IPTC 13636

The Use Of A Plume Modelling Study To Reduce The Risk Of H_2S Release In An Exploration Well To As Low As Reasonably Practicable (ALARP)

James G. McIlroy, Petroleum Development Oman

This paper was prepared for presentation at the International Petroleum Technology Conference held in Doha, Qatar, 7–9 December 2009.

Abstract

With the increasing likelihood of exploration wells being located near population centres, a blueprint for the evaluation of the risk of an uncontrolled release of gas reaching such a settlement needs to be quantified. This paper reviews a case study from Oman in which a plume (gas cloud) modelling study was completed to determine the level of H_2S away from an exploration well. Future wells drilled in Oman and other countries can use this work as a model for reference with which to compare and to assess whether further detailed risk analysis is required.

Reason for doing the work

To quantify the risk of an uncontrolled release of hydrogen sulphide H_2S in a well “near” to a human settlement.

To ascertain those risks.

To determine how to reduce those risks to ALARP (as low as reasonably practicable).

Effect of this work

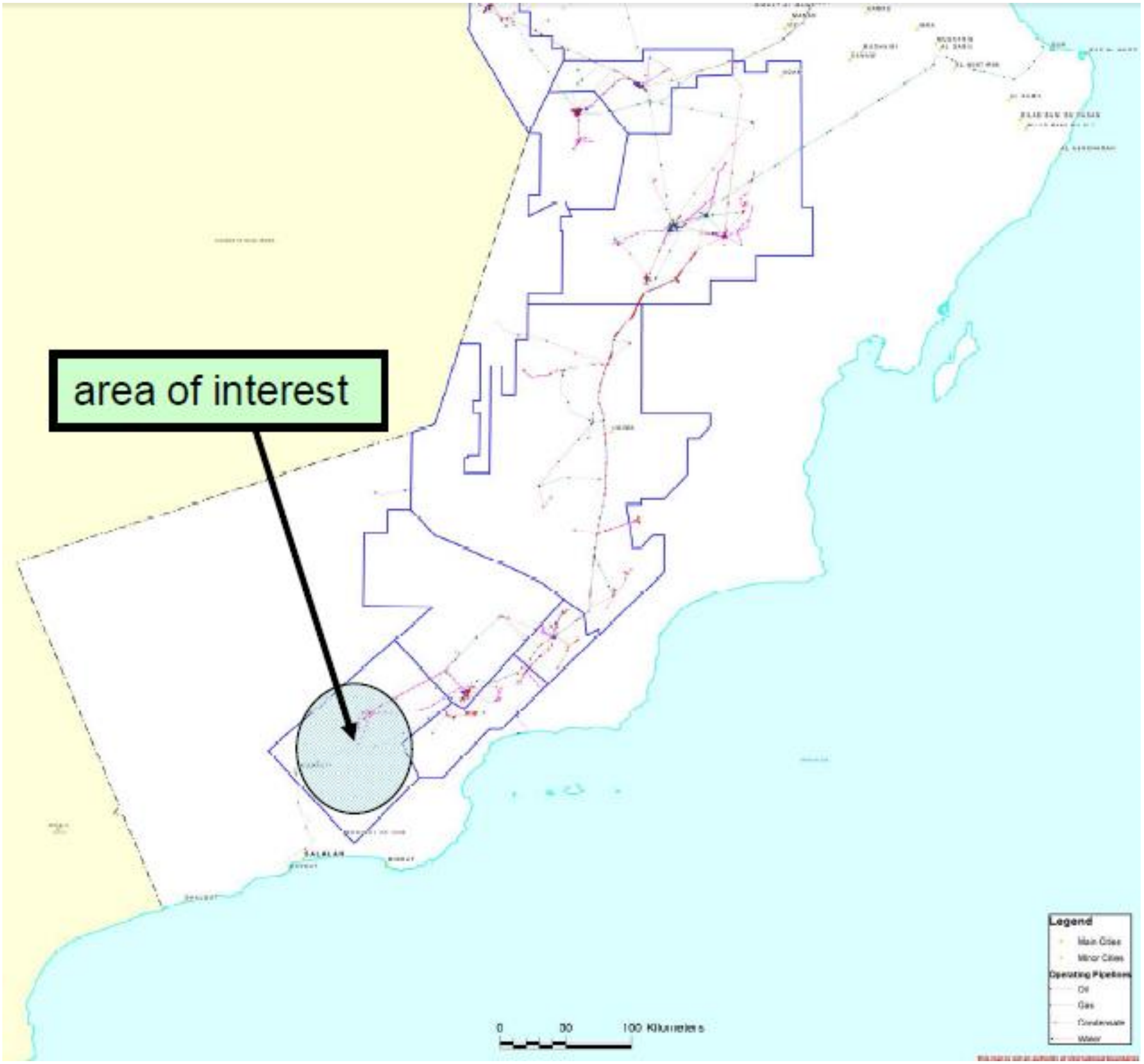
Delay in drilling the well.

Extra resources to be assigned to the well design and planning process.

Higher profile within exploration management during whole process.

Contributors

Various colleagues in PDO, Shell, Risktec Dubai and contracting companies.



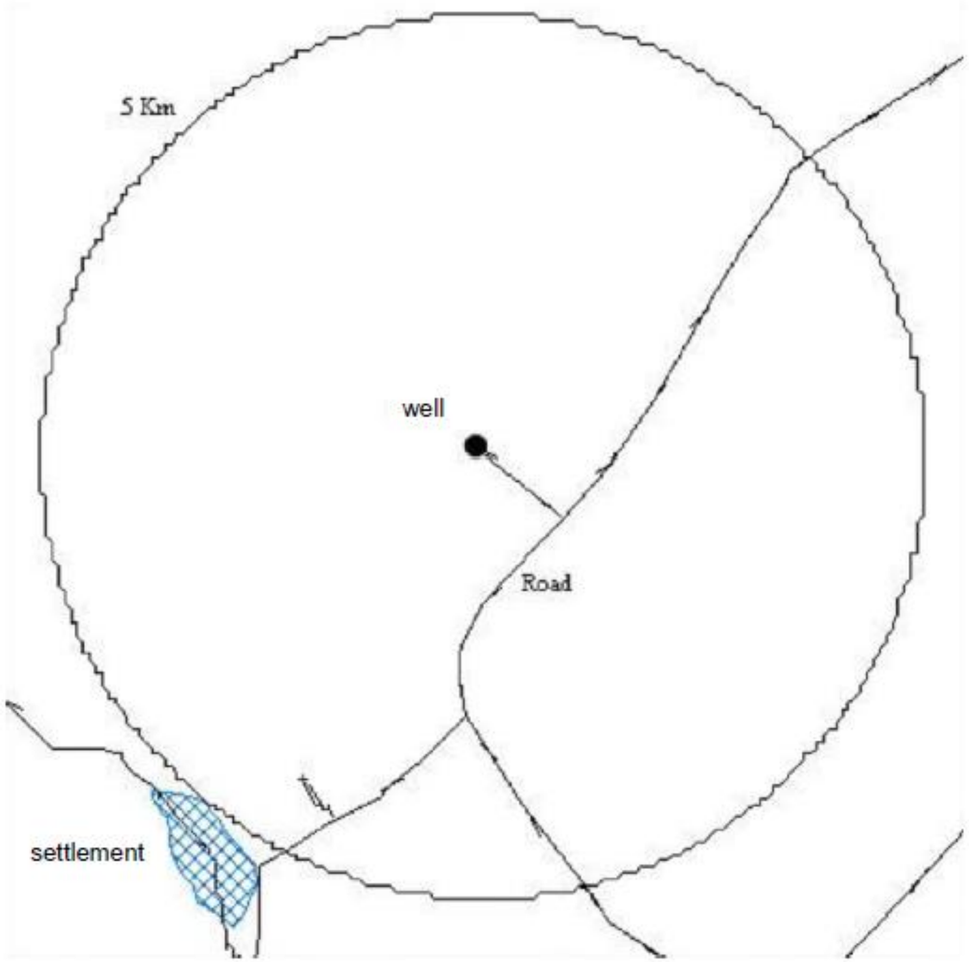


Figure 2: Prospect Location Relative to Settlement and 5km radius

JAMES McILROY

Senior Seismic Interpreter at Petroleum Development Oman (then with 25 years experience).

In South Oman Salt Basin Group, one of fifteen seismic interpreters with 2-32 years of experience.

Each interpreter as well owner assigned to one or more prospects to interpret, map and drill.

3-4 rigs to keep busy, 3-4 wells each per year.

Well Owner responsible for whole process including well design document of twenty pages.

Assignments were appropriate to your experience and seniority.

Targets depths varied from few hundred meters to 6000m.

Prospects in post-salt, intra- and pre-salt.

Intra-salt most challenging due to poor seismic data and over-pressures (where is Top Salt?)

PDO had drilled these for forty years so not a problem – correct?

Exploration well, a "standard" well

The South Oman salt basin involves drilling carbonate stringers encased in salt, TD from 2000 to 6000m.

Stringers like Southern Gas Basin often over-pressured, O/P seen up 22 KPa/m (twice the hydrostatic gradient!)

H_2S expected to be present, up to 8%.

But…..

This well is different because it is 5km from a settlement of 700 people – the closest in recent times certainly.

Not feasible to move people, nor to evacuate them in the event of anything happening.

Technical challenges

Where is Top Salt, where are the stringers in the salt?

Are the stringers normally or over-pressured, what mud weight to use and when?

These key steps were followed

1. An assessment of the likelihood of an uncontrolled release occurring based on worldwide statistics and the author's experience of similar projects.

2. Computer modeling of near and far-field H_2S concentrations. The software used was from the Energy Resources Conservation Board of Calgary (ERCB) and software developed by Shell (FRED) for consequence and risk modelling.

3. Assessment of the physical effects (toxic dispersion) of local meteorological and terrain using Shell's SHEPHERD software. This uses the parameters to quantify the effect and probability of these possible consequences.

4. A bow-tie or risk and outcome assessment to identify the barriers that can be put in place or the remedial actions that can be taken in the event of a release.

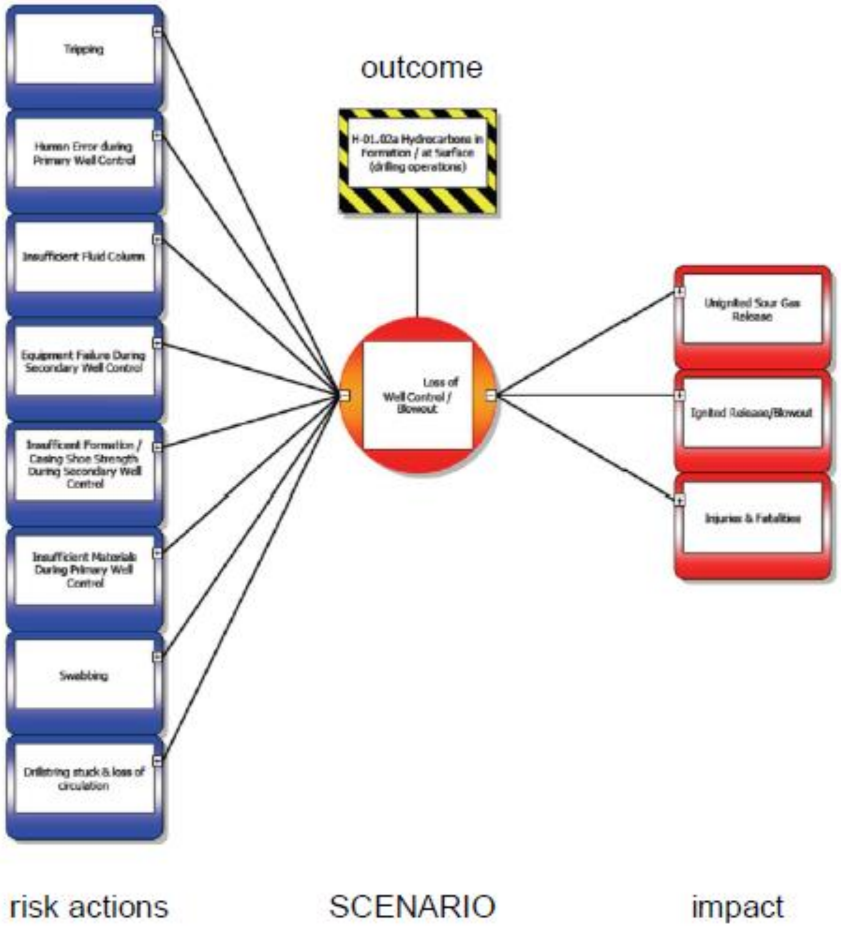


Figure 6: Threats and Consequences Bow-tie Diagram

Variables used in this study include

1. Oil or gas with high H_2S content
2. Vertical or horizontal blowout of gas from the well
3. Well bore with drill pipe in or without of the hole
4. Wind speed or direction

It is noted here that while H_2S is the most toxic gas to be released, on burning it converts to sulphur dioxide SO_2 which, while still toxic, has a lower toxicity and also that most blowouts do not ignite.

Table 1:- Stringer hydrocarbon content – gas condensate – "gas 1"

Example 1 Gas Condensate

- With drill pipe
  - Gas rate = 3.026 MMm^3/d = 35.6kg/s
  - Temperature = 5ºC
- Without drill pipe (vertical)
  - Gas rate = 28.125 MMm^3/d = 330.6kg/s
  - Temperature = 5ºC
- Without drill pipe (horizontal)
  - Gas rate = 27.830 MMm^3/d = 327.1kg/s
  - Temperature = 5ºC

Table 2:- Stringer hydrocarbon content – oil – "gas 2"

Example 2 Oil

- With drill pipe
  - Gas rate = 2.166 MMm^3/d = 26.5kg/s
  - Temperature = 83ºC
- Without drill pipe (vertical)
  - Gas rate = 21.294 MMm^3/d = 260.6.5kg/s
  - Temperature = 76ºC
- Without drill pipe (horizontal)
  - Gas rate = 21.128 MMm^3/d = 258.5kg/s
  - Temperature = 76ºC

Table 4: Scenarios used for modelling

scenario number	hydrocarbon type	drill pipe	breeze strength	direction	10ppm contour	50ppm contour	100ppm contour	190.66ppm contour
1	gas 1	no	strong	horizontal	7,072	1,920	980	500
2	gas 1	yes	strong	horizontal	1,864	640	310	150
3	gas 2	no	strong	horizontal	5,165	1,832	1,180	610
4	gas 2	yes	strong	horizontal	1,864	700	425	220
5	gas 1	no	weak	horizontal	15,640	2,200	1,020	500
6	gas 1	yes	weak	horizontal	4,520	680	285	125
7	**gas 2**	**no**	**weak**	**horizontal**	**86,771**	5,999	2,579	1,059
8	gas 2	yes	weak	horizontal	28,007	2,560	710	185
9	gas 1	no	strong	vertical	2,002	277	113	53
10	gas 1	yes	strong	vertical	551	92	39	18
11	gas 2	no	strong	vertical	3,619	295	113	51
12	gas 2	yes	strong	vertical	802	173	74	35
13	gas 1	no	weak	vertical	-	-	111	44
14	gas 1	yes	weak	vertical	1,223	88	31	15
15	gas 2	no	weak	vertical	25,926	458	108	42
16	gas 2	yes	weak	vertical	-	-	-	-

Gas 1 = from gas condensate, gas 2 = gas from oil.

concentration ppm	comments
700	instant death
500	represents potentially lethal levels
394	UK HSE 1% fatality
190.66	level at which 1% of people will become a fatality - lethal concentration threshold (from software)
100	IDLH 30 minute exposure - olfactory paralysis within 3 to 15 minutes exposure
50	highest acceptable exposure for a mximum of ten minutes
10	maximum permissible working tolerance - unpleasent odour with possible eye irritation
5	Irritation of eyes, nose and throat

Figure 8: H_2S threshold values

Table 3: Frequencies and probabilities from Scandpower report

Frequency of blow-out
- 5.3×10^{-5} per year [*1]

Probability of blow-out type given blow-out
- Outer Annulus = 0.95 (95%)
- Open Hole = 0.05 (5%)

Probability of fluid type given blow-out
- Example 1 gas = 0.05 (5%)
- Example 2 oil = 0.95 (95%)

Probability of blow-out direction given blow-out
- Outer Annulus = 49% horizontal & 51% vertical
- Open Well = 49% horizontal & 51% vertical [*2]

notes:-

1. Frequency of blow-out of 5.3×10^{-5} per year refers to the rate which includes all wells drilled in the North Sea and the US Gulf of Mexico.
2. Scandpower report has all vertical – author experience and associated correspondence suggest this is a more realistic breakdown

Table 5: Location Specific Individual Risk

LSIR – Location Specific Individual Risk - the risk for a hypothetical individual who is positioned at a location for 24 hours per day, 365 days per year. Base frequency from

Gas 1, with Drill Pipe, Horizontal:

- Base frequency = $5.3E^{-05}$ per year
- Probability of annulus = 0.95
- Probability of horizontal = 0.49
- Probability of Rabab gas = 0.95

= $5.3E^{-05}$ x 0.95 x 0.49 x 0.95 = $2.34E^{-05}$ per year

Gas 2, no Drill Pipe, Vertical

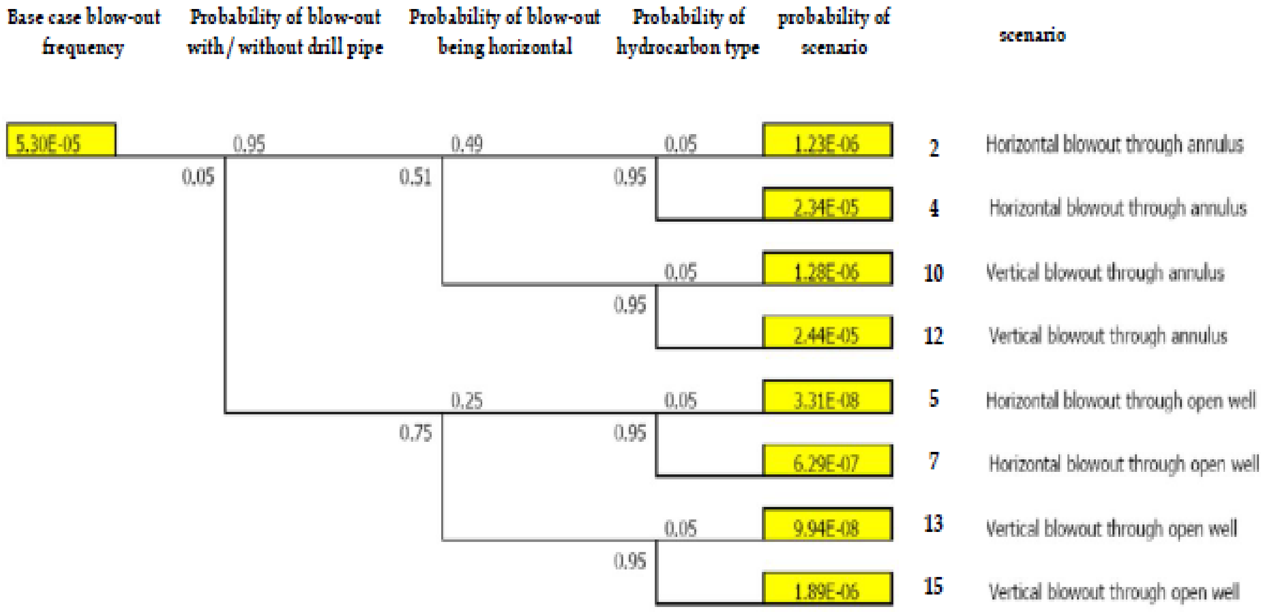
- Base frequency = $5.3E^{-05}$ per year
- Probability of open flow = 0.05
- Probability of vertical = 0.51
- Probability of Example 2 gas = 0.05

= $5.3E^{-05}$ x 0.05 x 0.51 x 0.05 = $6.76E^{-08}$ per year

Multiplied by probability of Location 'n' being affected (based on wind direction)

Multiplied by probability of Fatality (derived by software calculation)

SHEPHERD performs this calculation for every scenario and every location to generate iso-risk contours.

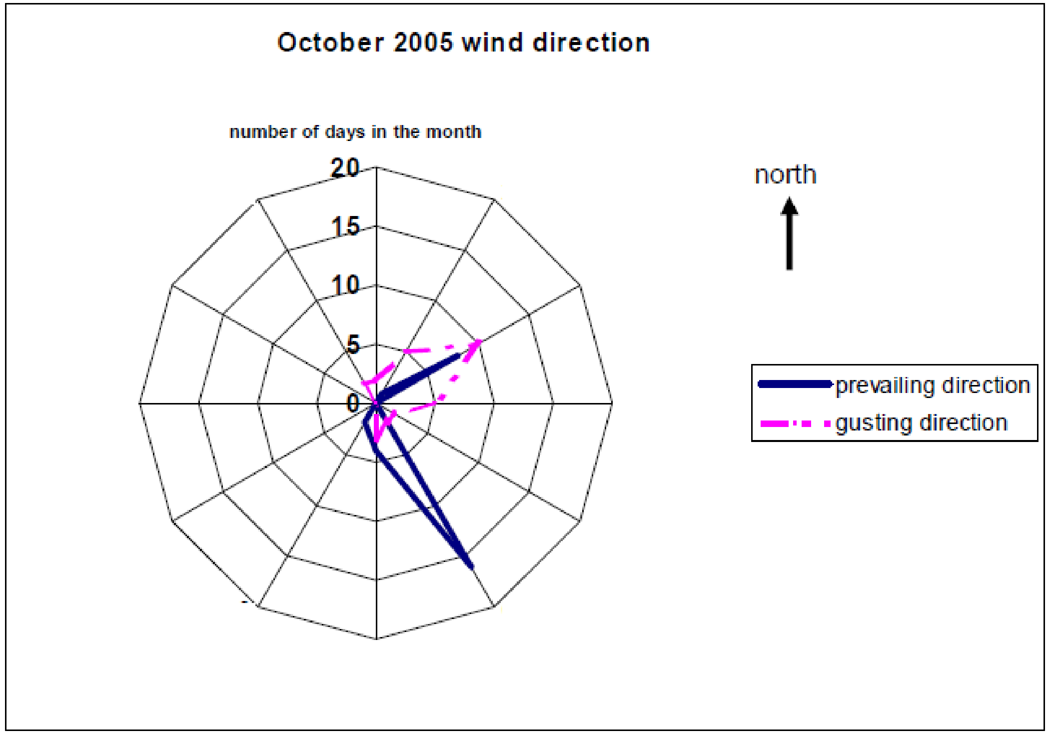


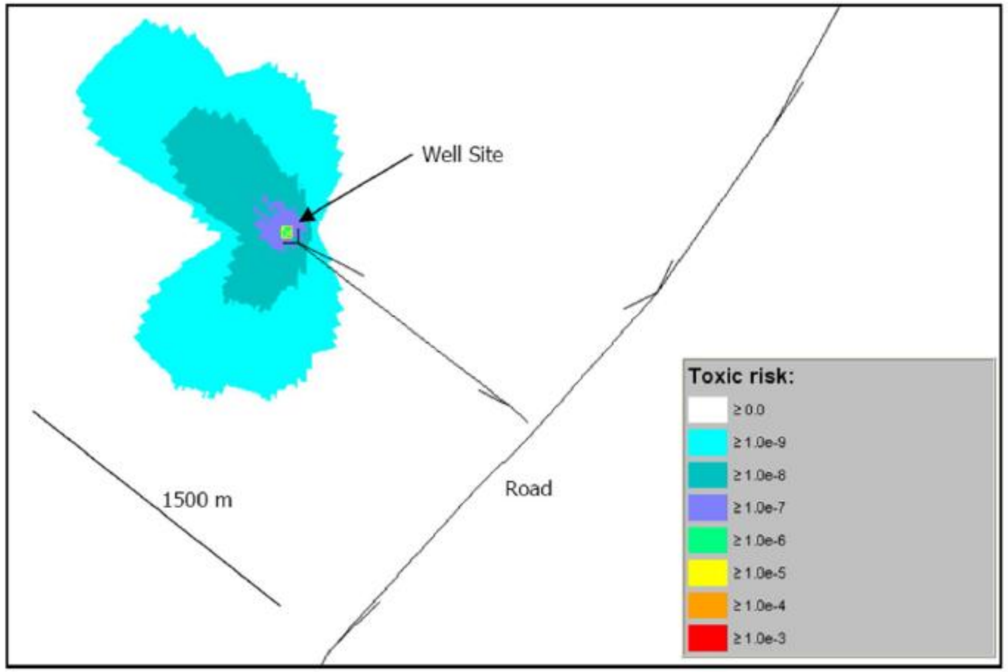
Also of major importance….

Wind direction and speed, derived from local airport weather station records.

Wind speed important as too strong it is likely to disperse the plume.

A more gentle breeze is most effective at moving the plume any distance.





Max distance to 1.0 x 10-6 toxic risk = 28m (green)

Rig site

The settlement was 5km away, the other side of a jabal.

The rig could not be seen from any point in the settlement.

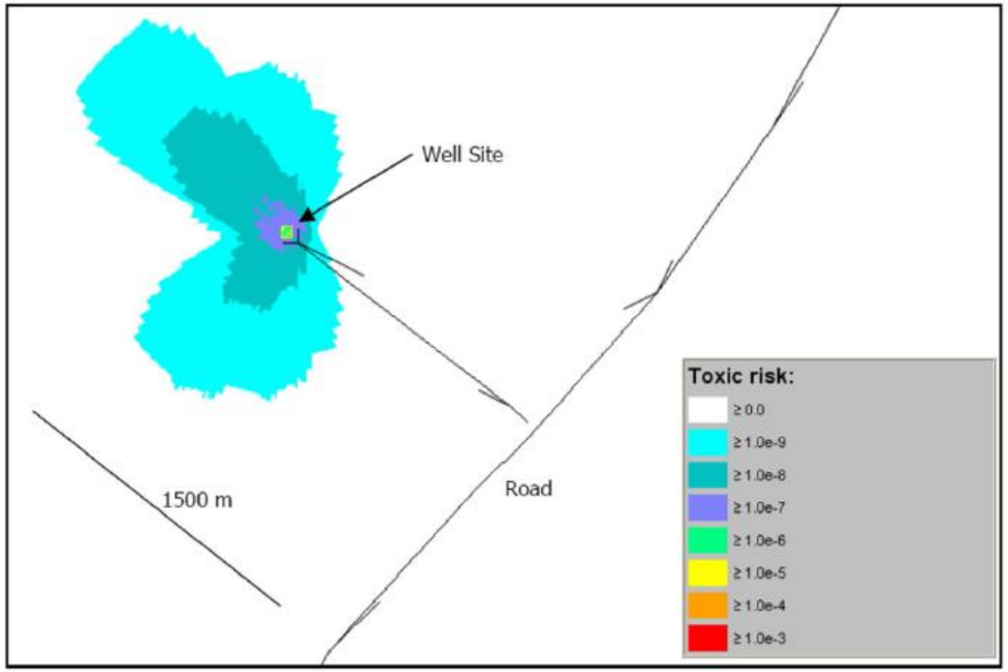
The area around the site was undulating.

Few scattered bushes.

The site drained to the SE away from the settlement.

The rig site was 40m below the level of the village.

In event of a blowout, the natural movement of any plume as expected to be down slope and away from the settlement.



Max distance to 1.0 x 10-6 toxic risk = 28m (green)

All well design, operations, emergency response etc to be signed off before approval

Working with well engineers etc

Consultant safety engineers

Chief Fire Officer

Community Liaison Officers

The worst possible case for a blowout being :-

- Through an open hole (no drill pipe) resulting in largest flow rates
- High overpressures
- Highest H_2S concentration
- Wind in the “wrong” direction, i.e. towards the settlement

All well design, operations, emergency response etc to be signed off before approval

Working with well engineers etc – part of process anyway.

Consultant safety engineers – to review whole operations and compare to other countries e.g. Kashagan.

Chief Fire Officer – in liaison with airport to prepare and coordinate Emergency Response Plan.

Community Liaison Officers – to deal with local community – the well is a standard PDO well.

The worst possible case for a blowout – how to mitigate the issues

- Do not POOH unless absolutely no movement on mud pit level – is this not obvious?
- Have most experienced crew with two rig superintendents on rig at all times, one on rig floor at all times.
- It is a “standard” PDO stinger well, could be high H_2S!
- Schedule well to drill during monsoon season, i.e. wind from the south.

In conclusion - The worst possible case for a blowout being :-

Through an open hole - no drill pipe.

High H_2S.

Blowout from well pipe directed towards the settlement.

The wind being a breeze in the direction of the village.

Not feasible to evacuate settlement, probably cause more problems than it solves.

If the above happened, what was the ultimate response in the event of a blow out?

- Rig supervisor to ignite the blowout on leaving the rig site. Two methods to do this – electrical and flare.

Why?

The China incident 2003

Gas well drilling, nearest human habitation 30m from wellhead.

Non-essential work undertaken on equipment.

In mountainous area, high valley sides – once gas cloud cools, H_2S being heavier than air collects in low areas.

After blowout, 24 hours elapsed before blowout was ignited (H_2S burns to SO_2 which is less toxic).

243 dead
10,000 hospitalised
60,000 evacuated

25 square kilometre “death zone”.

Figures only the last reported by BBC, actual figures likely to be much higher.

Just another industrial accident in China? Not acceptable in Oman for sure.

PDO well 2008 - what happened?

The well was drilled with no LTI’s

Within budget

Targets reached and appraised

Technical success

Drilling a well is like any multi-faceted operation which has a various parts.

It doesn’t require all to fail of course but one failure can lead to another.

If all parts of the operation is reviewed and risk reduced where possible then the operation should be safe.

Summary

Risk levels were demonstrated to be tolerable and well inside PDO’s risk tolerability criteria.

This work modelled the dispersion effects of an unconstrained flow of hydrocarbons.

It considered the frequency and probability of blowout type (vertical, horizontal) and with / without drill pipe.

This lead to a bow-tie analysis to consider the adequacy of controls (in-place and planned).

One scenario had raised H_2S levels at the settlement.

The likelihood of this happening demonstrated to be within PDO’s tolerability range.

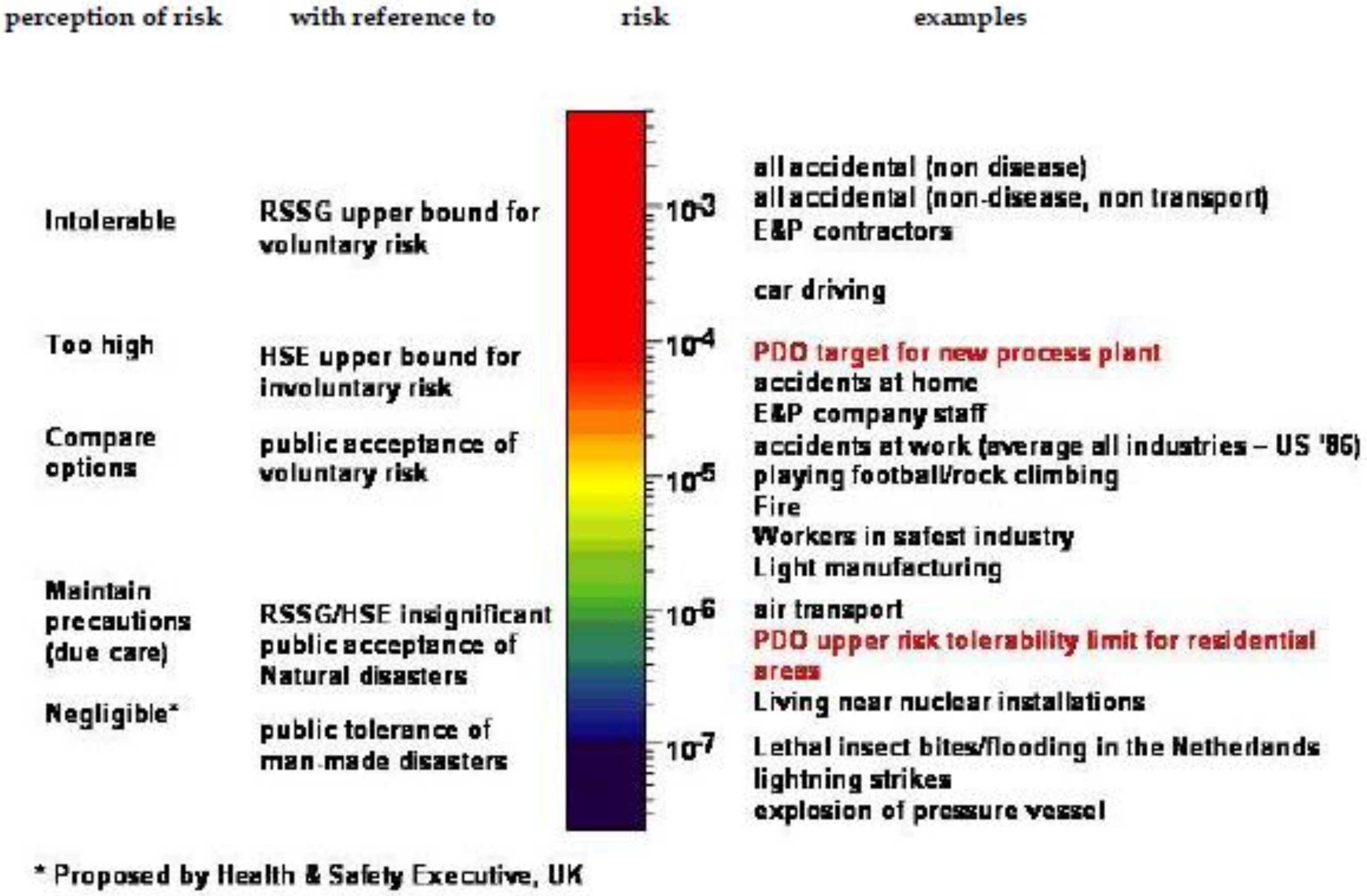


Figure 7: Tolerance Table

Thank you.

The use of a Plume Modeling Study to reduce the risk of a blowout to ALARP

As Low As Reasonably Practicable