National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling

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Determining the Rate of the BP Oil Discharge and Comparison with Natural Oil Seeps

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Determining the Rate of the Discharge

The final cement seal on BP's blown out well at 1500 m water depth, 75 km southeast of Grand Island, Louisiana was confirmed by the Unified Command on 19 September 2010, 150 days after the deadly explosion on the Transocean sister vessel Deepwater Horizon. Prior to the final plug, oil discharged for 84 days after the rig sank on 22 April, until a steel cap was installed and successfully closed on 15 July. In the aftermath, we can see how understanding consistently lagged behind events by considering the sequence of estimates made the authorities of the Unified Command and a few others about the singular, all-important, and very consequential variable in the ongoing emergency: the rate of discharge, from which one can estimate the total pollution load discharged into the deep-water Gulf of Mexico. Here is the full sequence of Unified Command estimates in magnitudes of barrels of oil per day listed in the order that they were issued with the consequent results (Table 1).

Table 1. Estimates of oil discharge rate from BP well. These estimates were give in press statements from spokespeople representing Unified Command: Coast Guard Rear Admiral Mary Landry, Coast Guard Admiral Thad Allen, and Dr. Marcia McNutt speaking for the Flow Rate Technical Group. Rates are median values in barrels of oil per day. The release is the total barrels that would have issued from the well between 22 April and 15 July 2010. The discharge subtracts 800,000 barrels that were recovered into ships from the total release to show the magnitude of oil that was in the ocean. E.V. Units are relative to the Exxon Valdez spill.

Date 2010	Authority	Rate (bopd)	Release	Discharge	E.V Units	Ref.
23-Apr	Landry	0	0	NA	NA	[1]
25-Apr	Landry	1,000	84,000	NA	NA	[2]
28-Apr	Landry	5,000	420,000	NA	NA	[3]
1-May	Allen	Accurate estimate impossible	NA	NA	NA	[4]
27-May	McNutt	16,000	1,344,000	544,000	2.1	[5]
10-Jun	McNutt	30,000	2,520,000	1,720,000	6.7	[6]
15-Jun	McNutt	48,000	4,032,000	3,232,000	12.6	[7]
2-Aug	McNutt	58,000	4,872,000	4,072,000	15.8	[8]

The trend of increasing rates and the increasing perception of possible grave consequences for the ecosystem and people of the region is obvious from the sequence.

During the first five weeks or more of the emergency, the official rate of release grossly underestimated the true rates that would eventually be determined. Of particular note was the interval from 28 April to 27 May during which authorities were responding to an estimated discharge rate of 5,000 bopd, which was more than an order of magnitude lower than the true rate happening as efforts went forward. Where did this rate come from and why was it allowed to stand for so long?

During the early days of the spill BP technicians and NOAA experts made estimates of the amount of oil on the water and from these calculated the rate of discharge. They based these estimates on remote sensing evaluation of the size and appearance of the oil that was floating on the water over the well site and was rapidly spreading to cover larger and larger areas.

Oil does not mix with water and a light, low-sulfur crude oil like that from the Macondo well will rapidly spread into thin layers on the surface of the ocean. Evaporation and other processes will consume about one third of the floating oil over the course of a few days, but initially the appearance of the oil is well-correlated to its thickness. NOAA (National Oceanic and Atmospheric Administration) has authored a useful field guide for judging the amount of oil released by pollution events [9]. This guide conforms to the International Bonn agreement covering how oil pollution at sea should be evaluated.

According to these standards, the thinnest possible oil layers are called "sheen;" they comprise no more than a few molecules--layers thinner than the wavelength of visible light and detectable only because they dampen small ripples and give the water a reflective appearance. Somewhat thicker oil layers called "rainbow" become visible when they refract light over a few multiples of the visible range: these layers are about 0.5 to 5 µm. Heavier oil begins to show "metallic" "dull" and "dark" colors in layers of 10 to >100 µm. For reference, remember that a human hair is about 100 µm, so "dark" oil is still a very thin layer, but when spread over hundreds or thousands of square kilometers the volume becomes large.

My public profile in the BP oil discharge story stems from back of the envelop estimates I made on 27 April along with my colleague John Amos. Although no one in the public yet had access to the video of oil jetting from the pipes, we could access a variety of satellite images of the surface oil. From previous work on remote sensing of natural oil seeps in the Gulf of Mexico, I had memorized a simple formula:

$$1\ \mu m \times 1\ km^2 = 1\ m^3$$

This allowed me easily to convert the area of the spreading oil into volume. By combining satellite images we had access to with the Coast Guard's description of the oil appearance and consulting the NOAA field guide for appropriate thicknesses, I estimated that the *minimum* rate of discharge had to be 26,500 bopd.

The Unified Command, who were looking at identical types of data, got a much different result. Technicians working for BP made a series of estimates of discharge rates beginning on 27 April--looking at data similar to what John Amos and I had reviewed. Their results were summarized in confidential memos numbered CE02095 to CE02099, several of which were obtained by Representative Edward Markey, who then had his staff copy them to me for independent evaluation.

In these worksheets, the technicians identify three classes of oil: sheen, dull, and dark, and make their calculations in imperial units based on variables of "area," "cover factor" (%), and "gal/sq mi." Multiplying through gives the volume in gallons for each of the oil classes and dividing by days of discharge gives the instantaneous rate. Unlike my estimate, these analysts compensate for evaporation and dissipation by using a multiplier of 2, meaning that they assumed that half of the oil discharged had disappeared by 26 April, four days after the spill began. The "Best Guess" was 5768 bopd. The other memos in the series CE02096 to CE02099 give best guess estimates of 5092, 5906, 5226, and 5707, respectively. The worksheets have header indicating that they were completed using ASTM Standards for oil estimation [10].

If the "gal/sq mi" parameter is recalculated in the accepted units of microns it is evident that the parameters for oil class thickness do not match the ASTM standards, which in any event do not provide reliable guidance for layers thicker than 3 µm. Nor do they match the NOAA field manual. The guidelines that were actually used by the BP technicians seem to have been taken from BP's official Regional Oil Spill Response Plan—Gulf of Mexico. This document has already been criticized because it included protection plans for sea otters and walruses, which do not occur in the Gulf. Possibly more serious however, is the table in Section 1D of the Plan, which is entitled "Oil Thickness Estimations." This set of standards uses the same gallons/square mile multiplier as is found in the BP worksheets, but the table in the plan also gives equivalent thicknesses in microns. Comparison of the BP table with the NOAA and Bonn standards shows that the BP technicians were using oil thicknesses that were as much as 100 time *smaller* than the NOAA guidelines. So the "Best Guess" was obtained using guidelines that were biased toward results much lower than would have been obtained by using accepted standards.

A pressing question would be why the Unified Command authorities apparently relied on BP's internal, and evidently erroneous standards instead of using NOAA's guideline that was formulated on the basis of international agreed upon standards.

Comparison of Natural Oil Seeps with the BP Discharge

This section of my testimony, which will not be given orally due to lack of time, concerns the differences in magnitude and distribution between natural oil and gas seeps in the Gulf of Mexico and the prolonged discharge from the BP well in Mississippi Canyon 252.

The existence of natural seeps in the Gulf of Mexico has been cited as a factor that has pre-conditioned the gulf ecosystem better to rebound from the pollution dose received due to the 84-day discharge of 4.1 million barrels of oil (550,000 tons) and 2.1 million barrels of oil equivalent of gas (185,000 tons) from the BP well. The natural seeps, it has been suggested, are a hydrocarbon-rich environment promoting the prevalence of oil-consuming bacteria, strains of which might then consume oil discharged from the BP well. Moreover, the wide-spread occurrence of natural seep provides a alternate, background source of hydrocarbons throughout the Gulf. Oil from these natural sources, goes this argument, might be mistaken for oil from the BP discharge.

An active natural seep discharges about 10 barrels of oil per day with variable magnitudes of gas1-2. The BP discharge was as much as 62,000 barrels of oil and over 31,000 barrels of oil equivalent gas during the initial phases of the emergency, decreasing to an estimated 53,000 BOPD at the end.

Oil from natural seeps, like the oil that rose to the surface from the BP well, leaves traces that can be detected by satellite remote sensing4. Natural seeps create floating layers (slicks) that are <1% of the thickness of a human hair (<1 µm) and cover surface areas of 0.5 to 1 km2. The oil from BP's discharge created large slicks with similar thicknesses and included substantial areas around the well where the oil was at least 100 fold thicker. In all, the surface oil from the discharge covered an area over 20,000 km2 during much of the discharge episode. Pelagic life--fishes, birds, turtles, and whales as well as plankton and planktonic larvae will have received a concentrated dose of hydrocarbons over many weeks. Widespread, deleterious impacts should be anticipated.

Natural seeps can be found from depths of about 300 ft (100 m) to the full ocean depth of the gulf 12,000 ft (3,600 m). They are concentrated in the central and western Gulf from the U.S. south to the Mexican side of the Gulf. The main concentration of natural seeps is about 100 miles west of the BP well.

Bacteria in seep sediments consume substantial quantities of oil and gas. The end-member oil signatures are very different: fresh oil is dominated by straight chain normal alkanes. Biodegraded oil is generally completely depleted in normal alkanes. This difference is readily seen in a whole-oil gas chromatograph.

Samples of surface oil in fresh, weathered, concentrated oil layers, and very weathered emulsion were collected and analyzed by gas chromatography. The resulting signatures show relatively little depletion of normal alkanes even in the most extensively weathered samples. These samples suggest that the breakdown of the surface oil has been dominated by physical and chemical processes, not extensive biodegradation.

With the dissipation of the surface oil, a fraction of the product remaining after the rate of evaporative loss diminished could take on enough water and suspended solids to sink. Recent samples raise concerns about wide-spread oil possibly sunk from the surface and now on the bottom. Animals that feed or burrow into deep-sea sediments are not adapted to oil. Burrowing organisms that are common in non-seep areas are completely absent in natural seeps, where oil saturates the sediments and oxygen is depleted immediately below the sediment water interface.

In summary, the BP oil discharge was at least 10,000 times more concentrated in space and time and about twelve times greater in magnitude than the total annual release from natural seeps of the Gulf of Mexico. In my scientific opinion, the bulk of this material was dispersed in surface layers, from which about one third evaporated and ten percent was removed by burning or skimming. An additional ten percent was chemically dispersed. The remaining fraction--over fifty percent of the total discharge--is a highly durable material that resists further dissipation. Much of it is now buried in marine and coastal sediments. There is scant evidence for bacterial degradation of this material prior to burial.

The BP oil discharge has been described as a unplanned and unwanted experiment. When we teach freshmen college students the scientific method, we explain that the rigorous approach to experimental results is to disprove the hypothesis of no effect: i.e., the experimental drug does not cure disease better than the placebo, or the toxin does not kill a significant proportion of the test organisms. If this *null hypothesis* is disproved, one can consider the alternatives--the drug is effective or the toxin is deadly. In the BP oil discharge experiment, the hypothesis we need to disprove is that the Gulf of Mexico coastal and marine ecosystem can absorb about 750,000 tons of hydrocarbons released from a single point in less than three months *with no lasting, harmful impact.*

We have to ask ourselves whether our tests are sufficient to disprove the hypothesis of no effect. If we reach a rapid judgment based on the numbers of dead birds, for example, we might miss the true impact. In Prince William Sound, for example, no dead orcas were found after the Exxon Valdez spill, none the less, the present orca population in the Sound was reduced by over half by the spill7. My concern in the Gulf is for a fractional loss of productivity and biodiversity across a broad sector of ecosystem components (populations and habitats) that persists for years to come--a lowered baseline. The worst case scenario is tipping point effects from which populations may not recover; because we must remember that this experiment was performed on an ecosystem that was already badly damaged by stresses like hypoxia, over-fishing, coastal runoff to name just a few.

My recommended approach would be to identify and monitor key habitats and populations to verify ecosystem health: e.g. pelagic—tuna, flying fish, whales; coastal—coquina, periwinkles, menhaden, etc. Track these populations over time because the test of a healthy ecosystem is the continued existence of the species that depend on ecosystem health. Finally, although we are very concerned to see fishermen and hotel owners compensated for their economic losses, a major component of the ongoing response effort should put repayment of the Gulf of Mexico ecosystem in the front of the line. We should use the BP fine (as much as $19billion) to establish an endowment to restore, understand, and sustain the coastal and marine environment in perpetuity.

Notes

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