Oil Deposition Modeling For Surface Oil Well Blowouts

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Abstract

A surface oil and gas well blowout can send a plume of oil droplets into the atmosphere near the discharge site. The location that the oil falls to the surrounding ground or water and the rate of deposition at this point depends upon the height to which the oil is propelled, the size of the oil drops and the prevailing wind speed. A simple method is presented for estimating the fallout width and rate as a function of distance from the source, for the range of oil and gas flows likely to occur in the Alaska North Slope operations. This paper summarizes the results of a project completed for Alaska Clean Seas.

Project Objective

The objective of the project was to estimate the likely fallout zone from a surface well blowout, under specific environmental conditions and blowout characteristics, for spill response planning purposes. The work was not intended to be a detailed scientific evaluation of the best modeling approach to the problem, but rather to use an existing method to meet the project's practical objective.

Model Description

A computer model was developed based on the workbook method for atmospheric dispersion estimation by Turner (1970). The blowout and oil deposition model functions as follows. Input parameters of oil flow, gas flow, discharge pipe diameter, oil density, average wind speed, oil drop diameter, release height, and atmospheric stability class are read into the model. The gas exit velocity is estimated using a simple "gas flow divided by discharge area" relationship. The jet rise is calculated using a cold jet rise equation (Beychok, 1979). The oil drop settling velocity is calculated using an iterative terminal velocity equation. The distance that the drop will travel prior to hitting the 'ground' is determined using the rise height, settling velocity and wind speed. The plume spread in both the vertical and horizontal is assumed to follow a Gaussian form as described by Turner (1970).

A factor of 2.67 is applied to the final travel distance to account for vertical spread (this adds three standard deviations to the mean distance travelled). This results in 99% of the droplets, of the diameter being considered, falling by the distance calculated. The width that the plume will spread to, at the point of ground contact, is determined using Turner's (1970) atmospheric dispersion relationships. The 2.67 factor also is applied to the plume width to account for 99% of the droplets.

Oil Drop Size Distribution

The oil drop size distribution from a surface oil and gas blowout is the one parameter about which little is known. Measured oil drop-size distributions for such events could not be found in a search of the libraries of S.L.Ross, Environment Canada and Canadian Institute of Scientific and Technical Information. The following steps were taken to provide an estimate of the size distribution of these drops.

Observational data from the Uniacke (Martec, 1984) and Ekofisk (Audunson, 1979) blowouts were used to approximate the volume median drop diameter from surface blowouts. The spill model was run using the blowout conditions reported in the literature for these two incidents and various volume median oil drop diameters. The reported slick conditions for these spills were adequately predicted when a 500 µm volume median diameter was used in the Uniacke discharge and a 750 µm volume median diameter (VMD) was used for the Ekofisk spill. The comparisons between reported and modeled values can be seen in Table 1. This provides an average drop size but does not reveal the drop-size distribution.

Table 1 : Comparison of Reported and Modeled Slick Characteristics

	Percent Evaporated		Slick Width (m)		Thickness (mm)	
Oil	Reported	Modeled	Reported	Modeled	Reported	Modeled
Ekofisk[1]	35-40	39.5	100-200	200	1	1.14
Uniacke[2]	70	67.5	200	700	0.003	0.0046

[1] 8.5 m/s wind, 0.5 m/s water current, 5°C air and water temp, 750 µm drop diameter
[2] 12.3 m/s wind, 0.26 m/s water current, 1°C air and water temp, 500 µm drop diameter

The only oil drop-size distribution data that could be found from an oil and gas discharge were from measurements taken during an experimental subsea release under an ice cover (Buist and Dickins, 1980). In this study oil drop-size distributions were measured from ice core samples taken at various distances from the release point. These distributions have been combined in an area- weighted scheme to identify the likely drop-size distribution of the oil as it was discharged. The result of this analysis can be seen in Figure 1. The resulting distribution is linear rather than the log-linear relationship exhibited by most gas-atomization systems. The reason for this is unknown, but, since this is the only data available, it is used in the final modeling with one modification. The volume median drop diameter of the subsea release was around 1050 µm. This is somewhat higher than the 750 µm diameter identified for above sea oil blowouts. This would seem reasonable since the gas flow would be reduced somewhat due to the over-pressure provided by the water above the submerged discharge point. This will reduce the gas exit velocity and result in reduced droplet shearing and larger drop diameters. To account for this, the measured drop size distribution in Figure 1 has been shifted so that the volume median diameter of the new curve is 750 µm, but the slope of the curve has been preserved. The resulting drop-size distribution has been used in our modeling to identify the oil fallout rate as a function of distance from the release location. Due to the lack of supporting data we were unable to identify different drop size distributions as a function of the gas and oil flow rates and discharge pipe diameter.

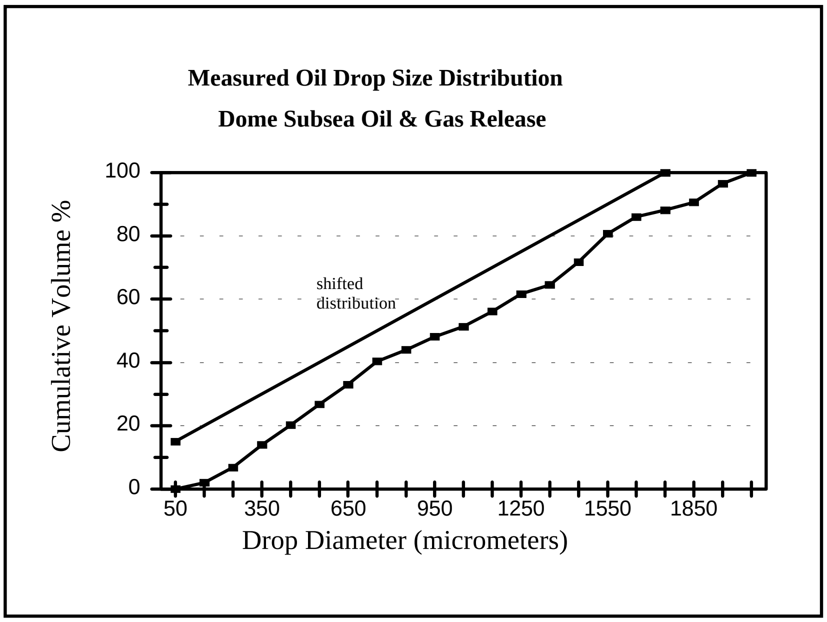

Figure 1 : Oil Drop Size Distribution from Subsea Oil & Gas Release

Pneumatic atomization equations, for predicting the VMD as a function of blowout parameters, have not given results that match the information available from field observations so they have not been used in this study.

Modeling Results

The input conditions considered in the modeling were as follows:

Oil Flow: Barrels of Oil per Day(BOPD)	5,500 8,000 12,000 15,000
Gas-to-Oil Ratio (GOR)(ft^3 gas/barrel oil)	400 750 2,200
Wind Speed (knots)	5 10 15 20
Discharge Pipe Internal Diameter (in)	4 & 6.3
Atmospheric Stability Class	D

The model was run for the drop diameters that correspond to the 10, 20, 30 ... 90 % cumulative volume cutoffs in Figure 1. Early modeling results identified that the wind speed has no effect on the deposition pattern due to two counteracting effects: the wind speed affects the rise height of the plume as well as the distance a drop will travel downwind prior to falling to the ground. A high wind reduces the rise height by bending the rising plume. Drops will fall to the ground sooner due to the reduced height but will travel just as far from the source due to the increased wind speed. The wind speed variable was therefore dropped from the test matrix. The results presented apply for most wind speeds but not for extreme cases (i.e., zero winds or very high winds will result in plume behavior different than that presented in this report).

It should also be noted that the horizontal dispersion relationship adapted from Turner (1970) is strictly valid only for distances greater than 100 meters from the source. We have applied Turner's relationships to points closer to the source and these results should be used with caution.

The gas flow exiting from the rupture controls the plume height and subsequent fallout characteristics. The plume fallout dimensions are therefore reported as a function of gas flow rather than oil flow and GOR. Figure 2 has been provided to permit a quick estimate of the gas flow from an oil flow (in barrels of oil per day) and a GOR (in scf/barrel). This figure also shows the maximum gas

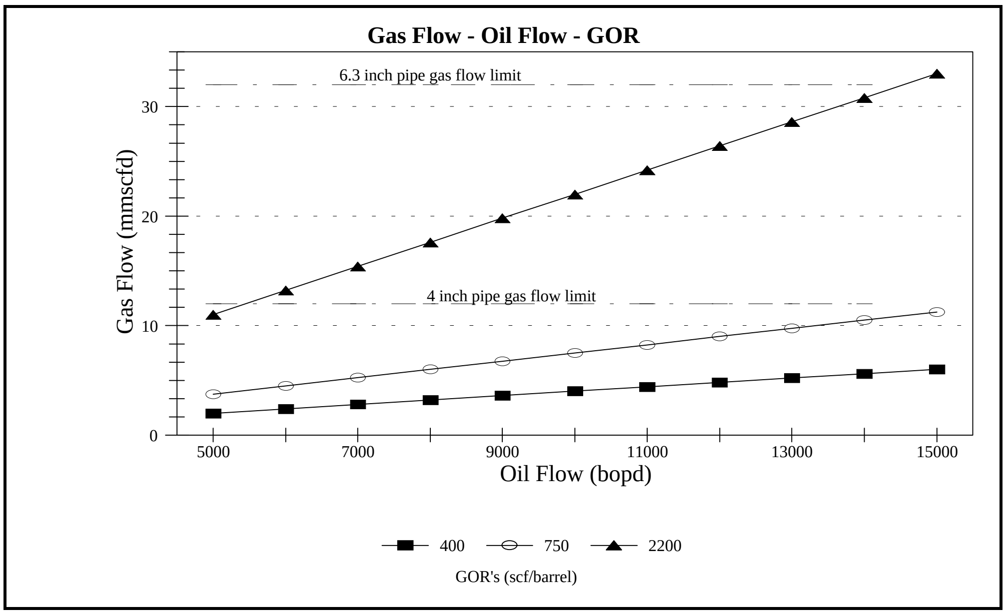

Figure 2 : Gas Flow - Oil Flow - GOR Relationship

flow possible through the two pipe diameters considered (4 and 6.3 inch inner diameter pipes). Gas flows at the limits shown represent sonic exit velocities.

Figures 3 and 4 can be used to determine the percentage of the total oil flow that will fall to the ground or water within a given distance downwind of the source for the 4 and 6.3 inch pipe diameters, respectively. The oil flow rate and the duration of the release can be applied to this number to determine the oil deposition rate and "average" oil thickness that would exist at the location.

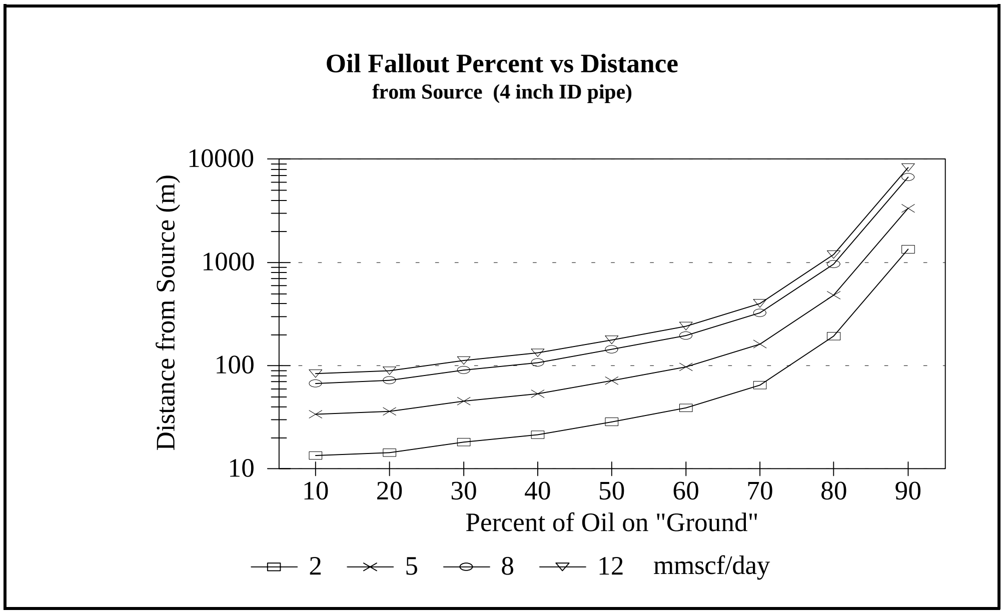

Figure 3 : Oil Fallout Percent vs Distance from Source (4 inch ID pipe)

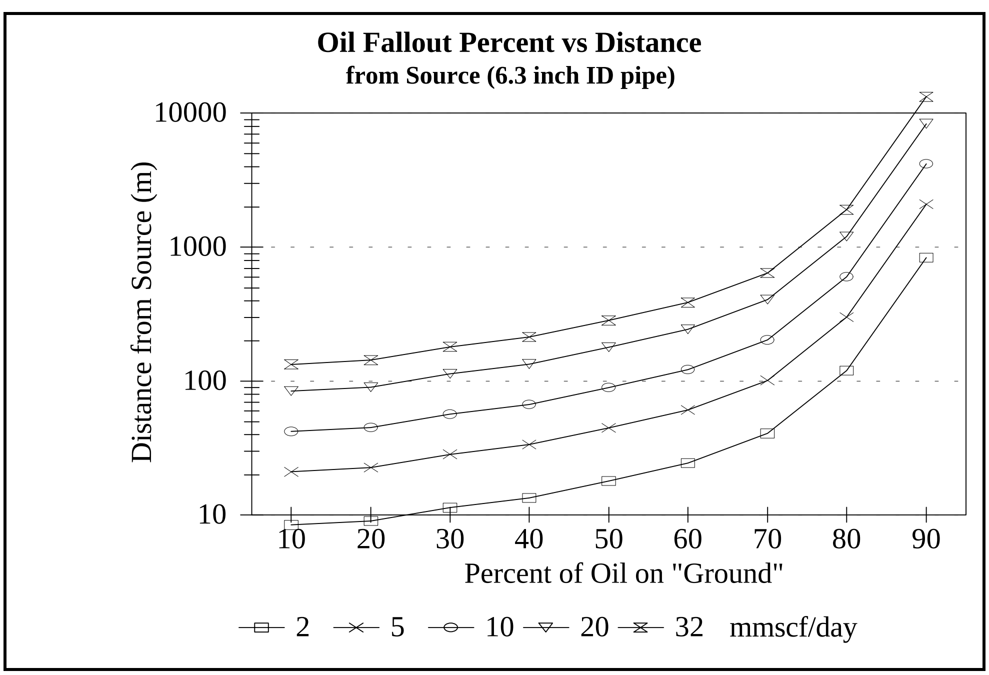

Figure 4 : Oil Fallout Percent vs Distance from Source (6.3 inch ID pipe)

Figures 5 and 6 can be used to determine the width of the plume at the location downwind.

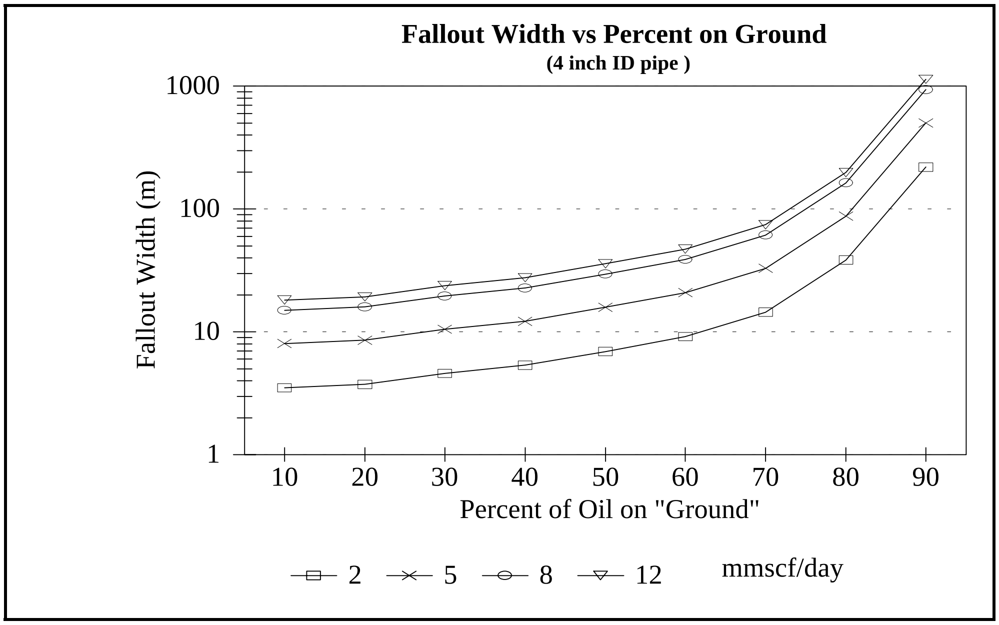

Figure 5 : Fallout Width vs Percent on Ground (4 inch ID pipe)

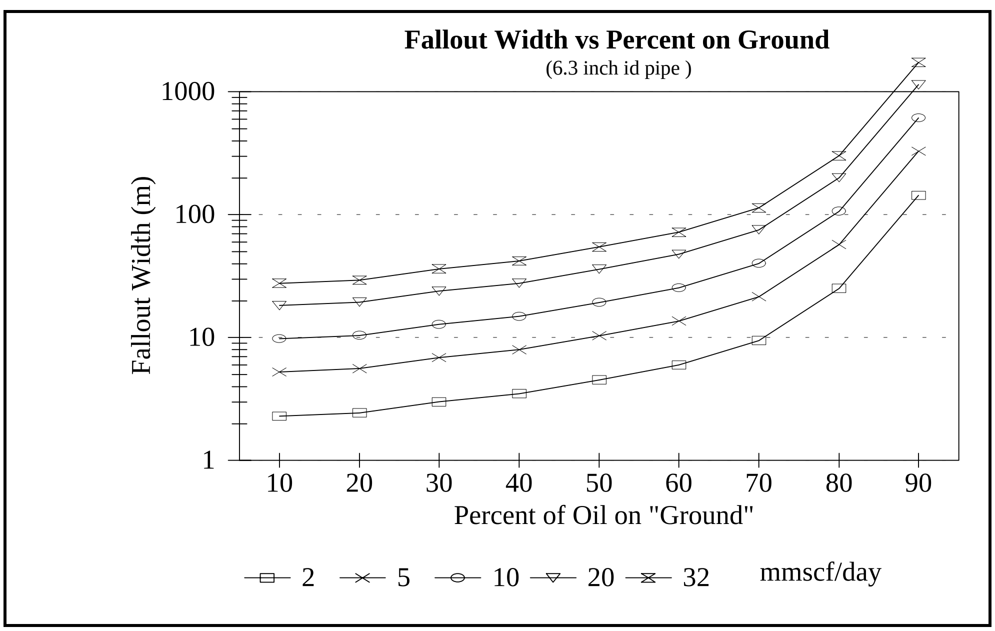

Figure 6 : Fallout Width vs Percent on Ground (6.3 inch ID pipe)

The following example is provided to illustrate how to use these figures. A well is assumed to be discharging oil and gas at a rate of 12000 BOPD with a GOR of 750 scf/barrel through a 6.3 inch diameter (7 inch outer diameter) pipe. To determine the amount of oil that falls within 200 meters from the source one would complete the following steps. From Figure 2 determine the gas flow to be about 8.75 mmscf/d. On Figure 4 interpolate between the 5 and 10 mmscf/d curves to approximate the required 8.75 mmscf/d curve. From this interpolated curve get the percent of oil falling within 200 meters of the source (about 72%). The total volume of oil falling within 200 meters of the source will be the total oil flow of 12000 BOPD times 0.72 times the duration of the blowout period. To determine the width of the fallout at 200 meters, use Figure 6 in the same way, and determine the fallout width at 72% of oil on "ground" (about 35 meters). This is the width that would be oiled if the wind came from the same direction during the entire release. If the wind is shifting the plume will deposit oil over a much wider area. If the wind's directional persistence throughout the release period is known these values can be applied to determine the percentage of oil falling and the resulting oil thicknesses in the various sectors around the spill source.

References

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