THE FLORIDA STATE UNIVERSITY
Department of Earth, Ocean, and Atmospheric Science
Meteorology Program, 1017 Academic Way, 404 Love Building
1.850.644.6205 (voice) • 1.850.644-9642 (fax) • http://www.met.fsu.edu/

Oil Spill Estimates – an Environmental Fluid Dynamics Perspective

Paul Ruscher[1], Department of Earth, Ocean, and Atmospheric Science and Geophysical Fluid Dynamics Institute, The Florida State University

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1) This estimate (first made on 12 May) is for the first spill at the Deepwater Horizon seabed from the first seabed video released by BP and the federal government. We start with an assumption that good (water) wells may produce 45 gal/min out of a 1" diameter pipe (water). The internal (sub-seabed) pipe diameter of the Gulf oil spill is apparently ~7" in diameter. Here, the oil well pipe cross-sectional area is approximately 50 [the ratio of 3.5^2 / $\frac{1}{2}^2$] times the area of a 1" pipe (here $r = \frac{1}{2}d$), and so we will use a calculation of 50 × 45 gal/min or 2,250 gal/min as an ambitious estimate of the flow rate out of the first spill for which video was available. In one hour (60 minutes), this equates to 135,000 gallons. In one day (24 hours), this leads to an estimate of 3,240,000 gallons per day. Counting the spill as if Day 1 = April 21st, as of midnight on May 27 (37 days), the estimated total volume of the oil spill, assuming a constant flow rate is potentially as large as 74,520,000 gallons to date (as of 27 May), or over 1.7 million barrels of oil. It has been pointed out to me that the outlet pipe may be 20" in diameter, rather than 7"; I am using a flow rate out of the riser (7") as the estimate here, rather than increasing the diameter, as I'll use in the later calculation below. Some of that space is occupied by flowing oil, and some by escaping gas/solids – we do not account for a reduction of volume flow rate in this calculation here since there is no consensus about the relative proportion of oil to natural gas in the stream.

   a) **135,000 gallons per hour**
   b) **3,240,000 gallons per day (~77,000 barrels per day)**
   c) **~120,000,000 gallons (~2,850,000 bbl) since the spill began[3]**

2) Now that a second video has been released from the site of the blow-out preventer (BOP), other estimates of a major spill site can be estimated. Only two view angles were available at the time the video was first made available. These indicate several individual

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[1] pruscher@fsu.edu , http://oilspill.fsu.edu/
[2] I welcome feedback and do not view this as a definitive calculation; however I am using numbers like these to respond to my students' questions in my Met 1010 class – they really want to know how environmental scientists do what they do. Perhaps these calculations would be of use to others as well, and so after some editing could be posted on the OSATF site.
[3] Estimates here are through 27 May 2010.

small jets of oil streaming from the top of pipes whose diameter we'll estimate (since we have no scale estimate here) at 1" diameter each. Using the same volume flow rate for a productive water well above, we approximate 8 orifices of about 1" diameter each for an approximate flow rate of 370 gallons per minute (information released since estimates were done in mid-May seem to suggest that there are three separate ~3" diameter leaks, which would be larger than the numbers below, all other factors remaining the same). This yields oil flowing at a rate of 22,200 gallons per hour in addition to the amount calculated in (1). Summarizing this estimate as we did in (1), we find

a) **22,200 gallons per hour**
b) **532,800 gallons per day (~12,700 barrels per day)**
c) **~20,000,000 gallons (~469,000 bbl) since the spill began**

Using this technique, the aggregate estimated totals from the two spills are:

a) **157,200 gallons per hour**
b) **~3,773,000 gallons per day (~89,700 barrels per day)**
c) **~140,000,000 gallons (~3,319,000 barrels) since the spill began**

Satellite-tracking of the oil plume has also been demonstrated to be extremely valuable and these were apparently used to help increase the initial official estimates by a factor of 5, but the technique is hampered by the use of dispersants which remove oil from the surface, and by evaporation, burning, and mixing of oil by strong wave and wind action on occasion; it may therefore also be an underestimate. However, such estimates (MacDonald and Garcia 2010) have also produced area size estimates that suggest a spill much greater in volume than 5,000 barrels per day, approximately 5 times larger than the public estimates being released through 26 May. On 27 May, USGS publicly acknowledged that spills were likely more like the 25,000 bbl/day that MacDonald and Garcia have been estimating since shortly after the spill began.

The calculations presented here provide no error bars, but is within the range of other predictions made public to date. Initial attempts at using photogrammetric techniques applied without the benefit of PIV analysis (such as have been recently published from Purdue) were unreliable and so were abandoned here for the time being, but are attempted anew below (consider the estimate below a first draft).

3) Alternative calculation. The initial video released by BP and the federal government provides tools that allow some crude photogrammetric techniques similar to those used by early tornado spotters to estimate wind speeds in assessing damage to structures. By tracking individual fluid elements out of the exit nozzle of the pipe at the seabed, we can estimate the flow velocity to be approximately 3 meters per second out of the pipe that reportedly has a cross-sectional area of approximately 2027 cm^2 (20" diameter); flow volume is $V = A \times v$, where A = the cross-sectional area of the pipe (πr^2) and v is the speed of the exit velocity of the pipe outlet.. Using an appropriate volume conversion from cm^{-3}

to gallons yields a volume flow rate of nearly 161 gallons per second. Assuming only 1/3 of the volume is oil (the rest being gas or perhaps sand or other debris), we find approximately 54 gallons of oil per second from the main leak on the seabed (the only one accounted for in this calculation). This is equivalent to:

a) **194,400 gallons per hour**
b) **4,665,600 gallons per day (111,086 barrels per day)**
c) **~173,000,000 gallons (4,110,000 bbl) since the spill began 37 days ago**

I have little confidence that these are realistic estimates, but since they and all other scientific estimates I've seen or heard are much greater than BP's initial estimates of 1,000 and then 5,000 bbl/day, I have no faith that theirs are anything but much too conservative. Mine could be easily high by a factor of 8 or so (using up to 50% uncertainties on the high side for each of 3 assumptions), and so should be used with great caution.

Summary Including Uncertainty Estimates

1. Estimate #1 uses an optimal flow rate from an unrestricted well of 45 gallons per minute from a 1" pipe and extrapolates geometrically. The main spill is assumed to flowing through a 7" riser before it exits the seabed. An additional estimate comes from video of the blow out preventer (BOP) which augments the estimate. My best guess is that the spill is between approximately 12,000 and 89,000 barrels per day (my lower bound is reduced by approximately a factor of 8 here as mentioned previously).

2. Estimate #2 attempts to crudely estimate flow rate by approximating the exit velocity from the plume base from the main spill. I would estimate flow rates between 14,000 and 111,000 barrels per day from this estimate.

It is clear from these estimates that this spill has greatly exceeded the spill from the 1989 Exxon Valdez and may be approaching the 1979 Ixtoc I spill in the Gulf of Mexico, if it has not exceeded it already in magnitude.