under investigation. The well was initially reported to be discharging approximately 5,000 bbls per day; more recent estimates place the rate at 12,000 to 19,000 bbl/day.

Despite this recent event, the overall trend of spills and blow-outs is decreasing world-wide. A spill of the magnitude of the Deepwater Horizon blow-out in recent years is unprecedented. An investigation will likely result in lessons learned in terms of improved technology, operational, safety and environmental procedures. However, in spite of potential improvements and advancements in spill prevention technology and practices, there still remains an element of safety and environmental risk in any drilling operation.

With respect to the Hebron Project, there will be an estimated 40 development wells drilled, and an estimated 200 well-years of production[1]. Using the above world-wide spill frequency statistics as a basis for prediction, the spill frequencies estimated for the Project would be as follows:

- Predicted ~~frequency~~ number of extremely large hydrocarbon spills from blow-outs during a drilling operation, based on an exposure of wells drilled:
  $40 \times 1.5 \times 10^{-5} = 6.0 \times 10^{-4}$
- Predicted ~~frequency~~ number of very large hydrocarbon spills from drilling blow-outs based on an exposure of wells drilled:
  $40 \times 6.0 \times 10^{-5} = 2.4 \times 10^{-3}$
- Predicted ~~frequency~~ number of extremely large hydrocarbon spills from production/workover blow-outs, based on an exposure of well-years:
  $200 \times 8.0 \times 10^{-6} = 1.6 \times 10^{-3}$
- Predicted ~~frequency~~ number of very large hydrocarbon spills from production/workover blow-outs, based on an exposure of well-years
  $200 \times 2.4 \times 10^{-5} = 4.8 \times 10^{-3}$

14.1.2 Blow-outs Involving Smaller Discharges of Oil or Only Gas

Gas blow-outs from offshore wells that do not involve a discharge of liquid petroleum are generally believed to be relatively innocuous to the marine environment. However, such blow-outs may represent a threat to human life and property because of the possibility of explosion and fire.

Two sources are used for historical statistics on blow-outs involving only gas or small hydrocarbon discharges. A particularly good source for US blow-outs is the BOEMRE web page (www.boemre.gov), because BOEMRE keeps track of spills down to 1 bbl in size. This is not the case in other parts of the world. Scandpower (2000) provides a report on blow-outs in the North Sea and in the US GOM, although the report provides no information as to whether or not hydrocarbon spills were involved in the reported blow-outs.

The US Outer Continental Shelf (OCS) data, representing the 34-year period from 1972 to 2006, are provided in Table 14-4 (Note that BOEMRE updates their data on a regular basis, but the most recent data they have published is

[1] Assumes half of all development wells are "oil producers" and that production wells have an average well-life of 10 years.

Year	Well Starts	Drilling Blow-outs				Non-drilling Blow-outs								
		Exploration		Development		Production		Workover		Completion		Total Blow-outs		OCS Production
		No.	bbl	No.	bbl	No.	bbl	No.	bbl	No.	bbl	No.	bbl	MMbbl
2004	861	2	16	0	0	0	0	2	1	0	0	4	17	567.0
2005	1,232	3	0	1	0	0	0	0	0	0	0	4	0	497.4
2006	1,586	0	0	0	0	0	0	1	0	1	50	2	50	503.1
Total	**34,576**	**67**	**316**	**91**	**1**	**24**	**627**	**39**	**125**	**15**	**110**	**207**	**1181**	**13963.9**

1 Two of the drilling blow-outs occurred during drilling for sulphur
2. Two of the drilling blow-outs occurred during drilling for sulphur
3 Estimated: cumulative total correct

The statistic, based mostly on US OCS drilling and blow-out records over the past 30 years, is derived on a conservative basis and does not take into account recent improvements in safety and blow-out prevention that have tended to reduce blow-out frequencies. There is also concern over gas releases and their effect on workers. For this reason, a more realistic assessment of the probability of a gas blow-out is required. The main factors that need to be re-considered are: (1) the differences between “shallow gas” blow-outs and deep-well blow-outs; (2) special blow-out prevention activities that exist for deep well drilling in Canada; and (3) decreases in blow-out frequency in recent years due to improvements in blow-out prevention. All three issues are covered thoroughly in Scandpower (2000).

14.1.2.1 Shallow Gas versus Deep Blow-out

A blow-out might occur if shallow gas is encountered unexpectedly during drilling operations. The driller has interest in shallow gas from the mudline to approximately 914 m (3,000 feet) and below. Gas that is trapped in the shallow sediments can originate from deeper gas reservoirs, but can also come from biogenic activity in the shallow sediments. The probabilities of the various blow-out categories are shown in Table 14-5, abstracted from Scandpower (2000).

The values in Table 14-5 (for the US GOM) are reasonably consistent with the values in Table 14-4, which show 29 blow-outs for the period 1980 to 1997. This means that the BOEMRE (the US regulator) classifies “blow-outs” in Table 14-5 as *all* categories in Table 14-5 (*i.e.*, well releases as well as blow-outs). The blow-out frequency from Table 14-5 for the US GOM is 28/8,466 = 3.3 x 10^{-3} blow-outs/releases per well drilled, which is close to the value derived earlier (4.1 x 10^{-3}).

Table 14-7 Shallow Gas Exploration and Development Drilling Blow-out Frequencies over Time, 1980 to 1997

Time Period	No. of Blow-outs	Number of Exploration and Development Wells Drilled	Blow-out Frequency
18 years (1980 to 1997)	53	22,084	24.0×10^{-4}
10 years (1988 to 1997)	23	13,870	16.6×10^{-4}
5 years (1993 to 1997)	5	7,581	6.6×10^{-4}
3 years (1995 to 1997)	1	4,924	2.0×10^{-4}
Source: Scandpower (2000)			

A more recent study by IAOGP (2010), is based on the 20-year record to 2005, and indicates a deep blow-out frequency of 4.8×10^{-5} blow-outs per well drilled. Using this figure results in a probability of one blow-out for every 21,000 wells drilled.

14.1.2.2 Blow-outs During Production Operations

The best accident exposure variable to use for production and wireline operations is well-years. It is also convenient to link completions and workovers to well-years of operation. The number of oil and gas well-years for the population in Table 14-4 from 1972 through 2006 can be estimated from other tables in MMS references; the number is approximately ~~235~~250,000 producing well-years.

For all the gas-producing areas and oil-producing areas of the US OCS, 78 blow-outs occurred during production, workovers and completions (Table 14-4). This yields a blow-out frequency of 78/250,000 = 3.12×10^{-4} blow-outs per well-year. The equivalent number for the US OCS and North Sea areas for the period 1980 to 1997 is 1.83×10^{-4} blow-outs per well-year (Table 14-8).

Table 14-8 Frequency over Time of Blow-outs during Production, Wireline Operations, Workovers and Completions, US Gulf of Mexico and North Sea, 1980 to 1997

Period	Blow-outs: Production and Wireline	Blow-outs: Completions and Workovers	Total Blow-outs	Well-years	Blow-out Frequency
18 years (1980 to 1997)	10	21	31	168,583	1.83×10^{-4}
10 years (1988 to 1997)	3	7	10	108,357	9.92×10^{-5}
5 years (1993 to 1997)	1	3	4	55,188	7.25×10^{-5}
3 years (1995 to 1997)	1 [a]	3	4	34,895	1.15×10^{-4}
Source: Scandpower (2000)					

As was done for the case of blow-outs during development drilling, it is important to note that blow-out frequencies during production operations in the North Sea and in the US GOM have been on the decline over recent years (Table 14-8).

IAOGP (2010), does not allow a comparison for each of the operations listed in Table 14-8, but confirms the overall blow-out frequency for production,

wireline operations, completions and workovers in recent years. The data, based on the 20-year record to 2005, indicate an overall blow-out frequency for these operations of 1.85 x 10^{-4} blow-outs per well year, based on 33 incidents over 177,474 well-years.

A certain percentage of the blow-outs involved some discharge of hydrocarbon. Of the 78 blow-outs that occurred during the four operations of production, wirelining, workovers and completions, only 12, or 15.4 percent, involved hydrocarbon (note that the average size of the 12 spills was only 72 bbl). Therefore, the frequency of blow-outs that produced a hydrocarbon spill from well blow-outs during the four above-noted operations is calculated to be 0.154 x 1.85 x 10^{-4} = 2.8 x 10^{-5} blow-outs/well-year.

14.1.2.3 Summary of Blow-out Frequencies Involving Smaller Discharges of Oil or Only Gas

There are an estimated 40 wells to be drilled for the Project, so the likely number of deep blow-outs during development drilling becomes 40 x 4.8 x 10^{-5} = 1.92 x 10^{-3}.

For gas blow-outs occurring during production and workovers, the statistic for Hebron becomes 200 well-years x 1.17 x 10^{-4} blow-outs/well-year = 2.34 x 10^{-2}.

For gas blow-outs that occur during production and workovers that involve some hydrocarbon discharge (>1 bbl), the statistic for Hebron becomes 200 well-years x 2.8 x 10^{-5} blow-outs/well-year = 5.6 x 10^{-3}.

14.1.3 Large Platform Spills

There have been very few large spills from platforms operating in US OCS waters. In addition to the six from blow-outs noted in Table 14-3 there have been seven others, which includes all US platform spills up to the present (Table 14-9). Note, that this does not include the 2010 Deepwater Horizon blow-out, which occurred during exploration drilling.

Table 14-9 Hydrocarbon Spills of Greater than or Equal to 1,000 bbl from Platforms on the US Outer Continental Shelf, 1964 to 2010

Date	Location	Size (bbl)	Cause
04/08/64	Eugene Island Block 208	2,559	Collision
10/03/64	Eugene Island Ship Shoal	11,869	Hurricane (7 platforms)
07/19/65	Ship Shoal Block 29	1,688	Blow-out (condensate)
01/28/69	Santa Barbara Channel	77,000[A]	Blow-out
03/16/69	Ship Shoal Block 72	2,500	Collision, weather
02/10/70	Main Pass Block 41	30,000	Blow-out
12/01/70	South Timbalier Block 26	53,000	Blow-out
01/09/73	West Delta Block 79	9,935	Storage tank rupture
11/23/79	Main Pass Block 151	1,500[B]	Collision, weather, tank spill
11/13/80	High Island Block 206	1,456	Pump failure, hurricane, tank spill
09/29/92	Timbalier Bay/Greenhill	11,500[C]	Production well blow-out

Date	Location	Size (bbl)	Cause
09/24/05	Cameron/Eugene Is./Green Canyon	3,915	Hurricane (9 platforms)

Source: BOEMRE OCS Spill Database, April 2010, www.boemre.gov/stats/index.htm
[A] Estimates vary between 10,000 to 77,000 bbl
[B] Refined product
[C] This spill was in Louisiana State waters and not OCS waters, but is included for interest

All but two of the OCS spills in Table 14-9 occurred prior to 1980. BOEMRE statisticians responsible for analyzing and predicting hydrocarbon spill frequencies associated with offshore oil and gas activities in the OCS have decreased the estimate gradually over the past 15 years, mostly in recognition of a statistical trend towards lower spill frequency. The estimate derived from statistics in Anderson and LaBelle (2001) is 1.5×10^{-5} spills/well-year for spills equal or greater than 1,000 bbl and 5.5×10^{-6} spills/well-year for spills equal or greater than 10,000 bbl[2].

The production well-years for Hebron is 200; therefore, the predicted number over the 30-year life of the Project would be $200 \times 1.5 \times 10^{-5} = 3 \times 10^{-3}$ events for 1,000-barrel spill, and $200 \times 5.5 \times 10^{-6} = 1.1 \times 10^{-3}$ events for a 10,000 barrel spill.

Note that the above statistic for spills >10,000 bbl (*i.e.*, 5.5×10^{-6} spills/well-year) is almost four times smaller than the statistic derived earlier for production blow-out spills >10,000 bbl (*i.e.*, 2.0×10^{-5}). This is impossible because the first category includes blow-out spills. The reason for the anomaly is that the US record was used for the former and the world-wide record was used for the latter. The world-wide statistic is higher than the US-derived one because the former was developed on a very conservative basis, which considered an exposure of only oil wells and not gas wells.

It is noted that there has been one production-related spill in Newfoundland and Labrador waters greater than 1,000 bbl, in 2004. There have been no spills greater than 10,000 bbl. Given the limited statistical database of Newfoundland and Labrador production operations, the US statistics are used in the frequency calculation.

14.1.4 Platform Spills Involving Small Discharges

Small spills occur with some regularity at offshore platforms. The data in Table 14-10 are derived from a more detailed table in MMS (1997) and covers small spills of all pollutants from facilities and operations on Federal OCS leases from the period 1971 to 1995. The spills involved various pollutants including crude oil, condensate, refined product, mineral oil and diesel. The period between 1971 and 1995 involved the production of

[2] These numbers are derived from statistics developed by Anderson and LaBelle (2001), who use an exposure of "billions of barrels of oil produced" and consider the period 1964 to 1999. During this period, 46,000 bbl of oil were produced per well-year, considering both oil and gas wells. The frequencies derived by the authors for spills greater than 1,000 bbl and 10,000 bbl are 0.32 and 0.12 spills per billion bbl produced, respectively. The equivalent numbers for the last 15 years are considerably less.