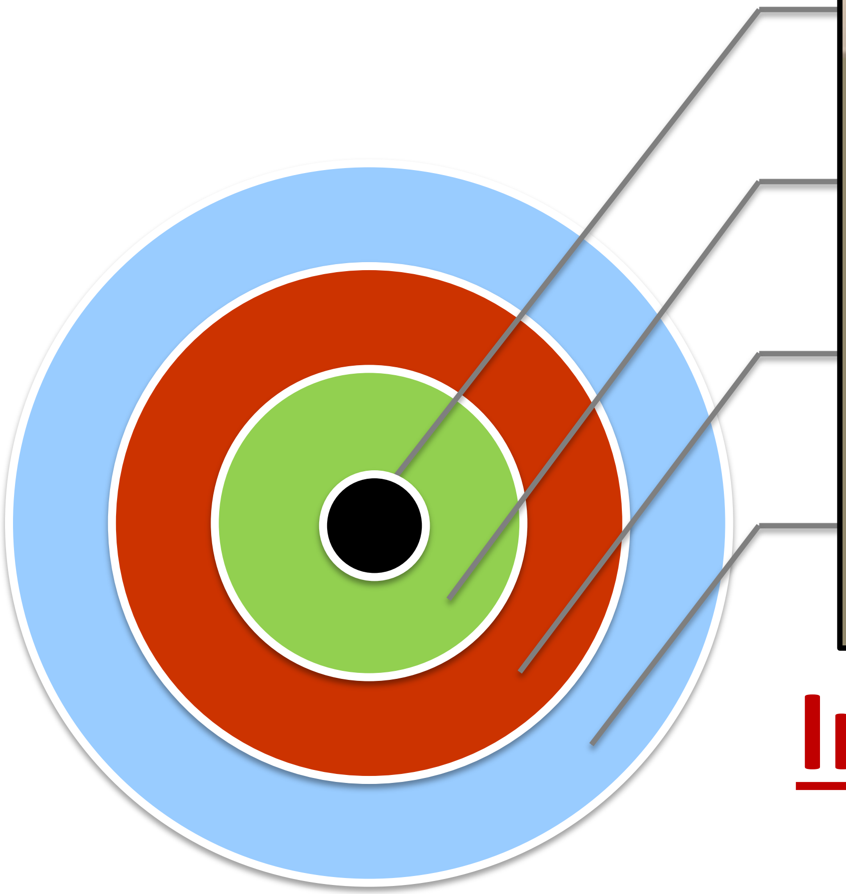
Field Production Target

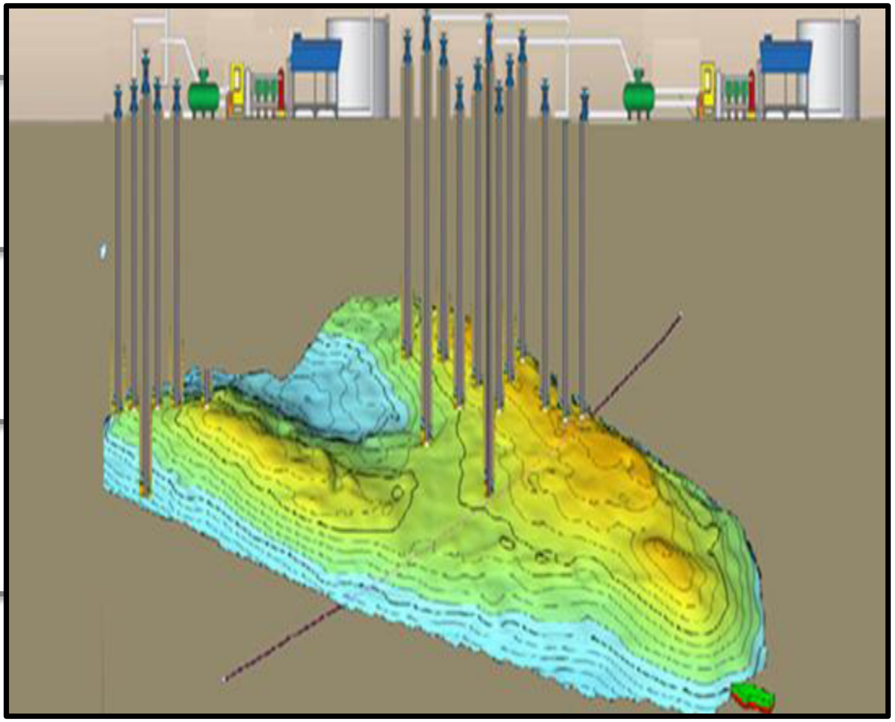
Surface & Sub-Surface Problem

Remove & Solve Restrictions & Bottle necking

Using **Integrated Asset Modeling** is the solution

Project Phases





Integrated Asset Modeling

Well Model (PHASE 1)

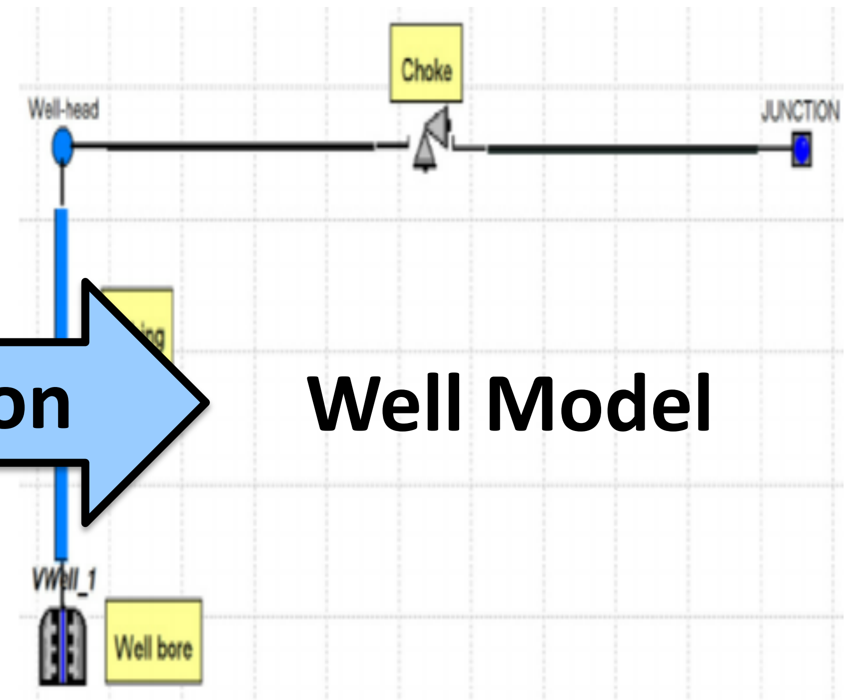
Well Production	
MPFM	Well Models

Portable Test

Calibration

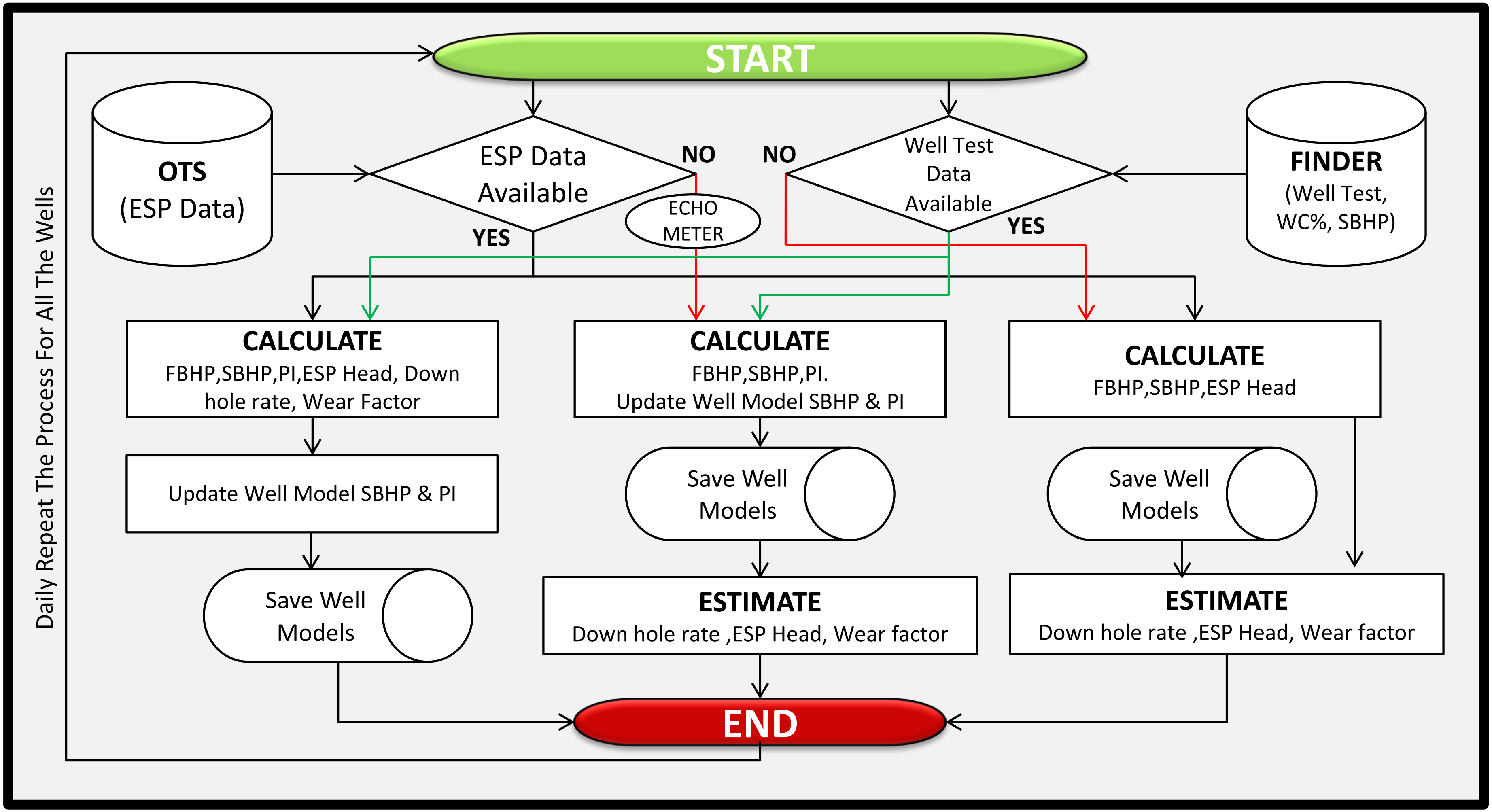
2%

Match Difference



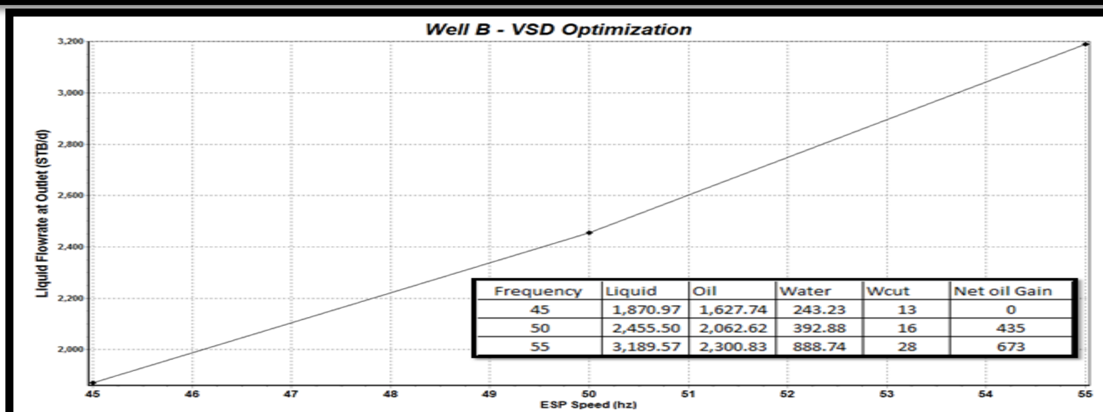
Well Model

Workflow – Live Well Models



Filed Optimization & Calibration

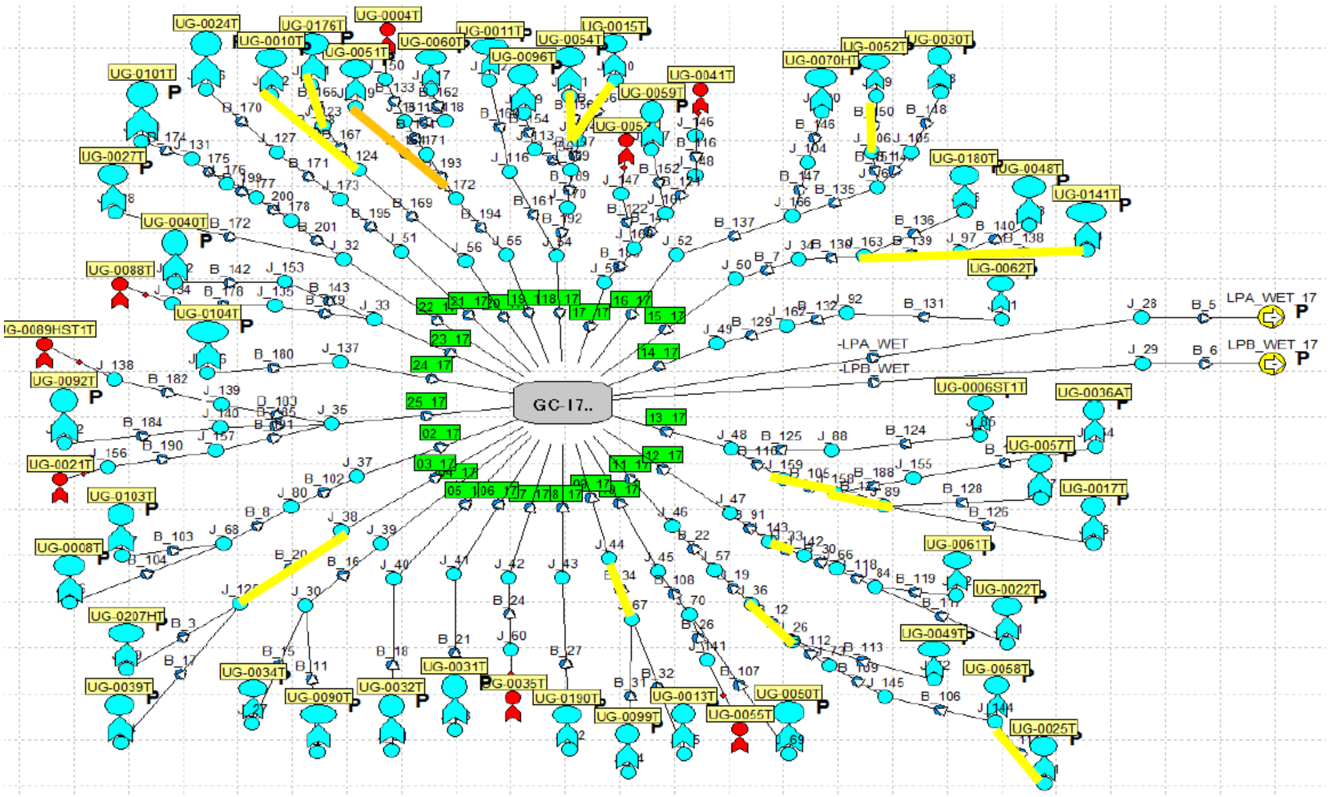
Rate	Wcut	Equivalent Choke size	ESP- PIP	Calculated PI	Head factor	Hz
BLPD	%	(1/64) inch	Psia	bbl/psi /d		
2905	2	143		2.50		45
3884	3	143		3.98		50
3146	6	42	996	3.74		
3067	8	42	1028	3.86	0.95	50
2850	8	42		3.50		
1936	10	64		2.60	0.65	45
1731	9	64				
1975	12	128				45
1844	8	64		2.74	0.63	45
1988	13	64		2.70	0.64	45
2026	14	64	1106	2.8 (3.5)	0.66	45
2073	16	64				
2791	16	128			0.67	50
3338	20	128	951	4.88	0.67	55
3187	28	128	840	4.08	0.67	55
3366	22	128	840	4.28	0.63	55



Production decline , ESP trip → Echo meter survey done & PI calculated → Production Decline is due to Pump wear → Optimization Evaluation using well model → Frequency increased to 55 HZ

GC Surface Network Model (PHASE 2)

Optimum Production	
100% Surface Facility Efficiency	Surface Network Model



Collaboration Surface Network Model TEAM

Filed Development

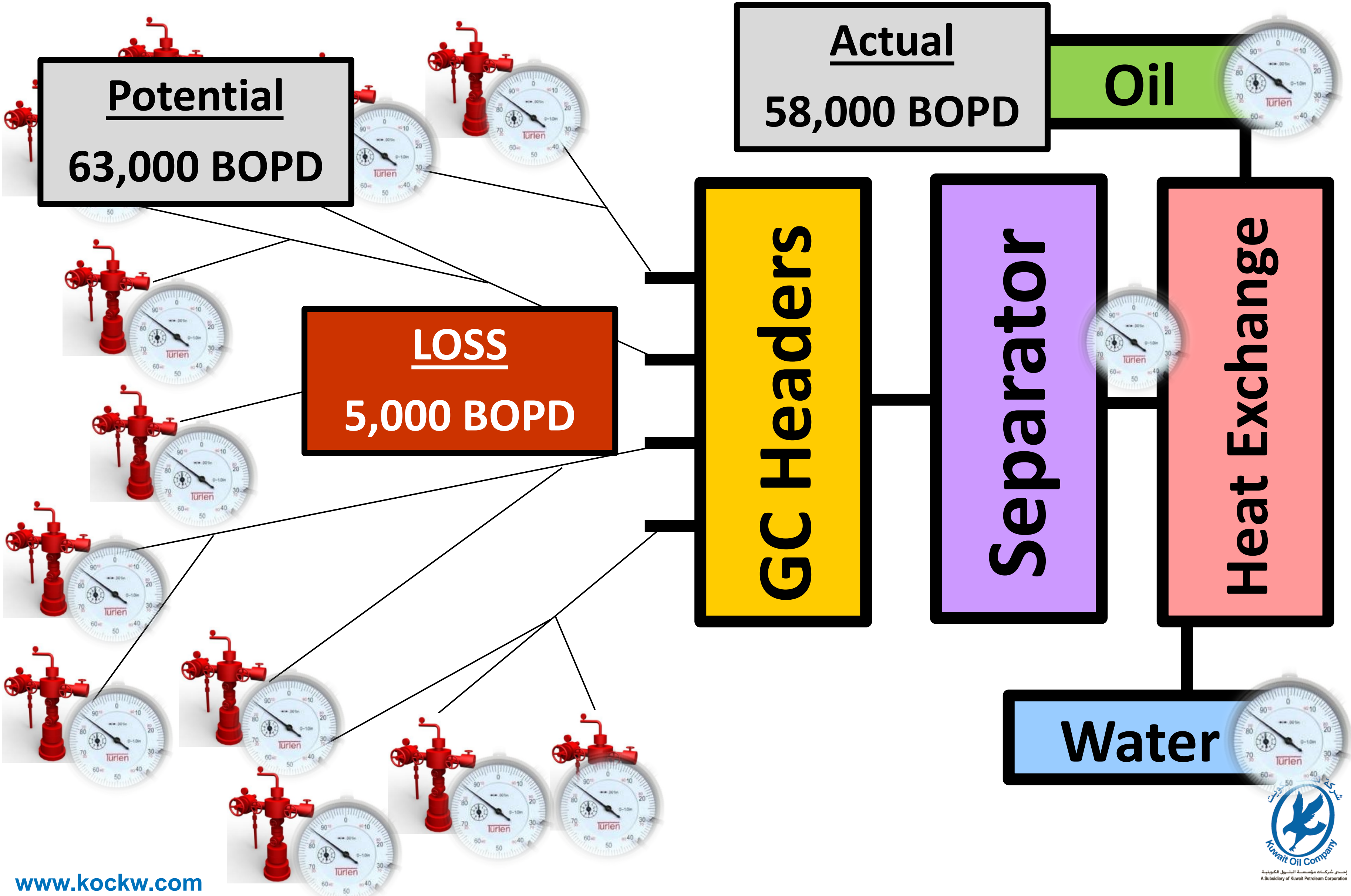
Information Solution Team (IS)

Production Operation

Information Managements (IM)

Surface Model

Calibration



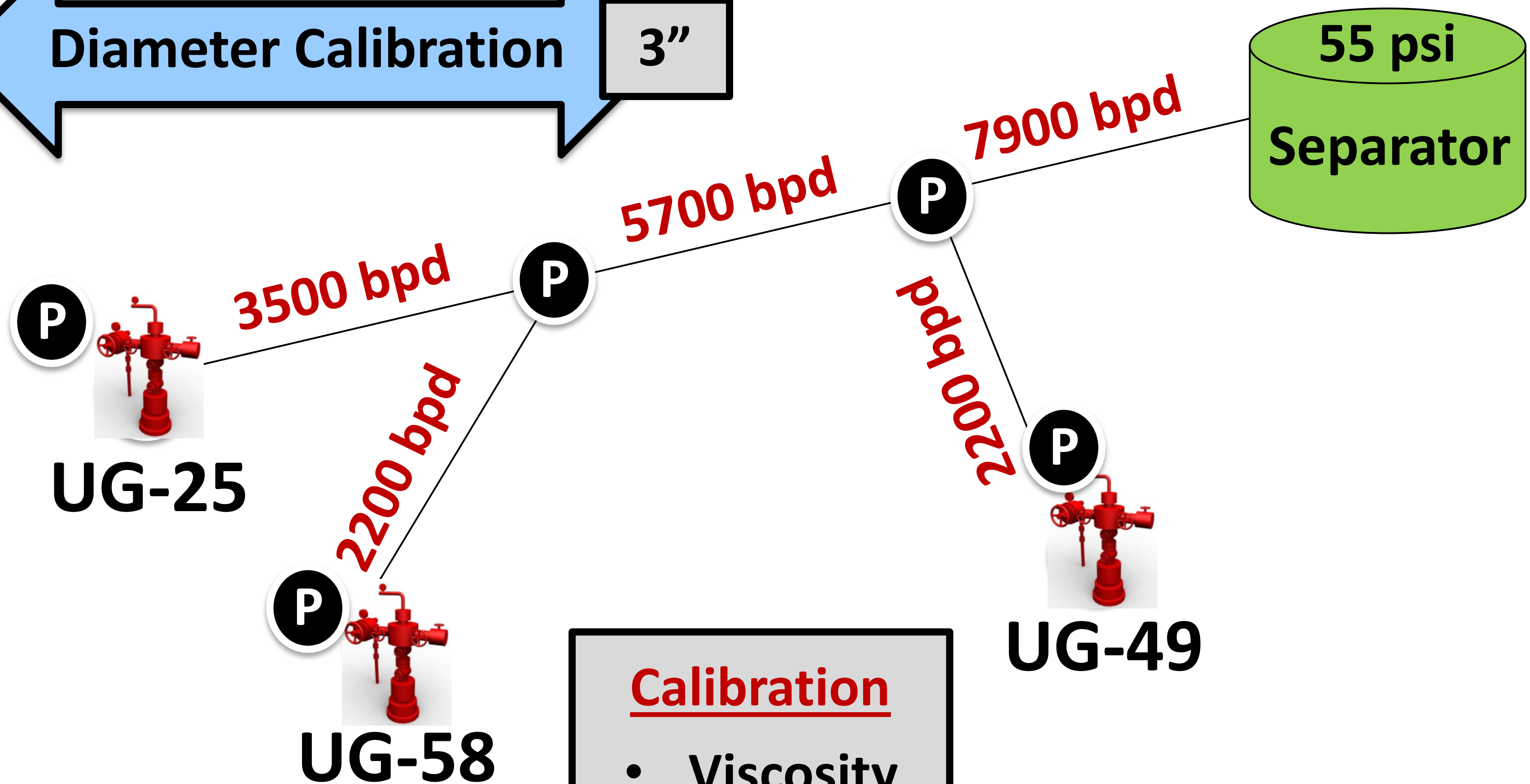
Test Rate Potential Vs Actual GC Production

What is The Reason Of Difference

- **Variation in Well Test (Portable Test) Rate .**
- **Total Liquid Rate Measurement Error In GC .**
- **GC Proceeding & Equipment efficiency**
- **Flow Line Network Bottle Necking Restriction & Back Pressure**

Calibration

6” Diameter Calibration 3”



Network = 160 psi

Actual = 250 psi

Calibration

- Viscosity
- Elevation
- Diameter

Calibration

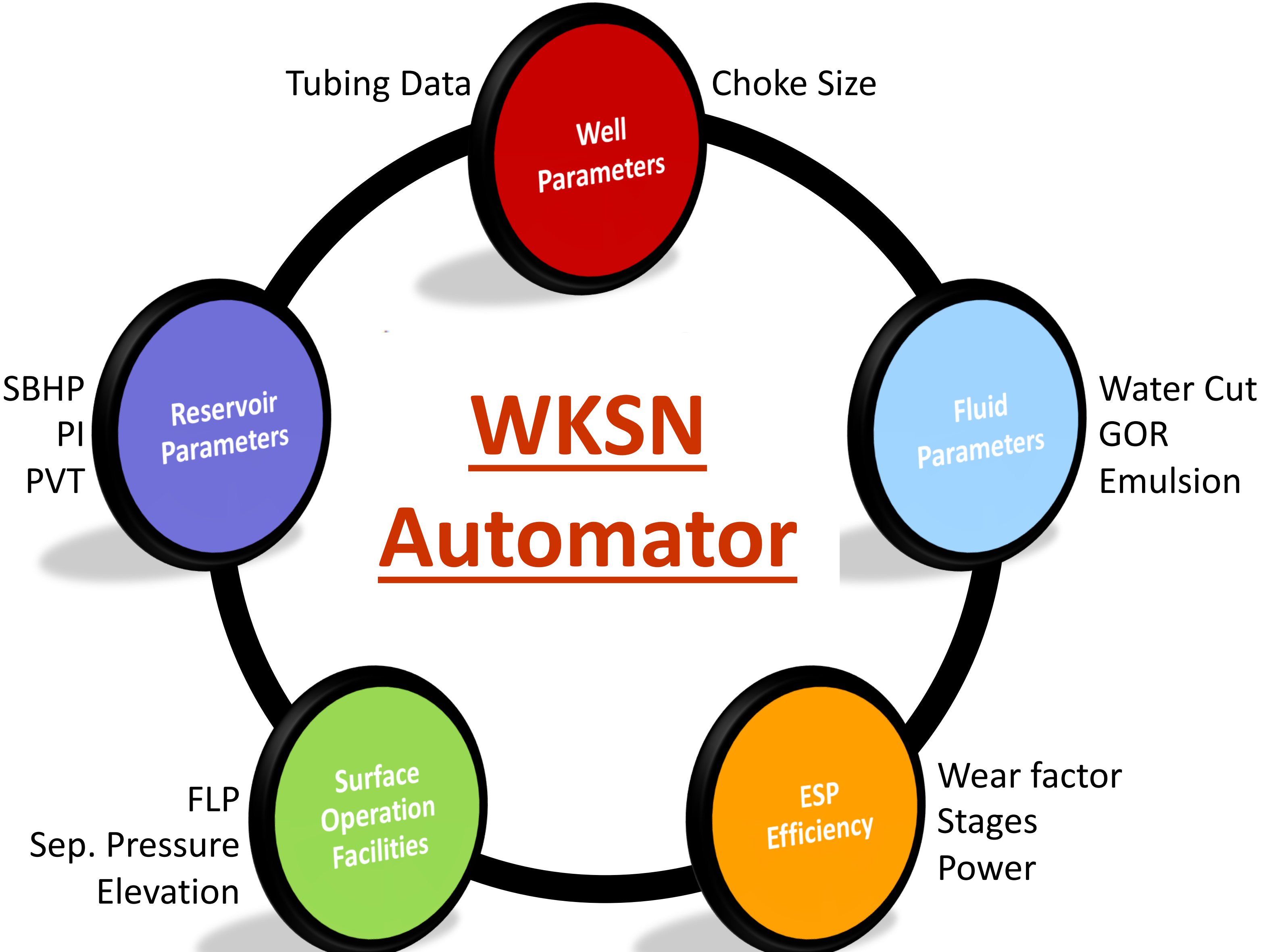
Ofmxy.Member	Slot	Header	Branch	PrevDiam	ModiDiam
UG-0006ST1T	13_17	LPA_WET_17	B_124	6	2.3
UG-0008T	02_17	LPA_WET_17	B_8	6	2.89
UG-0010T	20_17	LPB_WET_17	B_158	6	4.4
UG-0011T	18_17	LPB_WET_17	B_160	6	3.1
UG-0013T	09_17	LPB_WET_17	B_34	6	5.2
UG-0015T	18_17	LPB_WET_17	B_156	6	4.3
UG-0017T	13_17	LPA_WET_17	B_126	6	6
UG-0022T	12_17	LPB_WET_17	B_117	6	3
UG-0024T	21_17	LPB_WET_17	B_170	6	3.7
UG-0025T	11_17	LPA_WET_17	B-111	6	2.3
UG-0027T	22_17	LPB_WET_17	B_172	6	4.5
UG-0030T	16_17	LPB_WET_17	B_148	6	3.5
UG-0031T	06_17	LPA_WET_17	B_21	6	3.3
UG-0032T	05_17	LPA_WET_17	B_18	6	4.2
UG-0034T	04_17	LPA_WET_17	B_16	6	4.32
UG-0036AT	24_17	LPA_WET_17	B_187	6	6
UG-0039T	03_17	LPB_WET_17	B_20	6	5.2
UG-0040T	23_17	LPA_WET_17	B_142	6	3.1
UG-0048T	15_17	LPA_WET_17	B_140	6	6
UG-0049T	11_17	LPA_WET_17	B_113	6	6
UG-0050T	10_17	LPA_WET_17	B_108	6	2.7
UG-0051T	19_17	LPB_WET_17	B_164	6	3
UG-0052T	16_17	LPB_WET_17	B_150	6	3.5
UG-0054T	18_17	LPB_WET_17	B_158	6	2.7
UG-0057T	13_17	LPA_WET_17	B_128	6	6
UG-0058T	11_17	LPA_WET_17	B_106	6	3
UG-0059T	17_17	LPA_WET_17	B_152	6	3
UG-0060T	19_17	LPB_WET_17	B_162	6	2.15
UG-0061T	12_17	LPB_WET_17	B_119	6	6
UG-0062T	14_17	LPA_WET_17	B_131	6	2
UG-0070HT	16_17	LPB_WET_17	B_146	6	3
UG-0090T	25_17	LPB_WET_17	B_16	6	4.32
UG-0092T	25_17	LPB_WET_17	B_184	6	1.9
UG-0096T	18_17	LPB_WET_17	B_154	6	3.8
UG-0099T	09_17	LPB_WET_17	B_34	6	5.2
UG-0101T	22_17	LPB_WET_17	B_174	6	1.6
UG-0103T	02_17	LPA_WET_17	B_8	6	2.89
UG-0104T	24_17	LPA_WET_17	B_180	6	2.5
UG-0141T	15_17	LPA_WET_17	B_138	6	3.6
UG-0176T	20_17	LPB_WET_17	B_166	6	3.2
UG-0180T	15_17	LPA_WET_17	B_136	6	3.4
UG-0190T	08_17	LPA_WET_17	B_27	6	5.8
UG-0207HT	03_17	LPB_WET_17	B_90	6	5.2

Way Forward (Validation & Debottleneck)

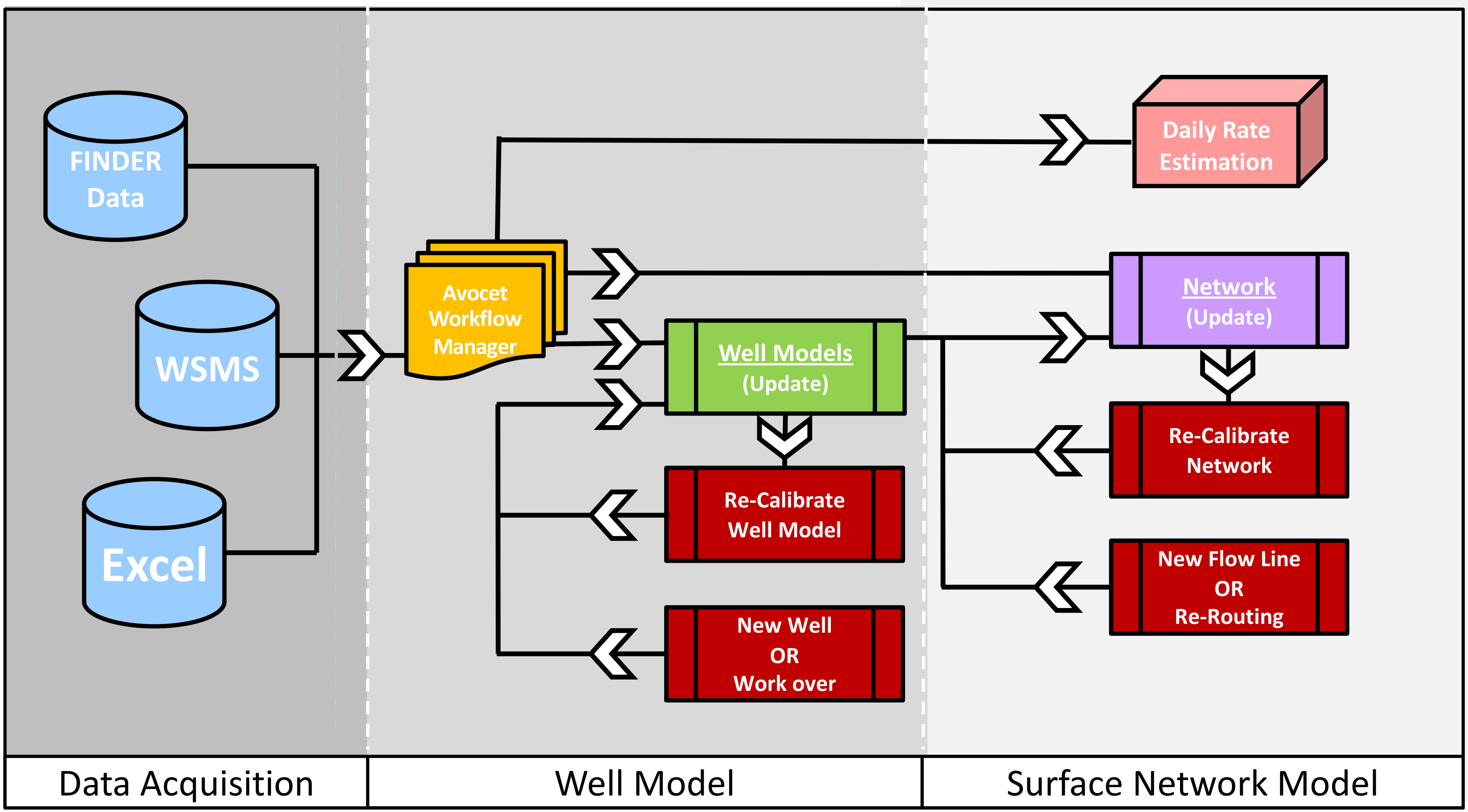
Actual Flow Line Pressure > Optimum Flow Line Pressure

Flow Line Integrity Issue	Difference Between GC & Well Test	Pipe Line Elevation	High Viscosity
✓ Thermal Camera	✓ Flow Meter	✓ Sensitivity Runs	✓ PVT Test
✓ Ultar Sound	✓ Red Eye	✓ Site Visit	✓ Lab Test

GC Surface Network Model



Real Time System – Work Flow



Live Surface Network & Well Models - Application

A. Screen The Under Performing Wells & Flowline

- Declining Rate and Productivity Index
- ESP's On Up or Down thrust condition and with high wear
- To identify problematic Wells (integrity and flow assurance issues)
- To identify integrity and bottle necking in flow line.

B. To Evaluate Production Optimization Scenarios

- Choke and ESP Frequency (VSD) optimization.
- Evaluate of Stimulation impact and need for ESP replacement.
- To Divert well from GC to other GC

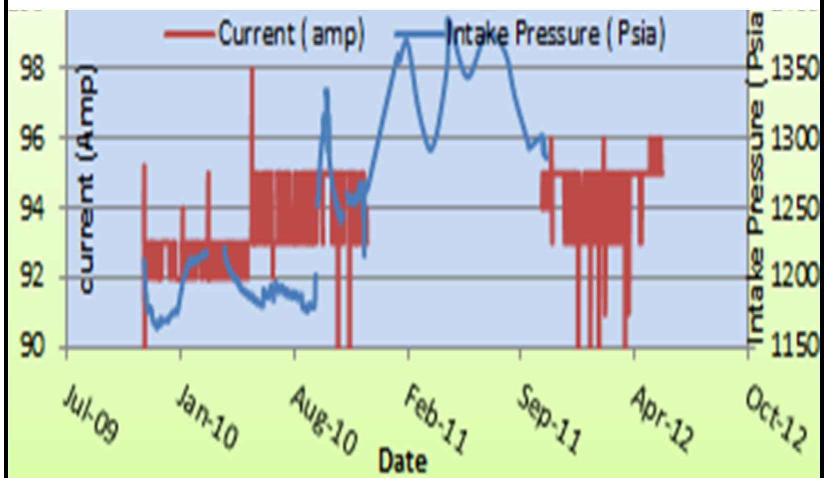
C. To Generate Daily Production Estimation Report

Filed Optimization – Well A

Well Integrity – Hole in Tubing :

Rate (BPD)	Water Cut (%)	ESP - PIP (Psi)	Tm (Deg F)	PI
4500	80	1170	210	10
4100	75	1190	217	11
4000	80	1200	218	11
3800	80	1350	218	10
Work over				
4500	80	1200	220	10

Well A
(Intake Pressure)



Observation **Minor Hole in the tubing above pump and circulation of the fluid.**

- There was a slight increase in motor Temp. around (4 Deg)
- Flow rate at the surface was Decrease around (800 bpd)

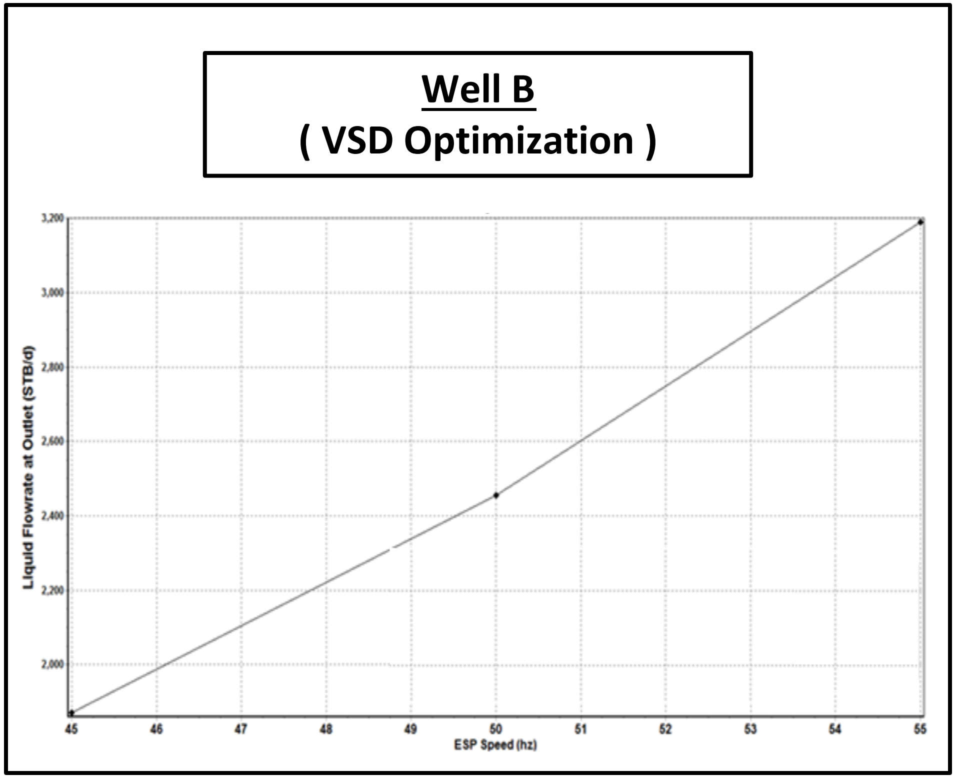
Production Decline → Increase in ESP P intake & Motor Temperature → Suspected hole in the tubing → Well Worked over and Hole in tubing confirmed → After workover Pi reduced to normal Range

Filed Optimization – Well B

VSD Optimization :

Rate (BPD)	Water Cut (%)	ESP - PIP (Psi)	Head Factor	PI
3000	5	950	0.95	4
2850	5	N/A	N/A	N/A
1900	5	N/A	N/A	N/A
1850	10	N/A	N/A	N/A
1700	10	1100	0.65	2
Install VSD (Freq. 55 Hz)				
3300	15	950	0.65	5
3100	15	900	0.65	4

Frequency	Liquid	Oil	Water	Wcut	Net oil Gain
45	1,870.97	1,627.74	243.23	13	0
50	2,455.50	2,062.62	392.88	16	435
55	3,189.57	2,300.83	888.74	28	673



- Production decline
- Echo meter survey done & PI calculated
- Production Decline is due to ESP Efficiency
- Optimization Evaluation using well model
- Frequency increased to 55 HZ

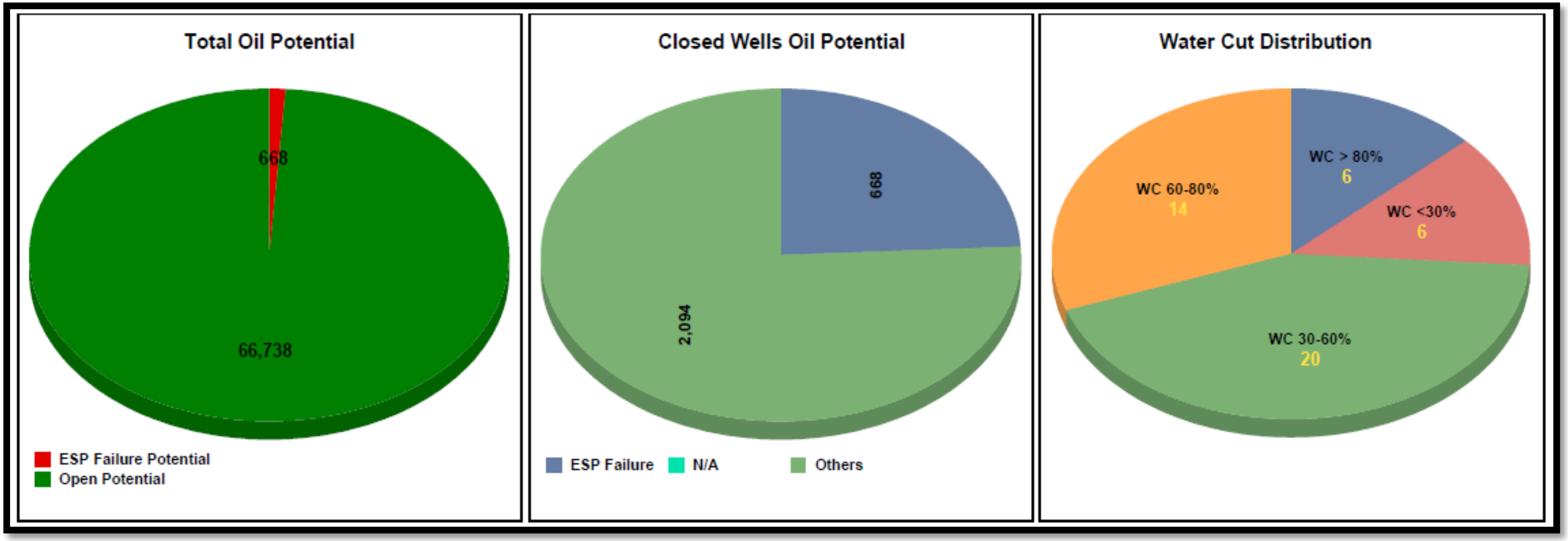
Daily Estimation Report

		Subsurface Potential					Daily Estimated Production			
		Liquid	Oil	Water	#Wells		Liquid	Oil	Water	#Wells
Reservoir 1	Open Wells	138,119	66,193	71,926	40	Reservoir 1	140,734	68,778	71,953	40
	Cutback	0	0	0	0					
	Closed	12,272	2,094	10,178	4					
	Failure	3,340	668	2,672	1					
	Sub-Total	153,731	68,955	84,776	45					
Reservoir 2	Open Wells	545	545	0	1	Reservoir 2	488	488	0	1
	Cutback	0	0	0	0					
	Closed	0	0	0	0					
	Failure	0	0	0	0					
	Sub-Total	545	545	0	1					
Sub-total Open		138,664	66,738	71,926		Open	141,222	69,266	71,953	
TOTAL		154,276	69,500	84,776	46		141,222	69,266	71,953	41
	TOTAL OPEN	138,664	66,738	71,926						

Daily Report :

- Groups the wells based on Reservoir / Status / GC wise .
- Potential for Cutback / Failure / Closed wells .
- Total Potential based on both well test and model estimated rates .

Daily Estimation Report



Report Summary :

- Pie chart shows the total oil and closed oil potential with WC% Distribution .
- Water shut 's off can be evaluated .

Daily Estimation Report

Reservoir 1
Open Wells
Switching Wells

Blue Date for DCS Test

Red if Δ > 10%

			Latest Well Tests							Calculated		ESP		Estimated											
#	Well	Test Date	Liquid	WC	GOR	WHP	FLP	LC	RC	Oil	Water	Pi	Pd	Liquid	Oil	Water	WC	GOR	WHP	FLP	LC	RC	R	C.R.	T.R.
1	Well 1	23/04/13	2,852	60.0	168	251	195	36	42	1,141	1,711	1,685	3,842	3,387	1,355	2,032	60.0	168	220	175	36	42			
2	Well 2	23/04/13	1,615	88.0	232	188	175	192	192	581	1,034	1,273	4,572	2,002	721	1,281	64.0	232	190	185	192	192			
3	Well 3	04/06/13	2,810	40.0	184	204	170	64	0	1,686	1,124	542	2,915	3,109	1,865	1,243	40.0	184	174	160	64				
4	Well 4	02/04/13	4,174	44.0	211	141	120	192	64	2,087	2,087	1,041	3,653	4,120	2,060	2,060	50.0	211	150	110	192	64			T.R
5	Well 5	17/06/13	6,511	31.0	255	446	320	60	0	4,493	2,018	2,173	3,941	6,948	4,794	2,154	31.0	255	440	240	60				
6	Well 6	09/04/13	2,663	65.0	189	215	138	0	48	959	1,704						64.0	189	210	150		48	M		T.R
7	Well 7	20/05/13	1,846	36.0	173	412	155	0	28	1,181	665	886	4,061	1,597	1,022	575	36.0	173	380	170		28			
8	Well 8	08/04/13	4,528	47.0	150	216	198	24	192	2,626	1,902	1,069		4,752	2,756	1,996	42.0	150	170	160	24	192			T.R
9	Well 9	26/05/13	4,768	67.0	122	325	311	128	128	1,430	3,338	1,631	4,018	4,660	1,398	3,262	70.0	122	255	210	128	128			
10	Well 10	21/05/13	1,702	40.0	202	145	100	0	48	987	715	623	3,450	1,659	962	697	42.0	202	180	80		48			
11	Well 11	22/05/13	2,519	62.0	169	206	185	64	64	907	1,612	1,236	4,042	2,656	956	1,700	64.0	169	230	170	64	64			
12	Well 12	30/04/13	2,319	22.0	169	95	81	64	192	1,716	603			2,295	1,698	597	26.0	169	70	69	64	192			
13	Well 13	05/06/13	5,228	85.0	236	258	227	128	0	1,046	4,182	1,704	4,202	5,560	1,112	4,448	80.0	236	210	170	128				
14	Well 14	04/03/12	2,025	60.0	201	152	136	128	128	608	1,418	1,173	3,697	1,848	554	1,294	70.0	201	110	90	128	128			T.R
15	Well 15	05/07/12	5,110	50.0	230	170	0	128	128	2,555	2,555			4,886	2,443	2,443	50.0	230	129	120	128	128			T.R
16	Well 16	28/04/13	3,942	68.0	137	222	212	192	0	1,025	2,917	1,047	4,335	3,655	950	2,705	74.0	137	280	180	192				
17	Well 17	30/06/13	691	60.0	71	174	165	128	128	276	415	1,354	4,272	2,027	811	1,216	60.0	71	200	200	128	128			
18	Well 18	29/04/13	4,223	76.0	281	214	163	0	64	1,689	2,534			4,486	1,794	2,692	60.0	281	235	183		64			
19	Well 19	23/04/13	795	30.0	59	561	120	0	16	604	191			985	748	236	24.0	59	327	100		16			
20	Well 20	20/05/13	2,845	32.0	217	171	130	0	64	1,764	1,081	818	3,662	3,011	1,867	1,144	38.0	217	190	160		64			
21	Well 21	03/06/13	3,101	31.0	220	181	150	0	128	2,233	868			3,478	2,504	974	28.0	220	176	134		128			
22	Well 22	29/04/13	3,269	19.0	126	182	126	0	64	2,615	654	827	3,450	3,330	2,664	666	20.0	126	160	96		64			
23	Well 23	10/06/13	5,601	80.0	310	242	170	64	0	2,240	3,361	1,169	4,075	5,457	2,183	3,274	60.0	310	200	124	64				
24	Well 24	26/05/13	2,300	73.0	150	243	164	40	0	621	1,679	653	4,188	2,199	594	1,605	73.0	150	240	190	40				
25	Well 25	29/04/13	5,449	26.0	132	222	208	64	192	3,814	1,635			4,474	3,132	1,342	30.0	132	180	156	64	192			
26	Well 26	24/04/13	5,149	75.0	145	206	185	128	128	1,287	3,862	1,408	4,119	4,873	1,218	3,655	75.0	145	210	160	128	128			
27	Well 27	28/04/13	1,723	56.0	143	203	170	0	64	758	965	1,099	3,842	2,127	936	1,191	56.0	143	200	190		64			
28	Well 28	30/04/13	4,743	45.0	189	220	200	192	64	2,609	2,134	1,524	3,899	5,438	2,991	2,447	45.0	189	220	170	192	64			
29	Well 29	28/05/13	5,177	40.0	216	192	150	0	192	3,106	2,071	1,611	3,753	5,297	3,178	2,119	40.0	216	140	130		192			
30	Well 30	24/04/13	446	0.0	116	142	125	0	32	446	0			1,064	1,061	3	0.0	116	170	110		32			
31	Well 31	29/05/13	2,322	42.0	201	184	162	192	0	1,347	975			2,621	1,520	1,101	42.0	201	220	170	192				
32	Well 32	22/04/13	2,019	60.0	122	345	278	40	0	808	1,211			2,576	1,030	1,546	60.0	122	300	240	40				T.R
33	Well 33	30/05/13	2,020	66.0	184	205	195	128	128	687	1,333			1,850	629	1,221	66.0	184	198	197	128	128			
34	Well 34	30/04/13	3,137	70.0	140	172	158	192	0	941	2,196	833	4,062	3,119	936	2,184	70.0	140	185	170	192				
35	Well 35	13/06/13	3,554	89.0	250	238	185	64	64	391	3,163	715	4,128	3,071	338	2,733	89.0	250	256	250	64	64			
36	Well 36	28/04/13	4,954	45.0	133	184	170	60	192	2,725	2,229	1,672	3,869	5,768	3,172	2,595	45.0	133	190	190	60	192			
37	Well 37	17/04/13	4,897	32.0	206	161	135	192	128	3,232	1,665	1,012	3,461	5,629	3,715	1,914	34.0	206	140	120	192	128			T.R
38	Well 38	30/05/13	5,292	76.0	231	179	150	192	52	1,270	4,022			5,415	1,300	4,115	76.0	231	200	200	192	52			
39	Well 39	30/05/13	5,322	77.0	286	267	185	0	64	1,224	4,098	1,496	4,054	4,524	1,040	3,483	77.0	286	250	240		64			
40	Well 40	27/05/13	4,478	2.0	175	167	136	128	128	4,478	0			4,781	4,771	10	0.0	175			128	128			

Open Wells Summary :

- **Flags if :** **well production variation is more than > 20 % .**

  well need to be tested .

  wells Need for calibration and model updating .

Daily Estimation Report

Reservoir 2

Open Wells
Switching Wells

Blue Date for DCS Test

Latest Well Tests | Calculated | ESP | Red If Δ > 10% | Estimated

#	Well	Test Date	Liquid	WC	GOR	WHP	FLP	LC	RC	Oil	Water	Pi	Pd	Liquid	Oil	Water	WC	GOR	WHP	FLP	LC	RC	R	C.R.	T.R.
41	Well 41	23/04/13	545	0.0	169	118	98	0	36	545	0			488	488		0.0	169	110	100		36			
Total			545							545	0			488	488	0									

R: Remarks

C.R: Calibration Required
T.R: Test Required

M	WellModel not Available
S	Sensors need Maintenance

Reservoir 1

Closed Wells
Switching Wells

Blue Date for DCS Test

Latest Well Tests | Calculated

#	Well	Liquid	Test Date	Oil	Water	WC	GOR	WHP	FLP	WHT	LC	RC	Oil	Water	Close Date	Reason
1	Well 1	2,128	08/04/13	128	2,000	94	301	169	120	161		48	128	2,000	07/06/13	High Water
2	Well 2	5,557	24/04/13	889	4,668	84	211	236	210	172	192		1,223	4,334	21/07/13	High Interface Wet/Daul Tank
3	Well 3	3,340	21/05/13	668	2,672	80	258	251	225	171		64	668	2,672	02/07/13	Failure of Pump
4	Well 4	3,564	28/05/13	713	2,851	80	229	177	153	170	128	128	713	2,851	21/06/13	Electrical Failure (P-P=4.2 , 4.4 , 3.9
5	Well 5	1,023	12/11/12	31	992	97	306	129	114	150	192	64	31	992	21/12/12	M/S due to No flow on surface.

Closed wells Summary :

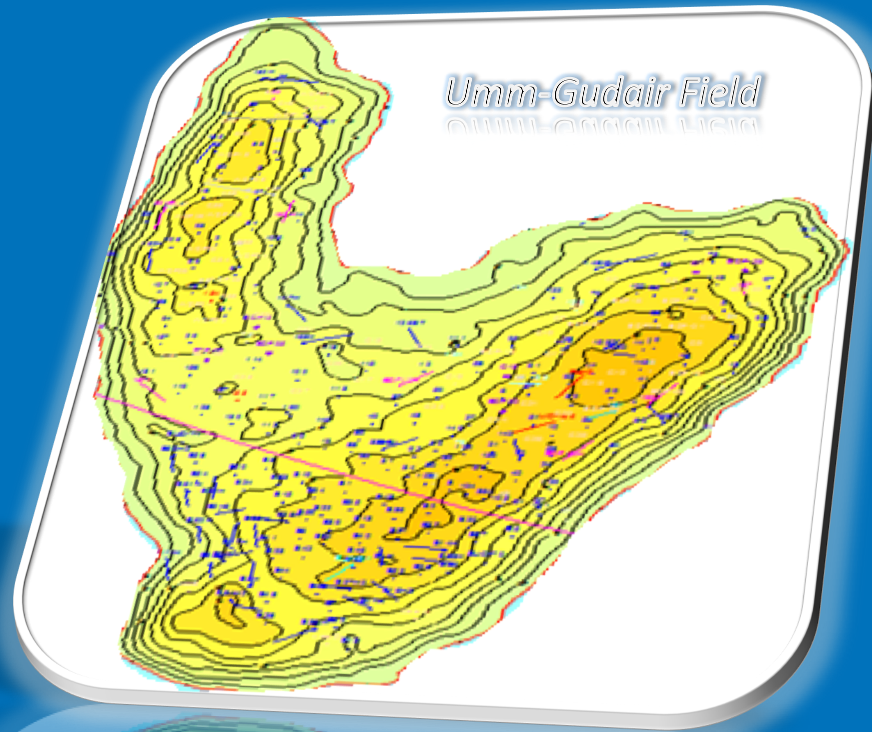
- **Show reason of wells closed due to trips / Water cut / Maintenance .**
- **To Rank the closed wells for Rig Schedule OR Divert them to other GC .**

Summary & Conclusions

Real time system was implemented in UG field (two GC's) for 250 wells and system was up and running for 2 years.

- RT System & Automation provided a platform for auto updating the Surface network model.
- Created a continuous Well & ESP performance monitoring system and a daily report to track the overall field production .
- Model are useful to evaluate Production Optimization scenarios with constraints of declining pump efficiency and reservoir productivity etc .
- Overall System improved the average ESP run life and minimized the flowline bottle necking and restriction.

Thank You



Kuwait Oil Company (KOC)

Fields Development - West Kuwait – UG

Information Solutions - Exploration & Production Team

Questions..

شركة نفط الكويت

Kuwait Oil Company

إحدى شركات مؤسسة البترول الكويتية

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