

Successful development of marginal fields through a progressive in-house approach: a case study from Western Offshore Basin, India

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Abstract

About 30% of the total oil production the world over comes from Marginal fields. Despite many challenges in developing these fields economically, it is largely recognized that if properly managed, marginal fields have the potential to offer excellent opportunities for production improvement and return on investment for companies of any size.

ONGC has been seriously strategizing for more than a decade on developing Small & Marginal fields either through in-house expertise or through outsourcing to a single party or a consortium of partners. ONGC had awarded for development a cluster of offshore marginal fields (B-192, B-45 & WO-24) called Cluster-7 situated at water depth of 82-88 m with estimated STOIIP of 141 MMbbl oil and 4.67 BCM gas to a consortium in 2006 with a stipulated assessment period of 3 years. Keeping in view that since the consortium did not make much progress during the assessment period, the ONGC Management decided to terminate the contract with the consortium and develop these fields with in-house facilities.

The hydrocarbon accumulations in Mumbai High-DCS area are found in Basement, Basal Clastics (Panna), Bassein, Mukta, Panvel and Bombay formations. While undertaking development study for B-192 & WO-24 fields, a reassessment of the entire area led to upward revision of STOIIP and GIIP to 345 MMbbl & 11.05 BCM, respectively. The initial development scheme envisages installation of 4 wellhead platforms and drilling of 20 development wells in B-192 & WO-24 fields. During development drilling, wells were targeted mainly for Panvel and Mukta pay sand through online monitoring, presence of hydrocarbons was confirmed in deeper pay of Basal Clastics which was not envisaged earlier. Successful monetization of this deeper Basal Clastics pay along with Panvel, Mukta and Bassein has boosted up oil production level of the Mumbai High area. Initial well test data of B-192 field had showed oil & gas rates of about 10,000 b/d & 0.19 MMm³/d, respectively, from 10 wells completed in Panvel, Mukta, Bassein & Basal Clastics pay zones as envisaged. This paper basically emphasizes the lesson learnt with a take away that the right in-house approach may be the preferred strategy for marginal field development. Thus, early monetization through in-house efforts may not only be successful in yielding early return on investment but even help in ramping up the production level of a surrounded brown field area.

Introduction

B-192, B-45 & WO-24 marginal fields are located in the Mumbai High -DCS block of Western Offshore Basin at a distance of about 210 km to the west of Mumbai city and are about 20 to 40 km to the south-west of the giant Mumbai High field (Fig.-1). B-192 is an oil field whereas WO-24 & B-45 are oil & gas fields. These three fields, together called as Cluster-7, were offered on ICB tender in December 2004 for development through Service Contract and were awarded to a consortium of M/s Prize Petroleum Company Ltd., M/s. Hindustan Petroleum Corporation Ltd. & M/s. Trenergy (Malaysia) BHD in September 2006 with an assessment period of three years from the date of award. The estimated in-place hydrocarbon volume at the time of the award was 137.48 MMbbl of oil & 4.67 BCM of gas. These volumes were confined to B-192-A, B-192-E, B-45, & WO-24 areas only. The consortium did not make any progress and the assessment period of 3 years ended in March 2009. In view of the slow progress of monetization efforts, prevailing international oil scenario and the spiraling domestic needs, ONGC management decided to terminate the contract and develop the fields along with nearby blocks (B-192-H, B-192-A-A). The G&G data of the entire Cluster-7 area has subsequently been visited and the re-estimated STOIIP is around 327 MMbbl of oil and total gas component is 11 BCM.

For the present development scheme¹, STOIIP of 266.14 MMbbl is considered based on the confidence level. The balance volume of 61.29 MMbbl mostly in the peripheral areas can be considered for development at a later stage after firming up of the in-place reserves based on the generated drilling data and reservoir performance. There is upside potential in terms of possible category in-placereserves estimated to the extent of 106.8 MMbbl of oil equivalent (O+OEG) in and around the fields like B-192-A, B-192-H, B-45 & WO-24 which requires further exploration efforts to prove and upgrade during the development phase.

Generalized Stratigraphy around the fields

Upper Cretaceous Deccan Trap basalt forms the basement in the area. The sedimentary sequence of about 3 km thickness in this area comprises of two distinct cycles of sedimentation, represented by carbonates and clastics. The sediments are ranging from Paleocene to Recent in age. The Tertiary sedimentary sequence overlying the Deccan trap consists of Panna, Bassein, Mukta, Panvel, Bombay, Mahim, Tapti, Bandra and Chinchini formations (Fig.-2).

Structural setup of the fields

B-192 field is a complex structure consisting of four anticlinal closures situated over a basement ridge emanating from Bombay High and trending in NNE-SSW direction. The structure is bounded by faults on the eastern & western limbs and is also affected by NE-SW trending cross faults of a later generation. The four culminations of B-192 structure are designated as B-192-A, B-192-E, B-192-H & B-192-A-A (Fig.-3). The B-45 and WO-24 structures along with the B-192 are part of a basement ridge emanating from Bombay High. The B-45 and WO-24 structure are also an anticline/fault closure trending in NNE-SSW direction. Two major sets of faults trending one in WNW-ESE and other in NNE-SSW directions are present in the area (Fig.-4).

Reservoir Geology

Hydrocarbon accumulations in Deep Continental Shelf (DCS) area of Mumbai High are found in Panna, Bassein, Mukta, Panvel and Bombay formations. In B-192 field, Panna, Bassein, Mukta and Panvel formations have proved to be oil and gas bearing. The lithological and reservoir characteristics of the pay zones are evaluated based on the study of cores, log evaluation and laboratory studies. In B-45 field, Basal Clastics, Panvel, and Bombay formations have proved to be oil and gas bearing. In WO-24, the hydrocarbon accumulations are found mainly in Panvel, Bombay formations. Panna, Bassein, Mukta, Heera and Panvel formations have oil and gas accumulations in the peripheral area of Bombay High. Most of the hydrocarbons are accumulated as a result of structural entrapment.

Reservoir testing and potential

The Mukta & Panvel pays are well developed throughout B-192 field and are prolific oil & gas producer. The hydrocarbons in B-192 field are of sour in nature & maximum H₂S concentration of 190 ppm observed in B-192-H area. The Panvel pay is gas bearing in B-45 structure, with maximum 20 ppm H₂S. During initial testing, B-45 and WO-24 structures proved to be oil & gas bearing in Bombay pay. The initial testing results and reservoir potential are given in Table-1.

Fluid Characteristics

The crude characteristics of Mukta pays are typical black oil with wide variation in pour point & wax content. However, Bassein pays crude oil comparatively heavier than Mukta pays oil. The crude of B-45 (Bombay L-IV) is light with lower pour point & having better mobility whereas in WO-24 (Bombay L-III) crude characteristic is of typical black oil in nature.

Field/ Structure	B-192-H	B-192-A, E, H	B-45	WO-24
Pay Zone	Bassein	Mukta	Bombay(L-IV)	Bombay(L-III)
°API	31-32	34.8-35.7	44.4	34.4
Viscosity, cp	4.3-4.5	3.8-5.9	-	-
Pour Point, °C	30	24-53	24	33
Wax content, (% Wt.)	9.9-10.4	5.2-17.5	10.5	-

The gas is dominantly composed of methane with higher hydrocarbons. Carbon dioxide varies from 3.8 to 24.3 percent in B-192 area and from 2.5 to 4.7 percent in B-45 & WO-24 fields.

Development Strategy

The development scheme¹ was conceptualized through Multi-Disciplinary Team (MDT) approach and prepared the exploitation scheme. MDT after due deliberations decided to develop B-192-A, E, H and WO-24 in the initial phase followed by B-192-A-A and B-45 in next phase. In the first phase, the development scheme envisages installation of four wellhead platforms at B-192-A, E, H and WO-24 and drilling of 20 development wells. Out of the 20 wells, fourteen are conventional high angle, four are vertical, one is dual vertical and one is dual high angle.

In the generated production profiles, better recovery was envisaged with water injection (25.5%), against depletion (11.7%). Water injection is considered from the 2nd year onwards. The expected peak oil & condensate production is 21,913 bopd and peak production of free gas is 1.0 MMm³/d. The cumulative production of oil & condensate is 71.54 MMbbl and total gas (associated gas+free gas) is 4.52 BCM over a period of 18 years from 4 structures in B-192 & WO-24 fields through water injection for pressure maintenance (Table-2).

The production profiles² as envisaged by the consortium of M/s. Prize Petroleum, M/s. HPCL & M/s. Trenergy (Malaysia) BHD shows the expected peak oil & gas production are around 18,000 bopd & 6.9 MMm³/d, respectively (Fig.-5). The estimated cumulative oil & total gas production is 43.2 MMbbl & 2.026 BCM over a period of 10 years through 12 wells from B-192, B-45 & WO-24 fields without any pressure maintenance support (Table-3).

Approved Scheme & Financial Analysis

In the approved option, 5 wells each from B-192-E, B-192-H & B-192-A fixed Wellhead (WH) platforms and 4 wells at WO-24 fixed wellhead platform were to be drilled and put on production through FPSO for entire project life. First oil production was considered from February 2012 through 2 wells from B-192-E, B-192-H and full production was envisaged from December 2012. Produced associated gas and free gas are to be exported to ICP trunk line through 41 Km gas export line (Fig.-6). Condensate would be spiked with gas and oil to be exported through shuttle tankers. Extra cost for additional gas compression has been considered in the rental charges of FPSO.

For better economic return, one additional well in B-192-A from second year of field life and additional completion of B-192-HB1 well in L-II layer of Bassein in the 10th year of field life had been considered over the above option. Facility schedule has further been fine-tuned. First oil production was considered from March 2012 through 2 wells from B-192-E, B-192-H. Full production was envisaged to be achieved by 31st December 2012. The IRR & NPV have been estimated as 15.23% & \$50.5 million considering Govt. regulated base oil price of \$50 per Barrel and gas price of \$4.2 per MMBTU (Table-4).

It can be seen from the above, that Cluster-7 marginal field development project is sensitive to increase in CAPEX and FPSO hiring charges and decline in production (Table-5). The cluster is planned to be developed with best production practices, including pressure maintenance and artificial lift. Accordingly, planning and requirement of relevant facilities are taken care of from the very beginning of production which reduces the probability of downward variations in production. As a result, CAPEX is loaded with secondary recovery process and artificial lift system since inception.

Results and Discussion:

Production from in-house development commenced from B-192 field in September 2013 and subsequently WO-24 field was put on production from June 2014. From both the fields, the Cumulative production till August 01, 2014 is around 2.4 MMbbl oil & 36.67 MMSCM of total gas (AG+FG). The current daily average oil production rate is of the order of 12,000 bopd oil & 0.25 MMSCMD total gas from 15 oil producers & 1 gas producer distributed in 4 platforms (B-192-A, B-192-E, B-192-H & WO-24) against envisaged oil rate of 19,700 bopd and total gas rate of 1.0 MMSCMD from 18 oil & 3 gas producers.

The proposed field development was conceptualized based on data of a single exploratory well on each of the three structures (B-192-A, E & H). During the process of drilling and online monitoring, hydrocarbons were confirmed with MDT sampling and established from deeper pays of Basal Clastics which were not a part of the initial development plan. Successful monetization of this deeper Basal Clastics pay has boosted up oil production level. The first well B-192-E-XM2, completed in Basal Clastics has produced @ 2,020 bopd oil on self-flow during initial testing. Development of this unconventional reservoir was observed in the well B-192-E-XP2. In the northern culmination, the well B-192-A-XP2 produced oil @ 2,700 bopd on self-flow with GOR of 106 m³/m³ & FTHP 800 psi, during initial testing. There is possibility of pool extension further east ward, opening a large area to be confirmed with appraisal / exploratory inputs. This resounding and landmark achievement during exploitation of Marginal fields has not only contributed to reserves accretion but to raising the production potential of the Asset.

Production from the fields has been originally envisaged through FPSO and it is likely to be operational by this year end (2014); an alternative arrangement has been made to produce the wells through a 46 km long, 16" gas evacuation line connecting B-192-E hub with the nearby process platform 'ICP' of Mumbai High field. Due to distance wells are producing with higher Tubing Head pressure (THP). The well fluid is reaching the

process platform, travelling a long distance of 46 km. due to sufficient pressure support from the reservoir. After installation of the FPSO, with lower THP, the deliverability of the wells is expected to be higher than at currently prevailing condition. This could be the remarkable beginning of focused in-house development of the significant hydrocarbon resource potential in the marginal fields besides opening up a new dimension for exploitation of unconventional basal clastics reservoir in B-192 area.

Conclusions:

1. Exploitation of Cluster-7 fields through in-house effort has helped to boost up the production level of Western Offshore Unit. The discovery of new unconventional oil pool in Basal Clastics, which was not envisaged earlier, has added significant contribution to the oil production (current production rate: 3,706 bopd oil & 25,000 m³/d gas).
2. The envisaged cumulative oil & gas production by 10th year is 10.3 MMbbl & 1.7 BCM respectively more in case of in-house development over the consortium generated production profile. The in-house development considered exploitation with only 2 fields (B-192 & WO-24) with pressure maintenance through water injection against 3 fields considered by the consortium through depletion mode.
3. Sensitivity of the project has been carried out with 12% hurdle rate for discounting the cash flow and 6% OPEX escalation as in actual practice. The Break-even oil price was achieved at \$47.01 / barrel.
4. The present development will lead to the opportunity to exploit the upside potential from B-45, B-192-A-A and B-192-E area after monitoring the performance of fields B-192 & WO-24.
5. Exploitation of Cluster-7 fields through in-house development has proved to be profitable from the company's perspective over the outsourcing to a private consortium.

References:

1. Internal Reports of ONGC (unpublished)
2. Report on 'Development of Western Offshore Marginal Fields Cluster-7 (B-192, B-45, WO-24) by the Consortium of M/s. PPCL, HPCL & Trenergy, Vol.-II (unpublished)

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Table-1: Initial Reservoir testing results

Field	Pay	Depth	Bean	FTHP	Oil Rate	Gas Rate	GOR/GCR	Res. Press.	Res. Temp.	Remarks
		m MSL	1/64"	psi	b/d	m ³ /d	v/v	psi	°F	
B-192-A	Mukta	2302	32	675	703	68752	615	3479	280	
	Panvel	2208	32	565	1670	27103	102	3310	280	
B-192-E	Mukta	2369	32	600	1572	30536	122	3569	282.5	H2S-40 ppm
	Panvel	2258	32	425	1300	15091	79	3466	279	H2S-10 ppm
B-192-H	Bassein	2538	32	425-490	1010	40416	252	-	-	W/C: 10-25%
	Mukta	2467	32	900	2130	40472	120	3662	-	H2S-190 ppm
	Panvel	2338	32	125	504	3319	41			
B-192-A-A	Mukta	2360	32	380	1283	11482	56	3345	290	
B-45	Basal Clastics	2065	32	570	236	71106	1895	3074	260	Gas well
	Panvel	2045	32	2050	-	197245	-			H2S-20 ppm
	Bombay	1735	32	1180	1025	134781	827	2676	260	°API-40
WO-24	Panvel	2111	32	2200	395	288000	4568	3320	270	°API-50, Gas well
	Bombay	1639	32	190	816	3621	28	2850	233	°API-33

Table-2: Envisaged oil & gas production profile for in-house development

Year	Oil Rate	Cond. Rate	WI Rate	Cum. Oil +Cond.	Associated Gas	Free gas	Cum. Total Gas	Strings on prod./ injection		
	bopd	bcpd	bwpd	MMbbl	MMm ³ /d	MMm ³ /d	BCM	OP	WI	GP
1	882	0	0	0.321	0.014	0	0.005	4	0	0
2	19707	786	0	7.800	0.458	0.562	0.377	18	0	3
3	20513	1400	9335	15.800	0.569	1.000	0.950	13	6	3
4	17628	1398	17685	22.745	0.494	0.998	1.494	13	6	3
5	17232	1396	18469	29.544	0.521	0.998	2.049	13	6	3
6	16110	1253	18757	35.884	0.496	0.896	2.558	13	6	3
7	14125	1026	18939	41.413	0.383	0.734	2.965	13	6	3
8	11982	830	18991	46.097	0.284	0.594	3.285	13	6	3
9	10215	680	18909	50.078	0.199	0.487	3.536	12	6	3
10	8794	560	18712	53.488	0.143	0.401	3.734	12	6	3
11	8182	478	18453	56.641	0.116	0.342	3.902	12	6	3
12	7602	415	16833	59.576	0.109	0.297	4.050	12	6	3
13	7108	324	15238	62.284	0.096	0.232	4.169	12	6	3
14	6660	272	15082	64.812	0.083	0.194	4.271	12	6	3
15	6261	230	14965	67.187	0.074	0.164	4.358	12	6	3
16	5911	193	14878	69.410	0.067	0.138	4.433	12	6	3
17	5276	164	14812	71.392	0.059	0.117	4.497	12	6	3
18	319	69	6818	71.546	0.003	0.049	4.517	4	6	3

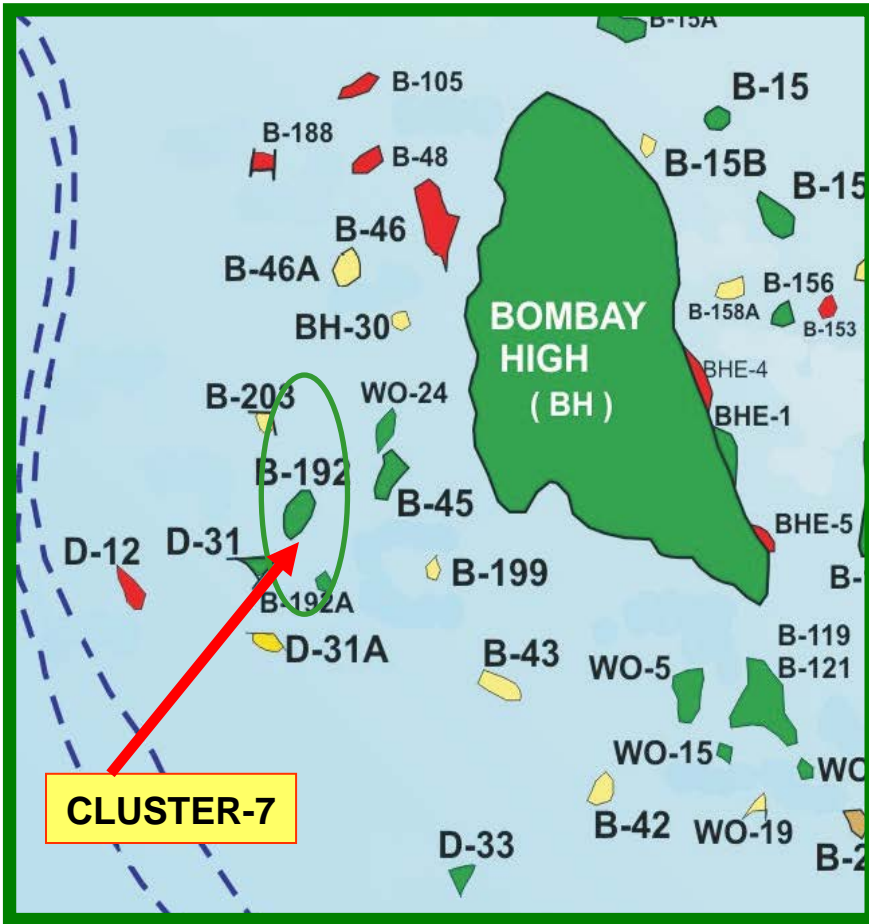
Table-3: Production Profile of the Consortium**Table-4: Financial Analysis**

Year	Oil Rate	Cum. Oil	Total Gas (AG+FG)	Cum. Total Gas	Strings on prod
	bopd	MMbbl	MMm ³ /d	BCM	OP+GP
1	17534.2	6.4	0.344	0.126	12
2	18082.2	13.0	0.688	0.377	12
3	18082.2	19.6	0.688	0.628	12
4	16164.4	25.5	0.688	0.879	12
5	13150.7	30.3	0.688	1.130	12
6	10684.9	34.2	0.688	1.381	12
7	8493.2	37.3	0.662	1.622	12
8	6849.3	39.8	0.507	1.807	12
9	5205.5	41.7	0.372	1.943	12
10	4109.6	43.2	0.228	2.026	12

Oil Price USD/bbl	Project Life		
	NPV @12% , Million USD	IRR, %	Break-Even USD/bbl
45	(-33.96)	9.58	47.01
50	50.46	15.23	
55	134.88	20.08	

Table-5: Combined Sensitivity Analysis (NPV @12%, Crores Rs.)

Exchange Rate (considered during 2009-10)	Rs 47/USD	Rs 48/USD	Rs 50/USD	Rs 46.32/USD
Base case	237.17	267.60	328.46	216.47
APEX +10%, OPEX +10% & Prod -10%	(-528.18)	(-514.39)	(-486.81)	(-537.55)
CAPEX +20%, OPEX +20% & Prod -20%	(-1293.52)	(-1296.37)	(-1302.08)	(-1291.58)
CAPEX +10%, OPEX +10%, Prod -10% & FPSO hiring + 10%	(-662.34)	(-651.41)	(-629.54)	(-669.78)
CAPEX +20%, OPEX +20%, Prod -20% & FPSO hiring + 20%	(-1586.24)	(-1595.32)	(-1613.49)	(-1580.07)



CLUSTER-7

AGE	STRATIGRAPHIC UNIT	THICKNESS (M)	LITHOLOGY	OIL/GAS	SEISMIC MARKER
LATE MIOCENE TO RECENT	CHINCHINI	1170-1280	3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3		
EARLY MIOCENE TO MIDDLE MIOCENE	RATNAGIRI	680-700	[Lithology pattern]		H1A
LATE OLILOCENE	PANVEL	280-320	[Lithology pattern]	●	H3D
EARLY OLILOCENE	HEERA/ MUKTA	60-115	[Lithology pattern]	●	H3A
MIDDLE EOCENE	BASSEIN	5-110	[Lithology pattern]	●	H4
PALEOCENE TO EARLY EOCENE	PANNA	10-55	[Lithology pattern]	●	
L. CRETACEOUS/ PRECAMBRIAN	DECCAN TRAP/ BASEMENT		[Lithology pattern]		

Fig.-1: Location Map of Cluster-7 fields

Fig.-2: Generalized Stratigraphy of B-192 area

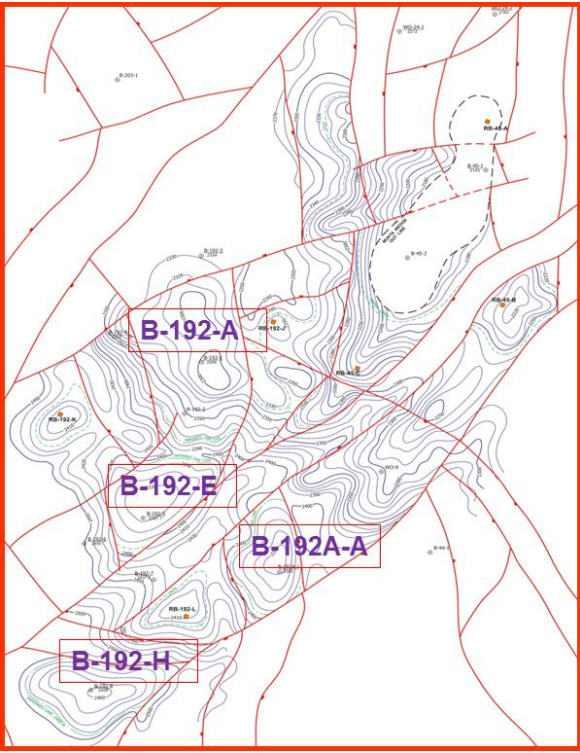
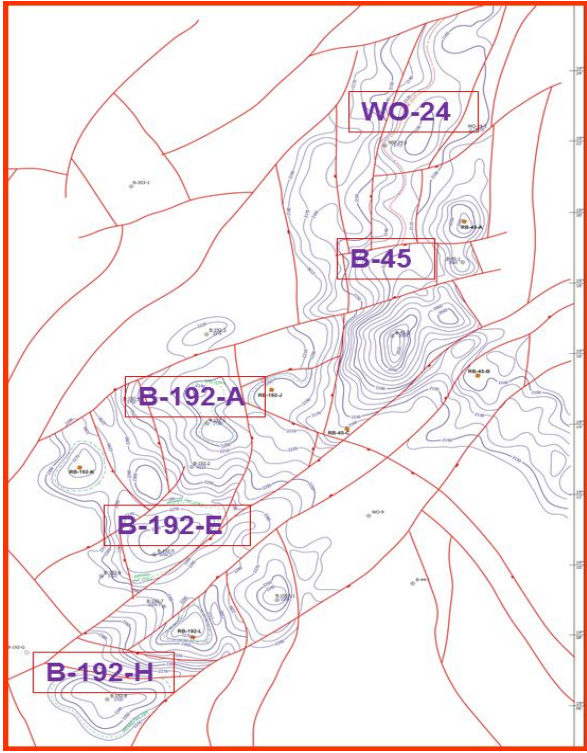


Fig-3: Structure contour map at top of Panvel pay

Fig-4: Structure contour map at top of Mukta pay

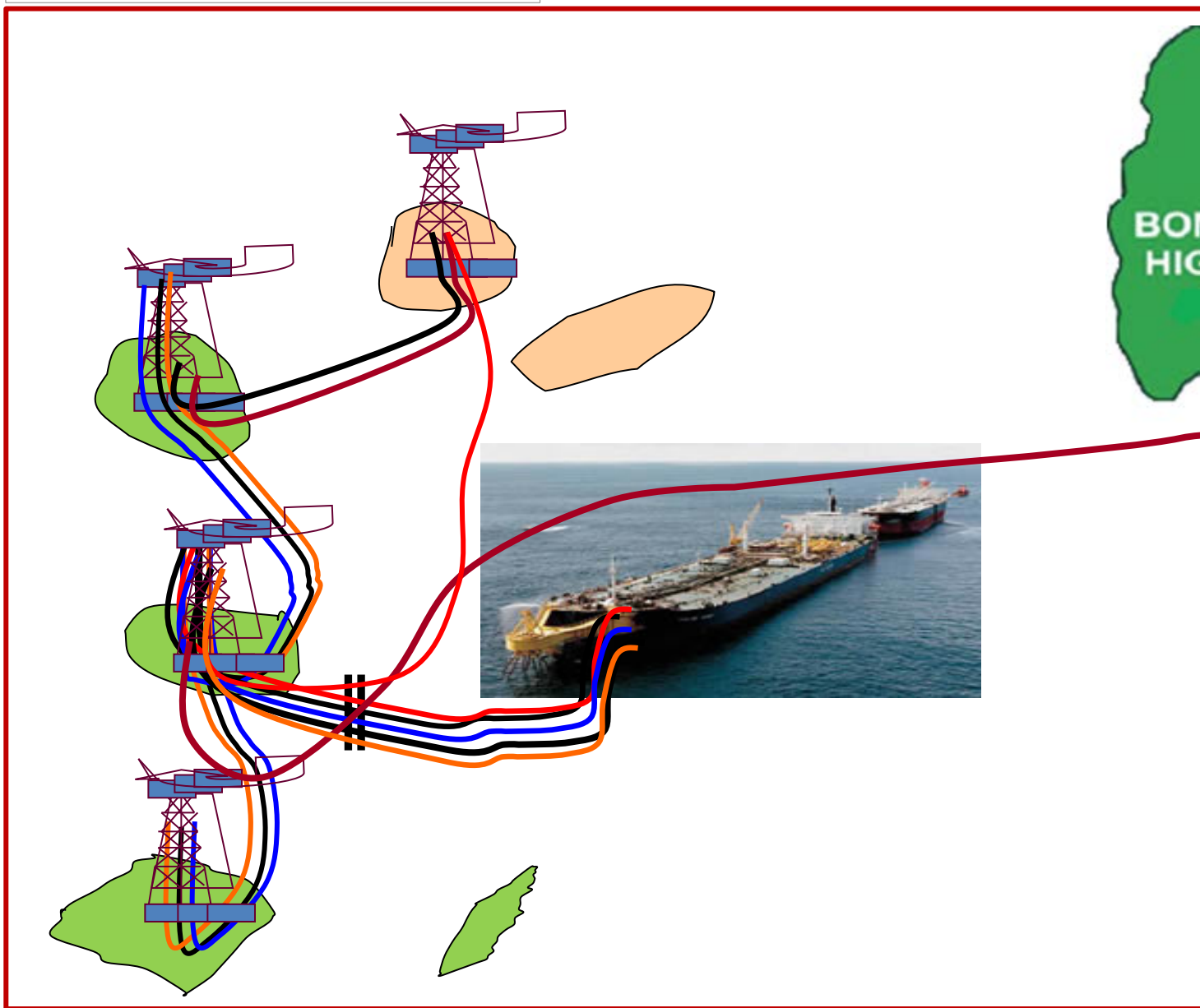
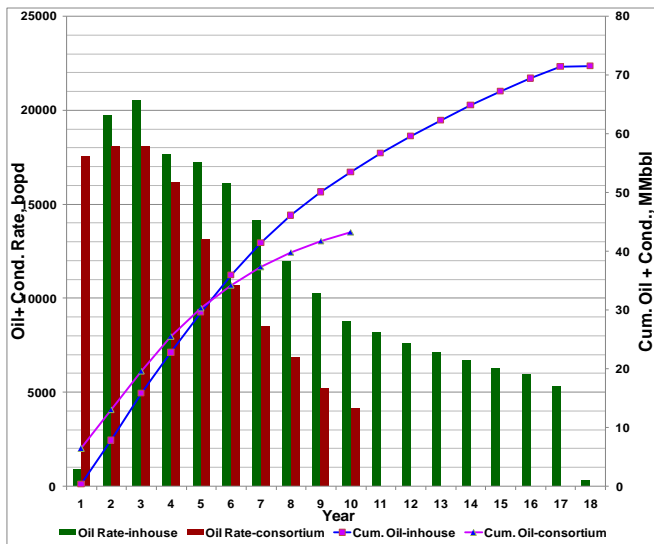


Fig-5: Comparison of oil Production performance

Fig-6: Evacuation Plan of Cluster-7