7.0 Additional Studies

7.1. Risk Assessment

Oil India Limited (OIL) of Kakinada, India, plans to carry out 18 additional exploratory drilling in Block KG-ONN-2004/1 awarded under NELP VI. As part of the procedure for clearance by the MOEF&CC, OIL need to submit a rapid risk assessment of the operations. OIL has appointed Bhagavathi Ana Labs Private Limited (BALPL) to conduct a rapid risk assessment of the proposed drilling operations and to establish that the level of risk will be as low as reasonably practicable (ALARP). OIL intends for drilling of exploratory Wells to the depth ranging from 2000 m – 5500 m.

7.1.1.Block Description

Location

18 Additional Exploratory Wells are located in 353.46 Sq.Km (315.46 Sq.Km) in East Godavari District of Andhra Pradesh and 38 SQKM in Yanam District of Puduchery). This block is situated in SE of East Godavari sub basin of KG Basin Onshore Area.

7.1.2.Rapid Risk Assessment Approach

Figure 21 shows the methodology adopted for the rapid risk assessment of the drilling operation.

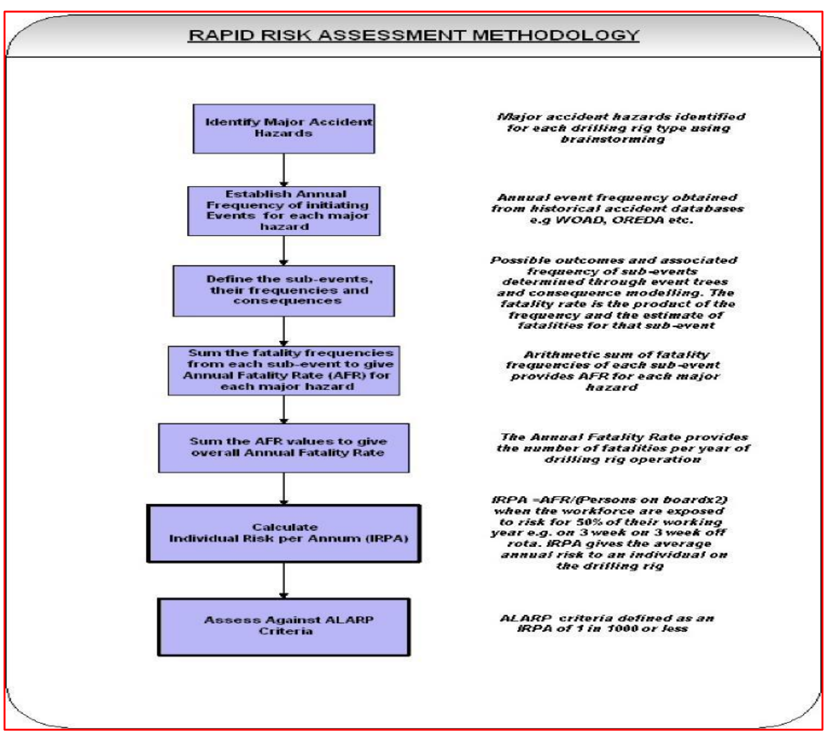

Figure 21 Rapid Risk Assessment Methodology

Study Assumptions

The quantified risk assessment (QRA) approach used in this rapid risk assessment is necessarily generic in nature as the drilling Rig type has yet to be selected. However, a credible QRA can be achieved by the careful setting of assumptions and generally by taking a conservative view of the event frequency, equipment performance and consequence modelling. This will be the approach that has been followed in this study.

The principal study assumptions regarding, drilling & testing lifecycle, study scope, Well data, legislative compliance, support services, operating practices are contained in **Table 61**. These assumptions have been applied to all generic QRA's. In addition, modelling assumptions specific to Drilling are provided below.

ALARP Risk Principles

The OIL definition of risk tolerability, against which all the QRA results have been assessed, below The definition of what level of risk is tolerable, difficult and necessarily subjective. For safety risks Oil India Limited (COMPANY) has adopted the ALARP principle (as low as reasonably practical) outlined in **Figure 22** below.

In general terms, the risk should be considered to be ALARP if the cost of reducing the risk further cannot be justified by the reduction in risk which would occur. For many risks these ALARP considerations may be addressed qualitatively. For high risk situations numerical risk tolerability performance standards are required.

If the risk is not considered to be ALARP even following the correct development and application of control measures, then alternative ways of achieving the operational objective shall be identified and considered.

Qualitative demonstration of ALARP

In relatively low risk situations when the ALARP justification is being made qualitatively some or all of the following can be applied where appropriate:

- demonstration of the application of best practice including technology and management techniques,
- reference to trends in accident and incident statistics,
- discussion /comparison of risk levels before and after possible change, i.e. identification of practicable options for reduction of risks following the preferred hierarchy as follows, elimination or minimisation of hazard, engineering design, suitable systems of working, and then personal protective equipment

Quantitative demonstration of ALARP

Where the consequences of a hazard being realised are very high, i.e. where multiple fatalities, severe environmental damage or damage to installations, and/or major loss of production would result, then quantitative risk assessment (QRA) techniques must be used to demonstrate ALARP. It needs to be understood that QRA is not an exact science; it relies on the use of historical data which may be inaccurate or not directly relevant. Nevertheless, it is valuable in comparing risks to identify priorities and can be used with caution to establish absolute levels of risk. These absolute levels can then be compared with criteria which establish the way in which risks are to be treated.

COMPANY has determined that, on the basis of generally accepted international risk acceptance criteria:

- No offshore installation shall pose an individual risk per annum (IRPA) of death to those involved in operating or maintaining the installation from major accidents greater than a 1 in 1,000 chance a year. If this risk can be shown to be less than 1 in 100,000 a year, then it will be accepted;
- Where the risk lies between these levels, then potential design improvements will be assessed to ensure that risks are reduced to an ALARP level.
- In other words: an IRPA greater than 1 in 1,000 a year cannot be accepted as ALARP; an IRPA less than 1 in 100,000 a year is automatically accepted; IRPA's between these levels may be accepted but additional safeguards should be examined to ensure that an ALARP level is reached.

Control Measures to Reduce Risks

Once it has been decided that a risk needs further control, the means of doing so should be evaluated in the following order of preference:

- Eliminate the hazard. Occasionally this may prove practicable, for example, by changing the material used, the process or the equipment. An example would be cleaning using a detergent instead of a flammable, toxic solvent;
- Technical solutions. Engineered control measures, for example enclosures, ventilation systems, alarms, trips and guards. These are relatively independent of the human factor, and generally can be made reliable;
- Procedural solutions. Doing things in a different way to improve safety relies on individuals complying with procedures. Training and communication are important to ensure that operators recognise the risks and know how to avoid them;
- Protective equipment (PPE). This is the least satisfactory form of control, and should only be considered after all others have been rejected.
- It should be noted that introducing controls can produce further risks which may need to be assessed in turn.

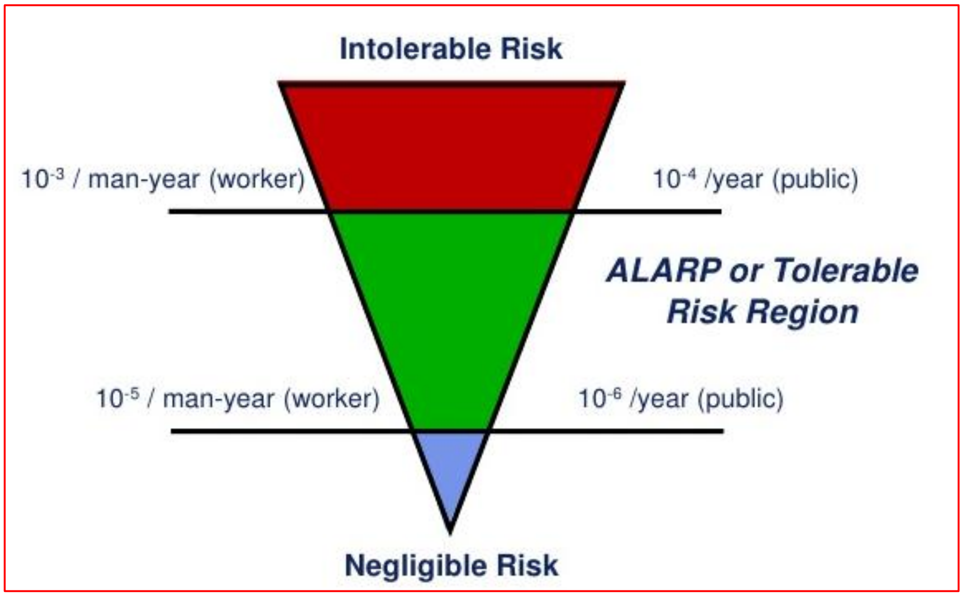

Figure 22 ALARP Criteria

Risk cannot be justified save in extraordinary circumstances

Finally, each QRA requires:

- The identification of major hazards specific to the units are being assessed The construction of an event tree for each major hazard to derive a set of credible sub – events Numerical values for major hazard occurrence frequencies and event probabilities are derived from international accident databases of historical incidents and are combined in the event tree to derive occurrence frequencies for these sub events. BALPL have consistently adopted a conservative modelling approach in defining these frequencies and probabilities. All such modelling assumptions are listed;

- The modelling of the consequences in terms of potential fatalities from each credible sub event. As these are 'rapid', generic risk assessments, this modelling does not take the form of detailed physical modelling but rather reflects typical outcomes based on historical data. BALPL have consistently adopted a conservative approach in deriving such outcomes and all such modelling assumptions are listed

It is OIL's intention to use the latest generation of drilling units for this work. Hence the use of historical records which reflect the performance of potentially lower design and operational standards, may introduce an additional element of conservatism into the approach over and above that inherent in BALPL's selection and application of data.

Table 61 Principal Study Assumptions

Assumption Number	Assumption Title	Description
1	Lifecycle	The risk analysis will assume that the drilling Rig is securely installed on location and will cover a typical 'whole lifecycle' of the Well operation including: a. Drilling / Casing / Cementing b. Well testing c. Decommission
2	Study Scope	a. The QRA will address those hazards with the potential to cause a "major incident" (e.g. multiple fatalities) b. The study is confined to events occurring on the Rig and the impact of any releases on the environment. c. In the event of Rig abandonment
3	Well Information	The Well has the potential to flow either oil or gas a. The Well is likely to generate High Pressure / High Temperature b. H_2S or significant CO2 may be present in the Well c. Drilling will be likely to take place at any time during the year d. The Rig will be on station for 30-45 days. For analysis purposes a conservative approach, assuming a 45 day Well (40 days drilling & 5 days testing) will be used
4	Drilling Rig Certification	a. The drilling Rig will fully comply with all relevant Indian and international standard and the Operator has certified it as fit for purpose at the commencement of drilling
6	Site Information	a. Prior to drilling Rig installation, the Operator will have carried out any required environmental study and identified all potential environmental sensitivities and an appropriate site survey for
7	Operator Information	a. Operator has and will apply a modern Safety Management System b. All drilling and other related operations carried out on the Rig reflect best Industry practices and comply with all relevant Indian and international standards.
8	Acceptable Risk Levels	The individual risk per annum (IRPA) will be assessed against the ALARP risk level
9	Supporting Study Data	Industry acceptable data sources will be substantially utilised in the assessments. These include but are not limited to: a. UK Health and Safety Executive (HSE) Hydrocarbon Ignition Database b. Purple Book

Assumption Number	Assumption Title	Description
10	Well Testing	a. Test equipment skid mounted, typically consisting of heater, test separator, surge drum, holding tank, metering runs, associated pipework b. Each test lasts for 5 days c. Ten (10) men in the immediate vicinity of the equipment during testing

7.1.3. Drilling Rig

This section summarises the rapid risk assessment for the exploration Wells on Block KG-ONN-2004/1 using electrical drilling Rig.

7.1.3.1. Risk Analysis Results for Drilling Rig

Major Accident Hazards

The major Accidental hazards identified for the Drilling Rig are shown in **Table 62.**

Table 62 Major Accident Hazards for Drilling Rig

Hazard No	Major Accident Hazard	Including
1	Well Blowout During Drilling	Drill Rig blowouts
2	Dropped Objects	Offloading & back loading: Movement of material on Rig: Dropped drill pipe
3	Structural Failure	It is assumed that the unit has been chosen to be fit for the purpose for its area of operation and that failure occurs as a result of extreme events due to high wind velocity/ground movement.
4	Non Process Fires	Cellulosic or electrical fires in accommodation: Diesel fuel tank or pipe leaks leading to fires & explosions in machinery spaces: etc.
5	Hydrocarbon Leaks During Well Testing	Leaks, fires and explosions

Table 63 Assumptions for Well blowout During Drilling in Rig

S.No	Assumption	Comments
1	Blowout Probability • Probability of blowout per Well is taken as 0.0063 • Frequency of Blowout is derived as 0.044 per year	Assume that a Rig drills 7 Well s per year made up of: • 45 days drill & test • 5 days move • 15 days WOW per year • Hence annual frequency becomes

S.No	Assumption	Comments
		0.0063*7 = 0.044
2	Ignition probability of gas escaping from either a top drive blowout is taken as 0.1	20 year historical data set and takes account of a trend to lower ignition probabilities in recent Well s. Note blowout ignition probability of 0.3
3	For blowouts, when ignition occurs: • 50% of the time it occurs immediately and results in a jet fire • 50% of the time it will be delayed and result in an explosion	In the event of ignition of hydrocarbons the following may occur. • pool fire: a burning pool of liquid (oil or Well fluid) • jet fire: a burning jet of gas which if ignited soon after it occurs results in an intense stabilised jet which is very destructive to anything within it or close to it • Flash fire: delayed (say after 15 minutes) ignition of a gas release. In this time the release may have formed an extensive plume and the ensuing fire will kill everyone within it who is unprotected but not damage structures • Confined explosion: delayed ignition of a gas release within a confined space, the delay (usually in excess of 5 minutes) giving time for an explosive mixture to build up. It has the potential for considerable fatalities and damage. It is assumed that the necessary degree of confinement does not exist on a jack up • Vapour cloud explosion: an ignited gas plume which burns in such a way that it generates overpressures characteristic of and explosion. • A simple but conservative approach has been taken that all immediate ignition events result in a jet fire while the results of all delayed ignition events (whether they are from a flash fire or a vapour cloud explosion) are equally severe
4	For blowouts on Rig resulting in immediate ignition: • 10% probability of fatality for all personnel on Drilling Rig • 0% probability of fatality for all other personnel who are assumed to evacuate the Rig	A blowout on the Drilling Rig with immediate ignition would be expected to lead to a gas jet. An ignited gas jet from a blowout would result in a large flame which has the potential to impact structural members of the drilling, leading to their failure. A prolonged fire (say one to 2 hours) could cause the collapse

S.No	Assumption	Comments
	• Personnel evacuating Rig will have escape & evacuation probability of fatalities	resulting in more extensive damage. Average number of fatalities per incident is around 3. The time averaged number of personnel on and around the Drilling Rig is 29. To reflect this historical performance it is assumed that 10% of these will be fatalities in the event of such an incident.
5	For ignited blowouts on Rig resulting in delayed ignition: • 50% probability of fatality for all personnel on Drilling Rig • 0% probability of fatality for all other personnel who are assumed to evacuate the Rig • Personnel evacuating Rig will have escape & evacuation probability of fatalities	A blowout on the Drilling Rig with delayed ignition could be expected to result in an explosion with the potential to kill all unprotected personnel within the gas cloud. This worst credible accident scenario could result in 100% fatalities on the Drilling Rig. To conservatively reflect this historical performance a 50 % fatality level is assumed.
6	For unignited blowouts assume a 5% probability that the reservoir contains volumes of H_2S or CO_2 at concentration levels high enough to cause fatalities	Estimate
7	Unignited Blowouts: If the gas contains low H_2S or CO_2 • 0% probability of fatality for all personnel on Drilling Rig • 0% probability of fatality for all other personnel who are assumed to follow the pre-arranged H_2S drill and successfully evacuate the Rig • c)Personnel evacuating Rig will have	Assume a precautionary evacuation of the Rig takes place There have been no recorded fatalities from unignited blowouts.
8	Unignited Blowouts: If the gas contains high levels of H_2S or CO_2 • 10% probability of fatality for all personnel on Drilling Rig as a result of H_2S poisoning • 0% probability of fatality for all other personnel who are assumed to follow the pre-arranged H_2S drill and successfully evacuate the Rig • Personnel evacuating Rig will have escape & evacuation probability of fatalities	It is conservatively assumed that large volumes of gas rather than oil are present in the reservoir. Assume that best practice H_2S protection measures are adopted and regular drills held. H_2S Detection system. All personnel follow procedures but, as a result of equipment failure or lack of training only 90% success is achieved

Table 64 Event tree For Well blowout During Drilling

	Blowout occurs under water	Ignition of blowout	Ignition of Well head	Delayed ignition	High H2S or CO2 concentration	Sub Event: Description	Sub Event: Frequency per year
Probability	0.17	0.1	0.1	0.5	0.05		
Blowout 4.4E-02 per year	7.5E-03	7.5E-04				1 Explosion around Rig	7.5E-04
		6.7E-03			3.4E-04	2 Gas cloud around Rig with high concentration of H_2S or CO_2	3.4E-04
					6.4E-03	3 Gas cloud around Rig with low concentration of H_2S or CO_2	6.4E-03
	3.7E-02		3.7E-03		1.8E-03	4 Explosion at Well head with delayed ignition	1.8E-03
					1.8E-03		1.8E-03
			3.3E-02		1.6E-03		1.6E-03
					3.1E-02		3.1E-02

Table 65 Consequence Calculations for Well blowout During Drilling

Sub Event	Frequency per year	Men in immediate area	Prob of immediate fatality	Estm. Immediate fatalitie	Men needing escape/ evacuati	Means of escape/ evacuati	Prob of fatality	Estm. Escape/	Total fatalities	AFR
1 Explosion around	7.5E-04	26	0.5	13	101	TR (note 1)	1.3E-05	1.3E-03	13	9.7E-03
2 Gas cloud	3.4E-04	26	0.1	3	111	TR (note 1)	1.3E-05	1.4E-03	3	8.8E-04
3 Gas cloud around	6.4E-03	26	0	0	114	TR (note 1)	1.3E-05	1.5E-03	0	9.5E-06
4 Explosion at Well head with delayed ignition	1.8E-03 1.8E-03	26 26	0.5 0.1	13 3	101 111	TR (note 1) TR (note 1)	1.3E-05 1.3E-05	1.3E-03 1.4E-03	13 3	2.4E-02 4.8E-03

5 Gas jet flame at Well head	1.8E-03	26	0.1	3	111	TR (note 1)	1.3E-05	1.4E-03	3	4.8E-03
6 Gas leak at Well head with	1.6E-03	26	0.1	3	111	TR (note 1)	1.3E-05	1.4E-03	3	4.3E-03
7 Gas leak at Well head H_2S or CO_2 with low concentration	3.1E-02	26	0	0	114	TR (note 1)	1.3E-05	1.5E-03	0	4.6E-05
TOTAL	4.3E-02									
AFR										
IRPA	1.9E-									

Evacuation methods

TR - muster in TR (no evacuation required)

H - Muster in TR and evacuation

Notes

1 Controlled evacuation

Table 66 Assumptions for Passing Vehicle Collision to Drilling Rig

S.No	Assumption	Comments
1	Frequency of passing Vehicle collision is 0.0008 per year	As per above references
2	In 90% of such cases there is sufficient prior warning to allow for precautionary evacuation	No data has been found. This estimate is based on the assumed existence of the following controls to provide for early warning: • Rig has radar which is regularly monitored • Control of Vehicle Movement
3	Of the remaining 10% of impacts, it is assumed that the following apply: • 75% do not impair the structural stability of the Rig; only 25% do • Of these 25%, one tenth also result in ignition leading to jet fires / explosion	Based on a conservative interpretation of data presented in reference. Collision energy of 35 – 70 MJ is required for column collapse in Rigs. Estimate taking account of the fact that fires and explosions can only occur when the Rig is in the reservoir (a small % - around 10% - of the time that the Rig is on station) coupled with the fact that, even when hydrocarbons are present controls exist to shut down flow (e.g. sub surface safety valves)and these would have had to be impaired
4	Ignore the possible impacts of a live Well at the same time as this	Assume that the Well is likely to be live (assuming that all Well s drilled are successful) for 5 days out

S.No	Assumption	Comments
	incident occurs	of 45, i.e. a probability of 0.11. In addition the live Well will have a number of barriers to prevent flow including the BOP and possibly safety valves. Assume a typical reliability of 0.01 per demand for these 2 safety barriers.
5	When the Rig is toppled • 25% of the personnel on the Rig are immediate fatalities • Remaining 75% escape to the land The probability of successfully rescuing is taken as 0.8	Estimate based on calculations using data from reference, assume moderate weather conditions

Table 67 Event Tree for Vehicle Collision to Drilling Rig

	Men on Rig	capsizes	Sub Event	
			Description	Frequency per
Probability	0.1	0.25		
Passing Vehicle impacts	8.0E-05	2.0E-05	1 Capsizes	2.0E-05
		6.0E-05	2 Impact	6.0E-05
8.E-04 per year	7.2E-04		3 Collision when unoccupied	7.2E-04

Table 68 Consequence Calculations for Vehicle Collision to Drilling Rig

Sub Event	Frequency per year	Men in immediate area	Prob of immediate fatality	Estm. Immediate fatalities	Men needing escape/ evacuati	Means of escape/ evacuation	Prob of fatality	Estm. Escape/ evac	Total fatalities	AFR
1	2.0E-05	114	0.25	29	86	R	2.E-	17	46	9.1
2 Impact	6.0E-05	114	0	0	114	H	1.3E-	1.5E-	0	8.9
3	7.2E-04	114	0	0	114	H	1.3E-	1.5E-	0	1.1

TOTAL9.1E-04

AFR 4.0E-06

Evacuation methods

TR - muster in TR (no evacuation required) H - musters in TR and evacuation

Table 69 Assumptions for Dropped Objects on Drilling Rig

.No	Assumption	Comments
1	Frequency of dropped loads per year is 0.55	“falling objects” (defined as all falling loads / dropped objects from crane, drill , or any other lifting equipment. Crane fall accidentally dropped to land and man overboard are also included) of 1.1 per year. However many of the contributions to this figure will not have a “major hazard” contribution and it is inappropriate to include all of them in a QRA modelling approach. Reference allows a figure for crane related dropped objects to be derived as 0.18 per year. Assuming that there are 2 cranes on the Rig this equates to a frequency of “crane related” dropped objects of 0.36 per year. These incidents are all likely to be major hazard related and are (in theory) included in the 1.1 per year figure. There may however be additional contributions to major hazards. We shall assume that 50% of the contributions in reference are major hazard related. Hence an annual frequency of 0.55 is taken for dropped loads.
2	The probability of a dropped load landing on a vulnerable area is taken as 10%	Operational experience suggests that there are few vulnerable areas over which crane loads are permitted to travel, hence this should reflect a conservative approach
3	The probability of such a dropped load resulting in loss of hydrocarbons is taken as 10%	Relatively few heavy lifts should be carried out. In addition, it is assumed that the Rig is managed to meet best operational practice such that very heavy lifts which have the potential to cause a major hazard are planned in advance. Where necessary, additional controls should be provided to minimise the chances and consequences of dropped loads
4	If hydrocarbons were released their probability of ignition is taken as 0.1	A very conservative interpretation of data for ignition following a small gas leak
5	For unignited hydrocarbon releases assume a 5% probability that the reservoir contains volumes of H_2S or CO_2 at concentration levels high enough to cause fatalities	Estimate
6	When the dropped object does not fall on a vulnerable area, there is no fatality	BALPL assumption
7	Unignited hydrocarbon releases: If	Estimate

.No	Assumption	Comments
	the gas contains high levels of H_2S or CO_2 • 0.1 probability of fatality for all personnel (10) around laydown area • 0% probability of fatality for all other personnel who are assumed to follow the pre-arranged H_2S drill and successfully evacuate the Rig • Release is quickly brought under control and no further fatalities arise.	
8	If a fire occurs as a result of a dropped load the probability of immediate fatality is taken to be 0.1 Fire is quickly brought under control and no further fatalities ensue	Reflective of a typical industry approach
9	For gas leak with low H_2S, there are no fatalities	BALPL assumption

Table 70 Event Tree for Dropped Objects on Drilling Rig

	Drop on vulnerable area	Loss of hydrocarbon	Ignition	High H_2S or CO_2 concentration	Sub Event: Description	Sub Event: Frequency per year
Probability	0.1	0.1	0.1	0.05		
Dropped object 5.5E-01 per year	5.5E-02	5.5E-03	5.5E-04		1 Fire	5.5E-04
			5.0E-03	2.5E-04	2 Gas leak at Rig level with high H_2S or CO_2 concentration	2.5E-04
				4.7E-03	3 Gas leak at Rig level with low H_2S or CO_2 concentration	4.7E-03
		5.0E-02			4 Damage to equipment or people	5.0E-02
	5.0E-01				5 No damage to equipment or people	5.0E-01

Table 71 Consequence Calculations for Dropped Objects on Drilling Rig

Sub Event	Frequency per year	Men in immediate area	Prob of immediate fatality	Estm. Immediate fatalities	Men needing escape/ evacuation	Means of escape/ evacuation	Prob of fatality	Estm. Escape/ evac fataliti	Total fatalities	AFR
1 Fire	5.5E-04	10	0.1	1	113	TR	0	0	1	5.5E-04
2 Gas CO_2	2.5E-04	10	0.1	1	113	H	1.3E-	1.5E-	1	2.5E-
3 Gas CO_2	4.7E-03	10	0	0	114	TR	0	0	0	0.0E+0
4 Damage to	5.0E-02	10	0.02	0	114	TR	0	0	0	9.9E-03
5 No damage to equipment or people	5.0E-01	10	0	0	114	TR	0	0	0	0.0E+00

TOTAL	1.1E-02
AFR	4.7E-05
IRPA	

Evacuation methods

TR - muster in TR (no evacuation required) H - muster in TR and evacuation

Table 72 Assumption for Structural Failure of Drilling Rig

S.No	Assumption	Comments
1	Probability of a structural failure in any year is assumed to be 0.0028	Structural failure includes: design error, fatigue failure, modification error, operating outside design parameters (e.g. extreme weather / earthquakes in excess of design conditions). It is assumed that the Rig has been correctly specified for the anticipated environmental conditions It is assumed that only the 2 most severe categories will contribute to major structural failure. These are: • total loss of the unit • severe damage to one or more modules of the unit / major damage to essential equipment These 2 categories comprise 12.8% and 22.8% of all structural failure contributions (35.6% in total) Hence

S.No	Assumption	Comments
		the annual Rig failure rate is 0.0077*0.36 = 0.0028.
2	90% of failures are assumed to give some warning and hence allow time for precautionary evacuation.	Estimate.
3	The remaining 10% of failures are split as follows: • 10% of them result in sudden collapse • The remaining 90% are the result of a progressive failure.	Estimate.
4	When escaping from the Rig sudden collapse scenario, personnel will have a 50 % survival probability.	A potentially conservative interpretation which assumes that the collapse is so sudden that many escape routes become unusable.
5	When escaping from the Rig progressive collapse scenario, personnel will have a 90 % survival probability.	Based on a conservative interpretation of reference assuming that all such events will occur during severe weather. Reference gives a probability of failure to survive as 0.06.

Table 73 Event Tree for Structural Failure Structural Failure of Drilling Rig

			Sub Event	
	No precautionary	**Progressive failure**	**Description**	**Frequency per year**
Probability	0.1	0.1		
	2.8E-04	2.8E-05	1 Loss of Rig, personnel have time to evacuate	2.8E-05
		2.5E-04	2 Catastrophic loss	2.5E-04
Structural failure 2.8E-03 per year	2.5E-03		3 Loss of Rig with no personnel on Rig	2.5E-03

Table 74 Consequence Calculations for Structural Failure of Drilling Rig

Sub Event	Frequency per year	Men in immediate area	Prob of immediate fatality	Estm.Immediate fatalities	Men needing escape/ evacuation	Means of escape/ evacuation	Prob of fatality	Estm. Escape/ evac fatalities	Total fatalities	AFR
1 Loss of Rig, personnel have time o evacuate	2.8E-05	114	0	0	114	H	1.3E-05	1.5E-03	0	4.1E-08
2 Catastrophic loss	2.5E-04	114	0.5	57	114	L/R	1.E-01	11.4	68	1.7E-02
3 Loss of Rig with no personnel on board	2.5E-03	114	0	0	114	H	1.3E-05	1.5E-03	0	3.7E-06

TOT AL AFR 1.7 E-02

Evacuation methods

TR - muster in TR (no evacuation required)

H - Muster in TR and evacuation

Table 75 Assumptions for Non-Process Fires of Drilling Rig

S.No	Assumption	Comments
1	Frequency of all fires is taken as 0.021 per annum	Possible sources are diesel spills, electrical fires, accommodation fires.
2	All (100%) of these fires are assumed to be non-process related	Conservative approach reflecting the reality that most fires will be minor and arise from non-process related causes
3	Assume that 20 % of all fires result in significant damage	Reference states that 19% of all fires are considered significant or greater. This figure is rounded up to 20% to ensure conservatism.
4	Two fatalities will occur where there is significant damage. Otherwise, no fatality	Conservative approach. As these fires are not process related the available inventory to feed the fire is assumed to be limited. Hence the fire will be contained and will not be capable of impacting many people on the Rig. It is also

S.No	Assumption	Comments
	will occur	assumed that Rig fire fighting capability will always be able to extinguish the fire

Table 76 Event Tree for Non-Process Fires of Drilling Rig

		Sub Event	
	Significant	Description	Frequency per
Probability	0.2		
Fire 2.1E-02 per year	4.2E-03	1 Fire causing no significant damages	4.2E-03
	1.7E-02	2 Fire resulting in no significant damages	1.7E-02

Table 77 Consequence Calculations for Non-Process Fires of Drilling Rig

Sub Event	Frequency per year	Men in immediate area	Prob of immediate fatality	Estm. Immediate fatalitie	Men needing escape/ evacuat	Means of escape/ evacuat	Prob of fatality	Estm. Escape/ evac	Total fatalities	AFR
1 Fire causing no significant damages	4.2E-03	N/A	N/A	2	112	TR	0	0	2	8.4E-03
2 Fire resulting in no significant damages	1.7E-02	N/A	N/A	0	114	TR	0	0	0	0.0E+00
TOTAL AFR	8.4E-03									
IRPA	3.7									

<u>Evacuation methods</u> TR - muster in TR (no evacuation required) H - muster in TR and evacuation

Table 78 Assumptions for Hydrocarbon Leaks during Well Testing

S.No	Assumption	Comments
1	Assume annual gas leakage frequency of 0.00027	Derived from reference assuming: • Test equipment skid mounted, typically consisting of; heater, test separator, surge drum, holding tank, metering runs, and associated pipework. This equates to 4 pressure vessels, 2 flanges, 2 valves (assume inlet and outlet to isolate skid) and an assumed 40 metres of pipework • reference gives the following annual failure frequencies: pressure vessel (0.00015), valve (0.00023), flange (0.000088), piping (4" to 11" – 0.000036 per metre) • This produces an annual leak frequency of (4*0.00015)+(2*0.000088)+ (0.00023*2) +(40*0.000036) = 0.0027 • Each test lasts for 5 days, there are 7 tests per year hence the equipment is at risk for 35/365 of a year = 0.1 • Thus annual leak frequency is 0.0027*0.1 =0.00027 • testing equipment pressurized at all times
2	Assume that 95% of leaks can be isolated	Typical value used in risk assessments. Detection can be by personnel or automatic equipment and relates to the probability of a single valve not closing. As isolation is possible via the Well head master control valve, the BOP or and ESD valve within the test equipment this can be considered a conservative approach
3	If the gas release is not isolated all workers in the immediate vicinity will be assumed to be exposed	Conservative approach Assume 10 men in the immediate vicinity during testing
4	If the release is isolated no fatalities occur	If the release is isolated only a short lived jet fire or small flash fire is possible in the event of ignition or a small volume of potentially poisonous gas in the event that the gas contains H_2S. In all these scenarios the threat is limited and contained and hence they do not result in any fatalities
5	Assume probability of ignition of 0.1	Reference suggests that the probability of ignition for small and large gas leaks is 0.005 and 0.3 respectively. Reference indicates that this upper value may be too conservative by recommending a probability of ignition for blowouts of 0.1. Most leaks from process equipment are small and hence a figure towards the lower end of the

S.No	Assumption	Comments
		scale will be most appropriate. Although a lower figure may be justifiable the figure of 0.1 is considered suitably conservative
6	When ignition occurs: • 50% of the time it occurs immediately and results in a jet fire • 50% of the time it will be delayed and result in an explosion	In the event of ignition of hydrocarbons the following may occur • **pool fire**: a burning pool of liquid (oil or Well fluid) on the Rig • **jet fire:** a burning jet of gas which if ignited soon after it occurs results in an intense stabilised jet which is very destructive to anything within it or close to it • **Flash fire:** delayed (say after 15 minutes) ignition of a gas release. In this time the release may have formed an extensive plume and the ensuing fire will kill everyone within it who is unprotected but not damage structures • **Confined explosion:** delayed ignition of a gas release within a confined space, the delay (usually in excess of 5 minutes) giving time for an explosive mixture to build up. It has the potential for considerable fatalities and damage. It is assumed that the necessary degree of confinement does not exist on a jack up • **Vapour cloud explosion:** an ignited gas plume which burns in such a way that it generates overpressures characteristic of an explosion. A simple but conservative approach has been taken that all immediate ignition events result in a jet fire while the results of all delayed ignition events (whether they are from a flash fire or a vapour cloud explosion) are equally severe
7	No allowance is made for the Rigs fire fighting capability	A very conservative approach which also reflects lack of knowledge of the Rigs safety equipment
8	Probability of fatalities if the gas leak is not isolated are as follows: • 0% probability for un-ignited releases if low H_2S or CO_2 present. Otherwise see items 9 and 10 • 10% for jet fires • 50% for explosions	Generally reflective of a typical industry approach

S.No	Assumption	Comments
9	For unignited gas releases assume a 5% probability that the reservoir contains volumes of H_2S or CO_2 at concentration levels high enough to cause fatalities	Estimate
10	Unignited releases if the gas contains high levels of H_2S or CO_2 • 10% probability of fatality for all personnel on Drilling Rig as a result of H_2S poisoning • 0% probability of fatality for all other personnel who are assumed to follow the pre-arranged H_2S drill and successfully evacuate the Rig • Personnel evacuating Rig will have escape & evacuation probability of fatalities	It is conservatively assumed that gas rather than oil is present in the reservoir. Assume that best practice H_2S protection measures are adopted and regular drills held. Assume personnel on the Rig are warned of impending danger by alarms, etc. Personnel at most risk assumed to be in open areas. All personnel follow procedures but, as a result of equipment failure or lack of training only 90% success is achieved

Table 79 Event Tree for Hydrocarbon Leaks during Well Testing

	Release is isolated	Ignition	Delayed ignition	High H_2S or CO_2 concentration	Sub Event: Description	Sub Event: Frequency per year
Probability	0.95	0.1	0.5	0.05		
Hydrocarbon leak 2.7E-04 per year	2.6E-04	2.6E-05	1.3E-05		1 Small flash fire	1.3E-05
			1.3E-05		2 Short-lived jet flame	1.3E-05
		2.3E-04		1.2E-05	3 Small gas cloud with high H_2S or CO_2 concentration	1.2E-05
				2.2E-04	4 Small gas cloud with low H_2S or CO_2 concentration	2.2E-04
	1.4E-05	1.4E-06	6.8E-07		5 Explosion	6.8E-07
			6.8E-07		6 Jet flame	6.8E-07
		1.2E-05		6.1E-07	7 Gas cloud with high H_2S or CO_2 concentration	6.1E-07
				1.2E-05	8 Gas cloud with low H_2S or CO_2 concentration	1.2E-05

Table 80 Consequence Calculations for Hydrocarbon Leaks during Well Testing

Sub Event	Frequency per year	Men in immediate area	Prob of immediate fatality	Estm. Immediate fatalities	Men needing escape/ evacuation	Means of escape/ evacuation	Prob of fatality	Estm. Escape/ evac fatalities	Total fatalities	AFR
1 Small flash fire	1.3E-05	10	0	0	114	TR	0	0	0	0.0E+00
2 Short-lived jet flame	1.3E-05	10	0	0	114	TR	0	0	0	0.0E+00
3 Small gas cloud with high H_2S or CO_2 concentration	1.2E-05	10	0	0	114	TR	0	0	0	0.0E+00
4 Small gas concentration	2.2E-04	10	0	0	114	TR	0	0	0	0.0E+00
5 Explosion	6.8E-	10	0.5	5	109	H	1.3E-	1.4E-	5	3.4E-
6 Jet flame	6.8E-07	10	0.1	1	113	H	1.3E-05	1.5E-03	1	6.8E-07

7 Gas cloud with high H_2S or CO_2	6.1E-07	10	0.1	1	113	H	1.3E-05	1.5E-03	1	6.1E-07
8 Gas cloud with low H_2S or CO_2 concentratio	1.2E-05	10	0	0	114	H	1.3E-05	1.5E-03	0	1.7E-08
TOTAL AFR	4.7E-06									
IRPA	2.1E-08									

7.1.3.2. Calculation of Individual Risk Per Annum (IRPA)

- Event trees and consequence analysis will be used to evaluate the Annual Fatality Rate (AFR) for each major hazard
- By their method of calculation these AFR's provide a measure of the average risk between the drilling, maintenance and support populations on the Rig. They essentially weight each groups contribution to fatalities by exposure
- All major hazard AFR's will then be summed to derive a total AFR for the Rig
- This figure is the average risk faced in one year by all personnel on the Rig and has been calculated assuming that the Rig always contains 30 personnel
- However, workforce of 30*2 = 60 to maintain a constant 30 man workforce on the Rig for the whole year.
- Hence the IRPA can be simplistically assumed to be (Total AFR / 60)

7.1.3.3. Analysis Results

The results of the risk analysis for the drilling in Block KG-ONN-2004/1 which are shown in **Table 81.**

Table 81 Risk Results

Hazard No	Major Accident Hazard	Individual Risk Per Annum (IRPA)
1	Blowout During Drilling	1.9E-04
2	Passing Vehicle collision	4.0E-06
3	Dropped Objects	4.7E-05
4	Structural Failure	7.6E-05
5	Non Process Fires	3.7E-05
6	Hydrocarbon Leaks During Well	2.1E-08
	TOTAL	**3.54E-04**

7.1.3.4. Comparison with ALARP Criteria

The total individual risk (IRPA) for the drilling operation in Block KG-ONN-2004/1 has been estimated to be **3.54E-04** fatalities per annum. This is within the ALARP region of less than **1.00E-03** but greater than **1.00E-05**. The calculated fatality frequency for each individual hazard is also within the ALARP region with the exception of Vehicle Collision **(4.0E-06)** and Hydrocarbon Leaks during Well Testing **(2.1E-08).** Which are both in the 'broadly acceptable' region. IRPA's in the ALARP Region are tolerable but additional safeguards should be examined to ensure that an ALARP level is reached in practice and the risk further reduced using cost effective solutions.

7.1.3.5. Oil Spill Frequency

The event trees have identified a number of contributions to the release of hydrocarbons from the drilling unit. The safety impacts of these releases have been modelled in the consequence analyses; this section addresses their potential environmental impact taking account of the relative remoteness of block KG-ONN-2004/1 from the coastline.

Hydrocarbon releases may arise from the drilling unit's own equipment / tanks, equipment / tanks or from the hydrocarbon reservoir itself. The releases are categorised as follows:

Tier 1 – spills <10 tonnes: These releases are assumed to have only a small, local to the unit, impact and to be capable of being managed solely by the unit. Most spills in this category are likely to be sufficiently small to be dispersed naturally; the remainder assumed to have a limited oil spill response capability. Such incidents can arise from: spills of oils /lubricants; diesel spillages etc. Events resulting in such minor spillages are not conducive to QRA and therefore have not been modelled as part of this QRA.

Tier 2 – spills >10 to 100 tonnes: These incidents may not be capable of being managed entirely by the drilling unit and may require some limited outside support.

Table 82 Initiating Events Leading To Tier 2 Oil Spill

Initiating Event (Major Accident Hazard)	Hazard No.	Annual Frequency
Dropped Objects	2	5.5E-03

Tier 3 – spills >100 tonnes These incidents, resulting from hydrocarbon releases from the reservoir, have the potential to impact a wider area and, particularly at the upper end of the range, to impact the coast no matter how remote from the shore the unit may be.

Table 83 Initiating Events Leading To Tier 3 Oil Spill

Initiating Event (Major Accident Hazard)	Hazard No	Annual Frequency
Well Blowout[1]	1	4.4E-02
Leak During Well Testing[2]	8	1.4E-05

NOTES:

1: Maximum volume = Open hole flow rate x days to plug Well

2: Maximum volume assumes that down hole and top drive safety equipment fail to isolate the reservoir

This gives a total spill frequency for Tier 2 and Tier 3 for a drilling operation of **5.0E-02.**

7.1.3.6. Recommendations

Recommendations are given in **Table 84** for each of the risks within the ALARP region. Implementing these recommendations will ensure that the assumptions in the risk assessment are valid and potentially provide cost effective risk reduction measures. These constitute 'best practice' for operational control and would form part of an effective Safety Management System. In addition recommendations have been made relating to preparedness for dealing with the risk of an oil spill during the drilling operation.

Table 84 Recommendations for drilling

Hazard No	Hazard	Recommendation
1	Blowout During Drilling	Through control of the Drilling Contract including the use of Audit ensure that: • The Rig is fit for purpose and fully certified • Properly certified equipment is used e.g. BOP etc. • The Drilling Contractor will be competent and will provide qualified staff and supervision
2	Passing Vehicle Collision	Ensure that there is adequate monitoring by Transporting team. Emergency exercises to include dealing with errant Vehicles
3	Dropped Objects	Through control of the Drilling Contract including the use of Audit ensure that: • cranes are fully certified • crane operators and banks men are competent • hazardous areas are outside areas used for lifting
4	Structural Failure	Through control of the Drilling Contract including the use of Audit ensure that: • the Rig is fully certified • the Rig maintenance is adequate • the Rig is operated within its design criteria
5	Non-Process	Maintain awareness of crew of fire risks within accommodation and engine spaces
ALL	All oil spills resulting from the major hazards	The drilling oil spill planning requires: • Response capability at the drill site. Some pollution control capability • back-up resources identified • adequate training in Emergency Response

As per the **Figure 23** proper zoning of the area is to be done to avoid cumulative fire scenarios. MSDS should be provided in the storage areas and clear demarcation of hazards is to be provided. Proper cementing and casing practices should be taken up.

Diesel tanks of 2* 6KL are proposed in each drilling site, if the tanks are caught with fire the heat radiation will reach a distance of 100mts which will be Well within the site premises. Automatic H_2S gas detection system is to be made available near the Well site to avoid fatality due to toxic gases. Heat radiation due to crude oil fire scenario will reach a distance of 326mts but immediate utilisation of BOP will decrease the distances of heat radiation. The proximity of DG sets as per the below figure may be an ignition source in case of any spillages. So safe distance should be maintained in between Well and DG Sets.

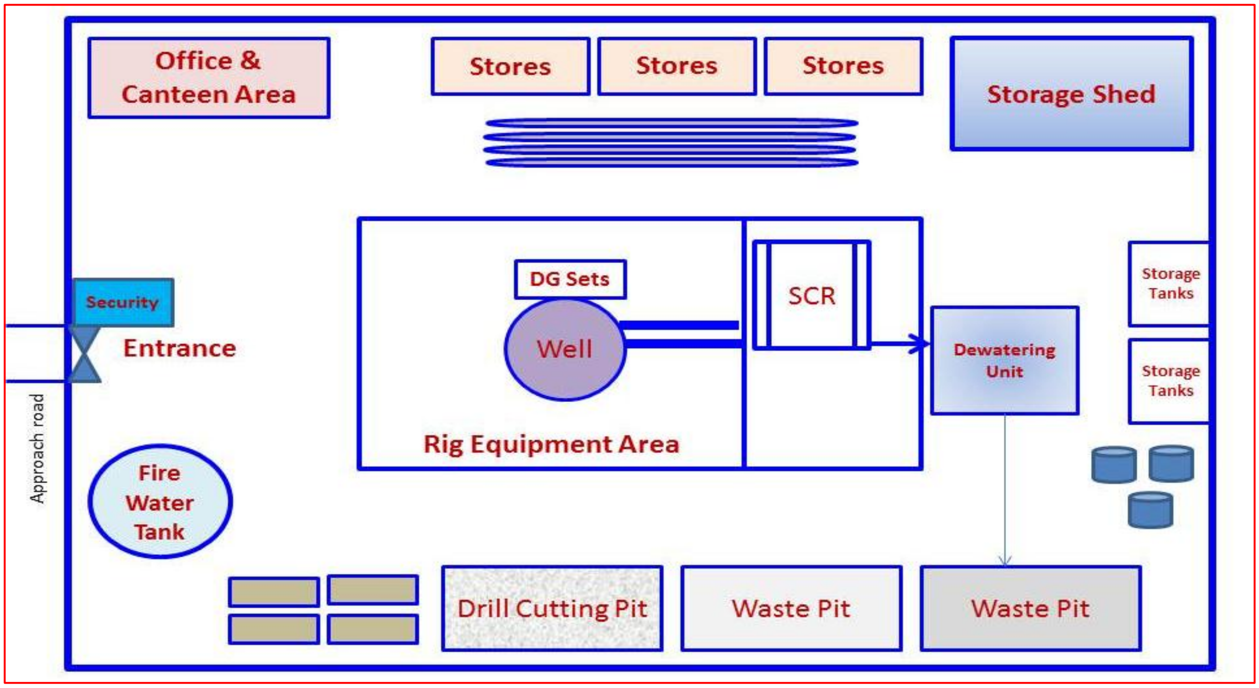

Figure 23 Drilling Site Plan

7.2. Emergency Response Plan

7.2.1. Objectives And Scope

The key objective of this Emergency Response Plan (ERP) is to outline the management, organisational arrangements and available facilities that will be utilised by OIL, in the event of an emergency situation arising during the proposed drilling activity in Block KG-ONN-2004/1. The plan identifies the philosophy and approach for managing an emergency and provides an outline of the roles and responsibilities of OIL and contractors for potential emergency scenarios identified as part of the rapid risk assessment conducted for the proposed drilling activity.

The plan should not include specific action items for controlling emergencies but provides a basis on which specific detailed emergency response procedures may be developed.

This section outlines the key elements of an Emergency Response Plan to support the drilling activity.

7.2.1.1. Emergency Response Organisation And Communication

Initial response to any incident will be managed on site. The overall level of response will depend on the nature and scale of the emergency.

Emergency incidents have the potential to impact both OIL (staff / reputation / schedule/ etc.) and the Drilling Contractor (staff / equipment / Rig / reputation / etc.) and require the involvement both OIL and the Drilling Contractors management. Hence there should be one ERP for the drilling operation that reflect the integration of both the OIL and Drilling Contractor's response plans. Where necessary, bridging documents may be required to fully integrate aspects of the two companies response plans.

The initial response to all incidents should be managed by the drilling unit. The Drilling Contractor having most personnel at risk and most knowledge of the drilling unit should take the lead in managing the immediate response to the incident.

The specific structure and organisation of the ERP will be dependent on the location and capability of the Drilling Contractor but will typically consist of On Site Response Team (managed by Drilling Contractor with OIL support);

7.2.1.2. Identified Emergency Scenarios

The Emergency Response Plan (ERP) must be capable of managing the response to the major hazards, identified and any associated environmental risks. In addition the ERP must also address "occupational" hazards including incidents such as Single and multiple accidents requiring medical evacuation (medevacs).

7.2.1.3. Emergency Classification

The required response will depend on the scale of the incident. Emergency scenarios are categorised into three levels, typically:

Tier 1 Incident (Local Alert)

Tier 1 incidents require no external assistance and can be managed by the Emergency Co-ordinator using on site resources. Typical incidents may include:

- Single casualty (medevac);
- Oil spills <10 tonnes;
- OIL equipment damage;

Tier 2 Incident (Site Alert)

Tier 2 incidents cannot be managed entirely on site. OIL response is typically activated, Incidents may include:

- Substantial security incident;
- Multiple casualty (medevac);
- Oil spill 10-100 tonnes ;

- Substantial fire;
- Cyclone/flooding;
- Cultural conflict.

Tier 3 Incident (External Alert)

Tier 3 incidents are major emergencies beyond site resources with the potential to impact beyond the site limit. External assistance is required and there is immediate mobilisation of OIL. Typical incidents may include:

- Major fire / explosion;
- Oil spill >100 tonnes;
- Fatality.
- Well blow up

It should be noted that for any tier incident, when determining tiers for oil spills, the quantity of oil spilt is not the only factor. The environment potentially threatened by the oil is also considered in determining the tier of spill.

7.2.1.4. Emergency Response Activation

The level of callout to deal with an emergency needs to be defined and co-ordinated by OIL. The Emergency Response Contact directory will be updated before the actual commencement of drilling activity.

7.2.2.Disaster Prevention Methods

Effective emergency management should include both detailed emergency response measures and appropriate prevention measures. OIL will assure that the process for assessing potential contractors includes an assessment of each Company's safety record and arrangements for emergency prevention and response.

It may be necessary for the Contractor to demonstrate inter alia:

- Properly documented EHS Management System
- Competent personnel trained in disaster response duties
- Appropriate detection equipment (gas detection including H2S, smoke detection, radar)
- Suitable fire fighting equipment available and personnel properly trained in its use
- Operational emergency alarm and PA system
- Effective communication equipment including VHF Radio, V-SAT / INMARSAT, mobile VHF radios
- All equipment required for emergency response undergoes routine maintenance and is regularly tested / calibrated
- Detailed evacuation procedures including appropriate muster areas, escape routes including clear signs where appropriate. Personnel should be made aware of evacuation procedures through appropriate training.
- Regular drills/exercises to test ERP’s

- Regular review of Emergency Response Plans with modifications as required.
- OIL is also having Operational Risk Management Committee
- BOP of 10000 to 15000 PSI are utilised based on Rig capacity

Decommissioning Phase and Well Abandonment Management

At the conclusion of the exploration-drilling program at each drilling site, an orderly withdrawal of all personnel and the removal of all drilling and testing equipment and non-fixed items from the drilling site will be undertaken.

Broadly, there are two such scenarios:

- In case that the Well is completed when economic quantities of hydrocarbons are found, the Well will be left with a Well head in place, but all other equipment and materials will be removed from the site.
- In any other case the site will be cleared and reclaimed to permit recovery to as near as possible the pre-existing local environment.

Temporary Suspension of Activities

In the event that economic quantities of hydrocarbons are found, all empty drums, wastes, used and unused drilling fluids, fuel and lubricants will be removed from the drilling site. Water supply and effluent discharge hoses and associated equipment will be removed.

Decommissioning Upon Abandonment

In the event that no economic quantities of hydrocarbons are found, a full abandonment plan will be implemented for the drilling sites in accordance with the applicable Oil Mines Regulation, 1984. The activities mentioned in the above section would apply to decommissioning upon abandonment as Well, but abandonment would be more permanent. The overriding principle being that the environment should, with time, be reinstated to broadly its oRiginal condition. Until such time as this is achieved, SOGL would actively manage the reinstatement process. All concrete or steel installations would be removed to at least 1 m below ground level, so as to ensure that there are no protruding surface structures. In the unlikely event if soil is found to be contaminated, measures would be taken to remove or treat appropriately all contaminated topsoil to promote its remediation.

OIL has accorded top priority to safety and protection of environment in the operational areas. The activities are oriented towards prevention rather than cure and conducted in such a way as to ensure:

- Health and safety of its employees
- Protect the environment
- Optimal utilization of oil field equipment, instruments without leading to any health hazards.
- Health, safety and environment (HSE) matters have given equal status with all other primary business objectives.

7.3. Occupational Health

- Health Check-ups for the work force should be carried out by the Drilling Contractors every year
- Vibration studies to be conducted and its impact on the workers should be assessed.
- Proper Illumination levels should be provided
- PPE to be provided in high noise generating areas to