In re: Oil Spill by the Oil Rig "*Deepwater Horizon*" in the Gulf of Mexico, on April 20, 2010

UNITED STATES DISTRICT COURT
EASTERN DISTRICT OF LOUISIANA
MDL NO. 2179, SECTION J
JUDGE BARBIER; MAGISTRATE JUDGE SHUSHAN

Rebuttal Expert Report of Adam L. Ballard, Ph.D.

June 10, 2013

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Summary of the Rebuttal Expert Report of Adam L. Ballard, Ph.D.

I am an engineer with training and expertise in the use and application of models to assess the properties of oil and gas when flowing through subsea and subsurface systems, such as deepwater wells and pipelines, including the use of such models to estimate fluid pressures and the rates at which oil and gas flow through subsea systems.

I have been asked by my employer, BP, to respond to portions of two reports filed on behalf of Transocean Offshore Deepwater Drilling, Inc. ("Transocean") and dated May 1, 2013. One report was written by Dr. John L. Wilson. [redacted] Dr. Wilson [redacted] offer the following opinions, among others, in their reports for Transocean:

- According to Dr. Wilson [redacted] in April and May 2010 BP hid from U.S. government officials working on the *Deepwater Horizon* response various types of information necessary to estimate flow rates from the Macondo Well ("the Well") using hydraulic models. Dr. Wilson [redacted] claim that BP's supposed concealment of that information impeded efforts to contain oil from and to shut in the Well.

- Dr. Wilson also claims that BP engineers and contractors had sufficient data and "tools" (referring to hydraulic models) in April and May 2010 in order to estimate the daily rates of discharge of oil and gas from the Well.

My qualifications to respond to the foregoing claims by Dr. Wilson [redacted] are summarized in Part I of this report. My resume is included in Appendix A. The sources that I have used to prepare my opinions and conclusions are listed in Appendix B.

A summary of my conclusions concerning the claims by Dr. Wilson [redacted] recited above are as follows:

1. Hydraulic modeling of flow from the Well required, among other things: (i) reliable data from subsea pressure instruments and (ii) an accurate understanding of the flow path for oil from the reservoir into the waters of the Gulf of Mexico (see pp. 3-8 below). In April and May 2010, in my opinion, no one, including anyone at BP, knew with certainty the flow path of oil from the reservoir to the surface. Contrary to the claim by Dr. Wilson, neither BP nor any other party had the "tools" in April and May 2010 necessary to reliably estimate daily discharge rates from the Well using hydraulic models.

2. BP and its contractors used hydraulic models and the available inputs for those models in April and May 2010 for primarily two purposes. One purpose was to understand how different source control options might affect discharge rates from the Well. The other purpose was to ensure that source control equipment could process the flow from the Well and eventually shut in the Well in a safe and efficient manner (see pp. 16-23 below).

3. In directing the response to the *Deepwater Horizon* blowout in April and May 2010, the *Deepwater Horizon* Unified Command relied on an estimate of the so-called "worst case discharge" for the Well that had been provided by BP at the time when the U.S. Minerals Management Service ("MMS") gave BP permission to drill the Well in 2009 (see pp. 17-18 below). That worst case discharge estimate was 162,000 bopd. Such a worst case discharge calculation is prepared before a well has been spudded, and per the regulations, it assumes extreme conditions, including the absence of any restriction by a blowout preventer ("BOP") or a riser, with no drill string in place, and with no sand bridging in the wellbore.

None of the hydraulic modeling performed by BP and its contractors in April and May 2010 produced daily discharge rates greater than 162,000 bopd. Even according to experts retained by the U.S. government (and whose conclusions BP and Transocean dispute), the highest daily discharge rate from the Well was 63,600 bopd (see United States' Phase Two Expert Witness Disclosure (March 22, 2013); Ex. 8615 at p. 1 (estimate by Dr. Paul Hseih)). Dr. Wilson [redacted] do not explain how a response to a subsea blowout, based on an assumption that a blown-out well could produce 162,000 bopd, could have been impeded by lack of access to modeling outputs that show less than 162,000 bopd. This is especially true when the highest flow rate currently attributed to that Well is 63,600 bopd.

Part II of this report explains the conclusions that I have presented above. [redacted]

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Rebuttal Expert Report of Adam L. Ballard, Ph.D.

I. Qualifications

I am a chemical engineer specializing in fluid flow and flow assurance.[1] I have approximately 15 years of experience in the oil and gas industry. I hold a Bachelor of Science in Mathematics from Willamette University (1996) and a Ph.D. in Chemical Engineering from the Colorado School of Mines (2002). My doctoral work focused on applied mathematics, hydrates, and multi-phase fluid equilibrium (PVT).[2]

I am a current member of the Society of Petroleum Engineers and the Institution of Chemical Engineers, and am a past member of the American Chemical Society, the American Institute of Chemical Engineers, and the National Association of Corrosion Engineers. For the past six years, I have been an Article Reviewer for the *Journal of Petroleum Science and Engineering*. From 2008 through 2010, I served as the Chairman for the Deepstar Flow Assurance Committee.[3] I have authored or co-authored 18 peer-reviewed publications and 11 non-peer-reviewed publications in the field of flow assurance, which are listed in Appendix A.

I have worked at BP for 11 years. During that time, most of my work has involved flow assurance. From January 2008 until May 2009, I served as the Lead Flow Assurance Engineer on BP's Thunder Horse platform, which is the oil industry's largest offshore production platform in the Gulf of Mexico. In May 2009, I became the Engineering Manager on Thunder Horse. As the Engineering Manager for

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[1] "Flow assurance" refers to a sub-discipline within engineering that involves the successful, economical, and safe flow of hydrocarbons from a reservoir to an intended location, such as a production facility.

[2] PVT is a shorthand term for pressure, volume, and temperature dependencies of fluid properties.

[3] "Deepstar" is a multi-company project focused on advancing deepwater petroleum technology. See http://www.deepstar.org/AboutDeepStar (last visited June 6, 2013). The project provides "a forum to execute deepwater technology development projects and leverage the financial and technical resources of the deepwater industry." The Flow Assurance Committee's goal is to assure reliable and economic production in deepwater.

Thunder Horse I was responsible for all process safety, operability, and compliance in the Thunder Horse field, as well as delivering and maintaining operational philosophy, strategy, and procedures. I held the Engineering Manager position until January 2013. While at BP, I have participated in numerous flow assurance presentations and have served as a coordinator and instructor for the Gulf of Mexico Flow Assurance Course. In 2009 I was awarded the BP Tallow Chandler Award for Excellence in the Innovation and Application of Technology.

At the time of the *Deepwater Horizon* blowout on April 20, 2010, I was serving as the Engineering Manager on Thunder Horse. I became involved in the *Deepwater Horizon* response shortly after the blowout and worked on the response until August 2010. Until the middle of May 2010, I remained the Engineering Manager on Thunder Horse, while also serving as a technical consultant for various source control efforts under way at the Houston Incident Command Post ("ICP") of the *Deepwater Horizon* Unified Command. In the middle of May 2010, I left my position on Thunder Horse and began working on the Unified Command's Containment and Disposal Project (the "CDP"). As a member of the CDP, I focused on the design of subsea infrastructure and system operations intended to capture and dispose of oil from the Macondo blowout. Like many other engineers at the Houston ICP, my typical work hours were 6 a.m. through 9 p.m. seven days a week.

In October 2012, I testified in this case as BP's corporate representative with regard to the methods used by BP and by BP's contractors to predict, estimate, characterize, or measure the daily amount of hydrocarbons flowing from the Well during the response using subsea pressure and temperature data. I also testified during my deposition about my own work on the response. I have provided no other depositions nor offered trial testimony in any other proceeding. I am not receiving compensation for my work and expenses as an expert for the Company in this litigation separate from my compensation as a BP employee.

II. Opinions

This part of my report, which explains the basis for my opinions related to the reports by Dr. Wilson [redacted], is divided into four sections. Section A provides background on hydraulic modeling necessary to evaluate the positions taken by Dr. Wilson [redacted] in their expert reports (see pp. 3-8 below). Section B provides an overview of the hydraulic modeling undertaken by BP and consultants working with BP during the *Deepwater Horizon* response (see pp. 8-16 below). Section C reviews specific claims presented by Dr. Wilson regarding the "four different workgroups" described on pages 7 to 25 of his report (see pp. 16-23 below). [redacted]

A. Background -- Hydraulic Modeling of Oil and Gas Systems

Although Dr. Wilson has a background in hydraulics, and comments on hydraulic modeling performed by BP and others, he offers no general description of hydraulic modeling. Used in a broad sense, hydraulic modeling covers the use of mathematical or physical techniques to simulate the behavior of fluids in systems, and to make projections about those systems.[4] Hydraulic modeling can be used to understand, for example, (1) air flow in a commercial ventilation system, (2) groundwater flow through sediments in an aquifer, (3) water flow for a sprinkler system, and (4) oil and gas flow in reservoirs, wells, and pipelines. The focus here is on the last application for hydraulic modeling, and more specifically on oil and gas flow in the Macondo Well system.

A hydraulic model can convert a given set of inputs (such as the geometry of the system containing a fluid) into an output or set of outputs (such as flow rates for a fluid or pressures within the system containing the fluid).[5] Generally, hydraulic modeling can take two forms. One form involves numerical modeling, in which a simulation is performed on a computer. The other form involves physical modeling, in which the physical flow geometry is modeled in a laboratory.[6] In this report I use the term "hydraulic modeling" to describe the former type of modeling -- numerical modeling in which a simulation is performed on a computer.

Reliable hydraulic modeling must start with a definition of a "system," meaning, for example, the "vessel" that contains the fluid and through which the fluid will flow, such as a pipeline. Once there is a clearly defined system and fluid, a user of a hydraulic model can typically specify two of three basic hydraulic variables

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[4] Novak et. al., Hydraulic Modeling – An Introduction: Principles, Methods and Applications, pp. 1-3 (2010).

[5] Novak et. al., Hydraulic Modeling – An Introduction: Principles, Methods and Applications, p. 2 (2010).

[6] See http://www.aldenlab.com/about/hydraulic_modeling_summary (last visited June 6, 2013); Novak et. al., Hydraulic Modeling – An Introduction: Principles, Methods and Applications, pp. 2-3 (2010).

in order to solve for the remaining, third variable. Those three basic hydraulic variables are (i) inlet pressure, (ii) outlet pressure, and (iii) flow rate through the system.

The basic principles for hydraulic modeling are illustrated by Figure 1 below. Figure 1 shows a simple pipe, having length (L), height (H), internal diameter (ID), and roughness (ε), and for a fluid (F). In this simple example based on a pipe, those basic properties are essential to a clear definition of the system of flow. If the inlet pressure (P_1) and the outlet pressure (P_2) are known, then the flow rate (Q) can be calculated using simple hydraulic theory. For a system that is not clearly defined, however -- and if, for example, one or more of the parameters that describe the system are not sufficiently known -- it is impossible to solve for flow rate, given the inlet and outlet pressures, in a reliable manner.

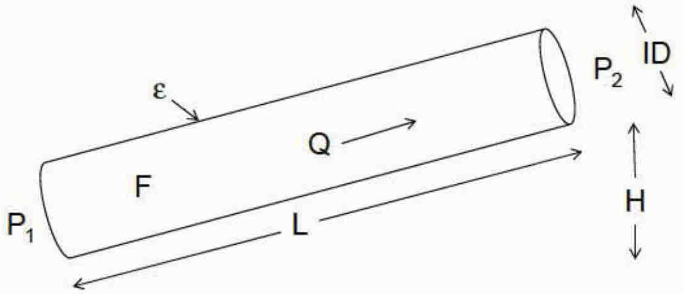

Figure 1 -- Simple Hydraulic Pipe System.

Several additional introductory points should be noted before turning to hydraulic modeling in the *Deepwater Horizon* response.

First, the example above illustrates how a simple hydraulic model might work. The hydraulic models that BP and other parties attempted to use in the *Deepwater Horizon* response also accounted for other factors, such as heat transfer, which adds another set of variables that must be known in order to solve.

Second, Dr. Wilson's report identifies a number of hydraulic models used during the response, but they all have the same three general features and requirements in order to produce credible and reliable results (which Dr. Wilson does not clearly explain). Those three essential features or requirements for credible and reliable model performance are as follows:

- The models must use a computational method to arrive at a numerical prediction of flow or pressure, or some other output of interest;

- The models must have sufficiently accurate inputs taken from calibrated instruments, such as pressure measurements, that can be used as inputs in the model; and

- The models must have a clearly defined system through which the fluids of interest -- typically liquid oil, gas, and water -- will flow.

Hydraulic modeling during the *Deepwater Horizon* response sometimes involved the entire Well system, extending for example from the "pay sands" of the reservoir to the breaches in the sunken riser that released oil into the ocean. To appreciate the complexity of hydraulic modeling in the response, it is therefore important to add a brief description of a hypothetical well system, in which a well is flowing from the reservoir to the surface.

Such a well system has four basic parts, as shown in Figure 2: (1) the reservoir, (2) the near well-bore region, (3) the well, and (4) the surface.

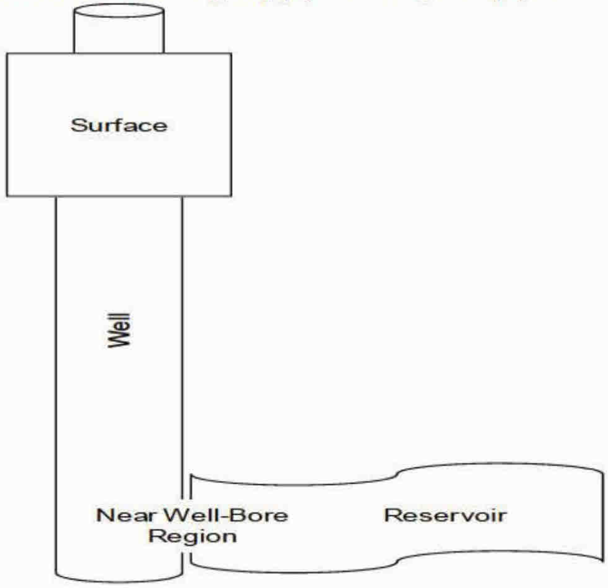

Figure 2 -- Hypothetical Well System with Flow to the Surface

Each part of such a well system must have sufficient inputs to perform a hydraulic analysis, if the goal is to estimate flow from the reservoir to the surface.[7] It is helpful to consider the list of the major inputs needed from the well system in order to try to model a complete well system; those major inputs are presented below.

Reservoir Inputs – Simplistically, the reservoir can be thought of as a large box with one or more openings that is initially filled with fluid. Pressure exerted on the fluid inside the box causes fluid to escape through the opening(s). The loss of fluid reduces pressure inside the box, which in turn reduces the rate at which the box expels fluid. In the case of a reservoir, it is important to know the ***initial reservoir pressure*** of a well, which is the pressure in the reservoir before a single drop of oil has been produced. It is also important to understand the ***actual reservoir pressure,*** which changes over time as the reservoir produces oil. Actual reservoir pressure depends greatly on ***reservoir volume*** and ***aquifer support***.[8] Other important characteristics of the reservoir include the ***number of hydrocarbon-bearing rock layers in the reservoir*** and the ***thickness*** of each such layer, along with the ***permeability*** (the resistance to flow through the rock layer), the ***porosity*** (the void space between sand grains for each layer), and the **water saturation** (the amount of water in the void space) of each layer.

Near-Wellbore Inputs – Other important features of the well system describe or relate to the interface between the rock of the reservoir and other parts of the well system. Those near-wellbore inputs include the ***productivity index***, or "PI," which is a measure of how many barrels of oil will leave the reservoir for each increment of pressure loss in the reservoir. The PI is usually expressed in barrels of oil per day per pounds per square inch ("psi") of pressure drop. The PI reflects the path taken by the oil from the reservoir to the wellbore as well as other factors.[9]

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[7] If a system is not very well defined, a common methodology in hydraulic modeling is to separate the system into sub-parts which are clearly defined in order to properly model a portion of the well system.

[8] Reservoir volume is the amount of oil and gas reserves for a producing reservoir. An aquifer is a deep groundwater system that is usually connected to a much larger volume of water when compared to the oil reservoir. For a large, connected aquifer the actual reservoir pressure does not decline much when oil is produced, because oil is supplemented with water.

[9] The upper limit of PI sometimes is calculated using a subset of reservoir parameters.

Engineers also consider the ***skin factor***, or simply “skin,” at the near-wellbore portion of the well system. Skin represents damage caused by a variety of factors when drilling and completing a well. A high skin factor results in less productivity from the reservoir.

Well Inputs – Well inputs include ***total depth*** (the planned end of the well, measured by the length of pipe required to reach the bottom) and ***measured depth***. The measured depth of a well is the actual length of the wellbore; unless the well was drilled completely vertical, that measurement will differ from the true vertical depth of the well. Other well inputs include ***pipe internal diameters***, ***pipe roughness*** (usually a measurement of the average height of peaks producing roughness on the internal surface of pipes), and ***pipe ovality*** (referring to the cross-sectional aspect of a pipe compared to perfect circularity). The ***flow path*** of the fluid from the near-wellbore region to the surface is also an important input.

Surface Inputs – Downstream of the wellhead are various surface facilities. In the case of the Well, they included the blowout preventer (the “BOP”) and the riser. Similar to the inputs for the well, the ***flow path, length, pipe internal diameters, pipe roughness,*** and ***pipe ovality*** are important to understand in order to define the surface system. In addition, components such as valves and chokes are typically in the flow path, and a full understanding of the pressure drop versus flow rate correlation is needed for these components.

Environmental Inputs – A description of the environment around the system is important when accounting for heat transfer and flow to the seafloor (as was the case with the Well system). A description of the ***ambient temperature profile*** from the seafloor to the reservoir is necessary to properly describe the system. Other variables important when including heat transfer into the modeling are the ***heat capacity*** and ***thermal conductivity*** of all equipment and sediments. Flow through a well system that is open at one end to the surface is also affected by ***ambient pressure*** (referring to the pressure where the system enters the external environment, which at most points during the *Deepwater Horizon* response was near the seafloor).

Fluid Inputs – Fluid inputs include a fluid’s ***detailed composition***,[10] ***watercut*** (the ratio of water produced compared to the volume of total liquids produced),

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[10] Detailed composition is a listing of all hydrocarbon and non-hydrocarbon molecules that comprise the fluid in its reservoir state. With a composition, fluid models can then be used to describe parameters or the fluid over a wide range of pressures and temperatures.

bubble point (the pressure at which gas first separates from the oil), the ***gas-oil ratio*** (or "GOR"),[11] ***compressibility,***[12] and ***density*** (the mass per unit of volume), among other inputs.

To understand the issues in controversy here, it is not necessary to examine each of the above inputs -- the key point, illustrated by the number of different inputs shown above, is that hydraulic theory applied to a real system is complex, and becomes even more complex as the system is enlarged and tries to take account of conditions from the reservoir to the exit of fluids from the complete system.[13] In addition, owing to the nature of the equations used in hydraulic modeling, relatively accurate inputs are needed in order to get accurate outputs. Due to the nature of the equations involved, the error bands on many input parameters will result in a larger error band in the output of the model. For example, referring back to Figure 1, if the internal diameter ("ID") of the pipe is unknown by up to 10 percent, the resulting flow rate calculation can have an error band greater than 25 percent. This emphasizes the importance of having a clearly defined system in order to produce useful hydraulic modeling results.

B. Overview of Hydraulic Modeling during the *Deepwater Horizon* Response

The first important observation about BP's efforts to use hydraulic modeling during the *Deepwater Horizon* response, which is based on my personal experience, is that the main focus for all involved was to stop the flow from the Well as quickly as possible, while managing risks to human life and the environment.

Consistent with industry contingency planning, the ultimate method of killing the Well was recognized to be a relief well. To achieve the goal of shutting in the Well as quickly as possible, and due to the timeline for drilling a relief well, federal officials, BP, and others undertook several efforts to stop or contain the flow from the Well until a relief well could be completed. The overarching remit

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[11] GOR is the ratio of the volume of gas to the volume of oil for a reservoir sample of hydrocarbon that is brought to the surface.

[12] Compressibility describes the pressure-volume relationship of a fluid (both gas and oil) and describes the expansion of fluid as pressure drops.

[13] The list in the text above is by no means a complete list of all factors and inputs used in hydraulic modeling of oil and gas systems.

was that any effort to stop or contain the flow from the original Well should not make the situation worse.

Of course, any attempt to stop or contain the flow had potential downsides, such as potentially increasing the flow from the Well, or preventing other source control options from being effective. One of the many ways in which the downsides of different source control options were evaluated during the *Deepwater Horizon* response was through hydraulic modeling.

In that respect, Dr. Wilson is correct in quoting my colleague, Mr. Simon Bishop, as saying that modeling was used "to assess the robustness of a number of operations associated with source control."[14] However, Dr. Wilson's report presents an incomplete picture of how the hydraulic modeling work during the response proceeded.

First, Dr. Wilson's report asserts that "BP engineers and their contractors doing the modeling appear to have had access to almost unlimited resources, except for the urgency of time."[15] In fact, very few engineers at BP or in the industry had the ability to work with the more complex hydraulic models that were used during the *Deepwater Horizon* response.[16] Those who could do the work frequently lacked the time to fully document their assumptions and the purposes of the modeling they performed.

Second, Dr. Wilson's report suggests an imbalance in access to data useful in hydraulic modeling. Dr. Wilson's report states that "BP engineers and their contactors had access to proprietary data regarding the reservoir and the engineered infrastructure of [the Well]," and that "BP engineers knew or had high-quality estimates of the reservoir, fluid properties and the engineered

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[14] Bishop Tr. at 95:7-9 (quoted in Wilson Report, p. 5, note 7). In general, the models to which Dr. Wilson's report refers (Wilson Report, p. 6-8) can be grouped into four categories: (1) steady-state multi-phase hydraulic simulators (such as PipeSim and PROSPER), (2) transient multi-phase hydraulic simulators (such as OLGA, OLGA-ABC, OLGA Well Kill, and WELLCAT), (3) general hydraulic simulators called computational fluid dynamic (or "CFD") models, and (4) the material balance reservoir simulator called MBAL.

[15] Wilson Report, p. 6.

[16] Tooms Tr. at 244:5-246:15.

infrastructure."[17] Dr. Wilson's report does not acknowledge BP's effort to provide the federal responders with the data needed to perform hydraulic modeling. BP provided pressure data from the same instrument at the base of the BOP, called "PT-B," that its engineers used.[18] BP also shared other data useful in hydraulic modeling with the scientists and engineers representing the government at the Houston ICP.[19]

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[17] Wilson Report, p. 6.

[18] For example, Dr. Wilson's report states that "BP engineers and their contractors had estimates and/or measurements" of pressure. (Wilson Report, p. 8.) But Dr. Wilson's report does not state that the record shows BP shared estimates and/or measurements of pressure with United States government personnel during the *Deepwater Horizon* response. See, for example, LAL137-015769 (May 8, 2010 e-mail from Federal Science team member A. Slocum noting availability of pressure measurements from the subsea PT-B instrument); IES009-015948 (May 9, 2010 e-mail from B. Domangue of MMS forwarded to Secretary Salazar containing PT-B pressure gauge readings); SNL115-005716 (May 12, 2010 e-mail transmitting PT-B pressure reading to government scientists); SNL066-012412 (May 13, 2010 e-mail transmitting PT-B pressure reading to government scientists); DSE029-000834 (May 16, 2010 email correspondence among government scientists listing current PT-B pressure readings); SNL116-006885 (May 17, 2010 e-mail attaching PT-B data summary from May 8 to May 16 and an overview of the pressure measurement system); DSE029-001309 (May 23, 2010 e-mail discussion among government scientists regarding PT-B pressures); DSE031-002643 (May 28, 2010 e-mail among government scientists attaching Top Kill diagnostics including PT-B pressures).

[19] In addition to the pressure data provided to the federal responders (see note 18 above), other data that BP provided to government personnel during the response and shared with government personnel included temperature measurements and fluid properties information. See, for example, Hughes Tr. at 277:13-25 (explaining the ability to view live video feed of temperature measurements taken by ROVs in the HIVE (the ROV control room)) and Hunter Tr. at 74:14-75:17 (discussing government personnel's access to live ROV footage during the response); S2S006-000802 (April 30, 2010 e-mail providing fluid properties data to NOAA); Ex. 9636 (May 1, 2010 e-mail reflecting MMS knowledge of reservoir characteristics); Ex. 8995 (same); BP-HZN-2179MDL04394208 (May 1, 2010 e-mail providing reservoir characteristics to MMS); BP-HZN-2179MDL03313230 (May 6, 2010 e-mail transmitting rotary core

Third, Dr. Wilson's report suggests that BP had "high-quality estimates" concerning the "engineered infrastructure" of the Well useful in hydraulic modeling after the blowout. Such a view is incorrect, if the relevant timeframe is April and May 2010. Until the original Well was intercepted by a relief well in August 2010, important features of the wellbore, including the flow path of oil from the reservoir to the BOP and out the riser on top of the BOP, were unknown.

Dr. Wilson's report states that the accident on the *Deepwater Horizon* "*could have* damaged [the] architecture" of the Well;[20] but there is no legitimate dispute that the explosion and later collapse of the rig did in fact damage what Dr. Wilson's report calls the "engineered infrastructure" of the Well. Dr. Wilson's report concedes "some uncertainty" about the relevant condition of the Well.[21] [redacted]

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analysis and PVT information to MMS); LNL083-000351 (May 6, 2010 e-mail transmitting fluid properties information to National Labs); IMT911-014001 (May 7, 2010 e-mail discussion of MMS analysis of reservoir properties from analog wells in the Gulf of Mexico); LAL013-021351 (May 10, 2010 e-mail sending GOR and bubble point information to National Labs); SNL008-018879 (May 11, 2010 e-mail discussion among government scientists regarding plume temperature measurement); LAL019-000583 (May 12, 2010 e-mail transmitting temperature estimate of 150-200F to government scientists); BP-HZN-2179MDL01951916 (C. Cecil notes summarizing transmission of data, including PVT properties, to scientists from National Labs between May 13 and May 18, 2010); LAL013-012807 (May 14, 2010 e-mail acknowledging National Lab scientists received PVT data); LAL013-013023 (May 16, 2010 e-mail among National Labs scientists discussing black oil tables); IMT911-014188 (May 18, 2010 e-mail transmitting Pencor PVT data to MMS); LAL013-020344 (May 24, 2010 e-mail transmitting fluid properties data and EOS to National Labs); ORL001-000271 (May 24, 2010 e-mail transmitting Pencor PVT data and a sidewall core report to MMS and National Labs scientists); NOA016-001452 (May 25, 2010 e-mail transmitting Pencor PVT data to NOAA); PNL001-032329 (May 27, 2010 circulation of Pencor PVT data among National Labs scientists); IMW028-020971 (May 28, 2010 e-mail noting MMS access to Pencor and Schlumberger PVT data); ORL003-006587 (May 28, 2010 e-mail distributing reservoir data to government scientists); PNL001-032991 (May 28, 2010 e-mail noting National Labs scientists use of Schlumberger PVT data).

[20] Wilson Report, p. 6 (emphasis added).

[21] Wilson Report, p. 6.

[redacted]

[redacted]

[redacted]

When Dr. Wilson's report refers to "typical inputs" and "typical outputs" of various "conventional" hydraulic models, his report should have also acknowledged that nothing was "typical" about the system being modeled during the *Deepwater Horizon* response.[22] None of the "conventional" models to which Dr. Wilson's report refers were designed or validated for use with a system as insufficiently defined as the Macondo Well following the blowout on April 20, 2010.[23] Dr. Ole Rygg, an expert in hydraulic modeling who had access to what Dr. Wilson's report calls a "capable software package specifically programmed to model difficult … flow situations" stated that there were too many unknowns to precisely estimate the simulation of flow rates.[24]

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[22] Wilson Report, pp. 6, 7.

[23] For example, many of the "conventional" models had to represent an important feature of the Well system -- the system's restrictions on flow -- as circular "orifices" of various sizes. See Appendix C.

[24] At his deposition last fall, Dr. Rygg testified as follows in response to questions from the Plaintiffs' Steering Committee: "I -- in -- in all my calculations and modeling, I found there was too many unknowns to -- to precisely estimate from the simulations any flow rates;" "I believe I don't have enough information on the flow configuration and -- and input to estimate from the modeling the

Finally, it is noteworthy that the federal responders, with their own access to hydraulic models (as well as data for use in such modeling (see notes 18 and 19 above)), did not offer any single-point estimate or range of estimates of daily discharge from the Well using hydraulic modeling during April or May 2010. The first report of the U.S. government's Flow Rate Technical Group ("FRTG"), released on May 27, 2010, presented daily flow rate estimates ranging from 12,000 to 19,000 bopd, but none of those estimates used any of the "conventional" hydraulic models identified in Dr. Wilson's report, or any other type of hydraulic modeling.[25]

Given the unknown features of the Macondo Well system in April and May 2010, what was the purpose of the hydraulic modeling performed by BP and its contractors in that timeframe? Broadly stated, the hydraulic modeling by BP and its contractors had two main purposes:

1. One purpose of the hydraulic modeling was to determine how a given event or source control strategy could potentially increase the flow of oil from the Well. One example of such modeling is the hydraulic modeling performed to determine, on a rough percentage basis, how much the cutting of the riser from the top of the BOP would temporarily increase discharge from the Well[26] -- a step deemed appropriate by the Unified Command in order to permit the installation of the Top Hat oil collection system.[27] A different example of such modeling, used to evaluate risks to the overall source control effort, is illustrated in Figure 1 of Dr. Wilson's report.[28] There, Dr. Rygg modeled potential discharge rates from the Well as if there were no BOP on top of the wellhead.[29]

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flow rate." Rygg Tr. at 190:20-192:3.

[25] See Flow Rate Group Provides Preliminary Best Estimate Of Oil Flowing from BP Oil Well; available at http://www.restorethegulf.gov/release/2010/05/27/flow-rate-group-provides-preliminary-best-estimate-oil-flowing-bp-oil-well (last visited June 6, 2013).

[26] Ballard Tr. at 61:23-63:4.

[27] Ex. 9675, Stipulations ¶¶ 90-92.

[28] Wilson Report, p. 9.

[29] Figure 1 presents six different "oil rates" -- three with a "back pressure" of 3800 psi (consistent with the pressure measured at the bottom of the BOP in early

2. Another purpose of the hydraulic modeling performed by BP and its contractors during the *Deepwater Horizon* response was, as Mr. Bishop stated (see p. 9 above), to evaluate the "robustness" of a given source control strategy against a variety of possible discharge rates, pressures, or temperatures. Dr. Rygg, for example, was retained to use his hydraulic models to determine the highest possible flow rates that a relief well might encounter, in order to assess whether the systems available to perform a "bottom kill" through the relief well could accommodate those flow rates.[30] Similarly, in my work on the CDP project, I had to determine whether the risers that would be used to collect oil from the Well to the containment vessels were designed properly to handle the flow rates and pressures they might encounter.[31]

Given the purposes of the hydraulic modeling performed by BP and its contractors, the calculation methodology employed during the April-May 2010 period was usually applied in one of three different ways, outlined below.

May 2010) and three with "back pressure" of 2244 (consistent with the pressure that would be exerted on the wellhead if the BOP were absent). While the precise scenario of concern is not spelled out in Figure 1 or explained in the record, Dr. Rygg's results would have been useful in showing what would happen if, for example, the *Deepwater Horizon* BOP had to be removed from the wellhead for some reason, or if the BOP fell from the wellhead as a result of a catastrophic event such as a subsea broach. Concerning the risks of subsea broach, see Expert Report of Mr. Dan Gibson, May 10, 2010, pp. 1, 25, 28, 32. It is important to note that none of the rates contained in Figure 1 were, according to Dr. Rygg's testimony quoted above, reliable estimates of daily flow rates from the Well. (See note 24 above.)

[30] Rygg Tr. at 53:1-54:9; 83:5-20 (describing "bottom kill"). A "Dynamic Kill Technical File Note" describes Dr. Rygg's modeling results of 43,000 bopd, 63,000 bopd, and 87,000 bopd as the result of simulations "for worst case dynamic kill requirements, which means no restrictions in the flow path (i.e., downhole gravel pack, the effects of the wash string, flow choking across the subsea BOP rams, etc.) and no underground blowout. Ex. 10603 at WW-MDL-00143673-74.

[31] Ballard Tr. at 306:14-307:22.

- ***"Sensitivity" calculations*** presented discharge rates essentially as functions of some other condition or feature of the well system. The goal of this calculation was to assess the sensitivity of flow rate to various input parameters. The results were often shown in Cartesian plots in which a discharge rate was shown as a variable (one of many unknown variables in the relevant time period) versus another variable.[32] By definition, such calculations were not intended to estimate daily discharge rates from the Well, and they implicitly recognized that conditions were too uncertain to estimate such rates in a reliable manner.

- ***Relative impact calculations*** were performed to understand how the discharge rate might change based on the change of another variable. Parametric studies (the sampling of inputs into models) were typically performed under a given set of conditions and then, with a single input parameter changed, the parametric study was re-run. This type of analysis provided an understanding of relative change in flow rate from the well under certain conditions. Examples of such calculations are shown in Figures 1 and 10-12 of Dr. Wilson's report in which the modelers posit removal of the *Deepwater Horizon* BOP from the wellhead.[33]

- ***Assumed studies*** used a given flow rate in order to determine a key feature or characteristic of a flowing system (relevant to a source control

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[32] An example of such work is Ex. 9446, in which my colleague, Dr. Tim Lockett, depicted discharge rates as functions of temperatures, pressures, and velocities in the well. As Dr. Lockett testified at his deposition, his work was intended to explore how data concerning fluid, velocity, temperature, and pressure could potentially be linked in order to estimate flow rates from the Well. Lockett Tr. at 155:5-20; Ballard Tr. at 118:4-20.

Contrary to Dr. Wilson's suggestion (Wilson Report, p. 20), in using the term "best estimate" to describe the work reflected in Ex. 9446, Dr. Lockett was not denoting his results as a reliable prediction of flow from the Well. As Dr. Lockett testified, a best estimate of flow could only be derived when there is corroboration between the different methods of estimating flow. Lockett Tr. 156:3-16. Dr. Lockett's work shown in Ex. 9446 showed no such corroboration.

[33] See note 29 above.

effort) using a hydraulic model. An example of such an assumed study would be an evaluation of the pressures that would be encountered in a system that was "producing" oil from the blowout to a vessel on the surface that would collect the oil for transshipment and disposal, which was one type of analysis that I performed at the Houston ICP. Another example of such an assumed study, to which Dr. Wilson's report refers, was the project assigned to a BP contractor called Stress Engineering, which used hydraulics-based models in May 2010 to assess the upward force of a plume of oil coming from the top of the *Deepwater Horizon* BOP if a portion of the BOP were removed.[34]

C. Review of Specific Hydraulic Workstreams in the *Deepwater Horizon* Response

I accept for purposes of this section of my report the delineation of "four different workgroups within BP" that, according to Dr. Wilson, were using hydraulic modeling in the April-May 2010 timeframe.[35] I review each of Dr. Wilson's comments on those four workgroups below.

1. Reservoir Team

I disagree with the statement in Dr. Wilson's report that "BP began modeling the flow from the Well immediately following the blowout."[36] To the

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[34] Contrary to the claim in Dr. Wilson's report (see Wilson Report, pp. 11-12), 70,000 bopd is not a "best estimate" of the daily discharge from the Well. Holt. Tr. at 266:2-270:22. The initial plan was for Stress Engineering to run sensitivity studies for assumed flow rates of 5,000, 10,000, 20,000, 40,000, 80,000, and 160,000 bopd. Given the significant length of time (10-12 hours) required to complete each modeling run, a case of 70,000 bopd, a number near the midpoint of the range of assumed flow rates, was selected as the first case. Stress Engineering was then asked to run cases of 35,000 and 17,500 bopd, reducing the total number of cases to be run (and computation time) by half. Ex. 9629. The results of the Stress Engineering modeling were shared with a group that included personnel from Transocean, Cameron, Oceaneering, and Wild Well Control. TRN-MDL-02950206-07.

[35] Wilson Report, p. 7.

[36] Wilson Report, p. 13.

contrary, BP engineers modeled potential discharge rates from the Well long before the blowout, in 2009, when the Company filed its Exploration Plan ("EP") for the Macondo Well. BP reservoir engineers used PROSPER, one of the hydraulics models listed in Dr. Wilson's report, to estimate what the governing federal regulations call a "worst case discharge" (or "WCD") for the Well they intended to drill at the Macondo prospect.[37] That model produced a worst case estimated discharge of 162,000 bopd.

The worst case discharge estimate for the Well prepared by the BP reservoir team assumed a blowout at the sea floor in the absence of any restriction by a BOP or a riser, with no drill string in place, and with no sand bridging in the wellbore.[38] The only restriction to flow used in BP's WCD estimate for the Well was "hydrostatic pressure," referring to the downward pressure of seawater over the wellbore and which was assumed to be 2270 psi.[39]

An estimate of a daily discharge rate prepared before a well has been spudded, and that assumes truly extreme conditions like those used to calculate a regulatory worst case discharge scenario, is not an estimate of the actual flow rate for the Macondo blowout.[40] As Admiral Allen, the National Incident Commander for the *Deepwater Horizon* response, stated at his deposition, he "would...differentiate ...worst case discharge from flow rate."[41]

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[37] 30 CFR § 254.47(b) (2012); BP-HZN-2179MDL00001000.

[38] Gansert Tr. at 56:10-58:18; 217:3-13.

[39] Ex. 10007 at BP-HZN-2179MDL05729013.

[40] The Wilson Report may instead intend to support its claim that the reservoir group "began modeling the flow from the Well immediately following the blowout" (Wilson Report, p. 13) by reference to the update of the pre-drilling WCD estimate of 162,000 bopd prepared on April 21, 2010. If so, Dr. Wilson's report is still incorrect, because there was no identifiable flow from the Well on April 21, insofar as the rig remained on the surface with the riser intact. The *Deepwater Horizon* did not sink until April 22, at which time oil was found to be flowing from the sunken riser. Ex. 9675, Stipulations ¶¶ 26-27. The same may be true of the open hole flowing calculation attributed to Alistair Johnston, performed on or before April 22, 2010. Ex. 8656; see Wilson Report, p. 32.

[41] Allen Tr. at 685:3-4.

A key fact about the reservoir team's worst case discharge estimate, which Dr. Wilson [redacted] ignore, is that the WCD estimate became the daily discharge rate used by the federal government in the *Deepwater Horizon* response. As Admiral Allen testified, he was "skeptical" about the early numerical discharge estimates after the *Deepwater Horizon* sank.[42] Referring to the WCD value of 162,000 bopd in the 2009 Macondo EP, along with an even higher WCD estimate contained in BP's 2009 Regional Oil Spill Response Plan,[43] Admiral Allen testified:

> "And, frankly, I told my people to -- to focus on the response, getting the equipment out there, assuming the worst case scenario, and the numbers would take care of themselves. And ultimately, I told them it would be decided in Court."[44]

Neither the actual flow from the Well, nor any of what Dr. Wilson calls "modeled flow rates" in April or May 2010, exceeded the worst case discharge estimate prepared by the BP reservoir team in 2009. I therefore do not agree with Transocean's experts that any failure by BP to publish lower discharge estimates could have had any impact on the overall conduct of the *Deepwater Horizon* response.

2. Flow Assurance Team

I also disagree with Dr. Wilson's review of hydraulic modeling by BP flow assurance engineers[45] whose work consisted mainly of the types of "sensitivity calculations" that I have previously outlined (see p. 15 above). None of that work was intended to estimate a single-point daily discharge rate or a range of such rates.

Dr. Wilson's opinions about the work of the flow assurance team (in which I was to some extent personally involved) are confusing and incorrect, because he either does not understand or does not explain some of the basic features of the

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[42] Allen Tr. at 210:9.

[43] Ex. 769.

[44] Allen Tr. at 210:20-25.

[45] Wilson Report, pp. 18-21.

relevant modeling. For example, his analysis would lead a reader to believe that, when hydraulic modelers refer to "orifices" that are depicted as fractions of an inch or as a very small number of inches in size, the real-world system they are modeling has restrictions that are actually the same size as the modeled orifices. That is incorrect: an "orifice" in a hydraulic model is not intended to depict the area of an opening in the actual system, but is intended to be used as an input to indicate restriction to flow.[46] What Dr. Wilson calls "small" orifices were included in the modeling in order to simulate a number of features in the well system that were creating resistance to flow, not to depict the actual area of a restriction in the well system through which oil could reach the sea.

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[46] To understand Dr. Wilson's error, one can start with a specific example in his report. In discussing some work that he attributes to the reservoir team, Dr. Wilson states as follows:

> "[T]he restrictions necessary at the wellhead to generate flow rates of only 5,000 or 10,000 BOPD were quite severe for modeled conditions. The shallow choke required an orifice with a diameter of only 0.355 and 0.52 inches, respectively. Given that the riser was approximately 19 inches in diameter, and its internal pipe was approximately six inches in diameter . . . even when kinked over, such a small orifice is unlikely."

Wilson Report p. 16. Dr. Wilson's statement suggests that, in the work he is describing, the modelers intended to simulate flow through a "real" orifice (or restriction) having an area of only 0.355 to 0.52 inches. That is not correct, as Dr. Wilson should know if he understands the hydraulic models that he is discussing in his report. As explained in Appendix C of this report, the "orifice" in the relevant models is a theoretical opening in the system (a perfect circle) used to create resistance to flow. The *circumference* of the circular opening in the model, and not its area, is critical, because the circumference of an opening (among other variables) in a fluid system determines the resistance to flow through the opening. (See Appendix C.) Dr. Wilson's references to orifices with very small area are meaningless at best, and could mislead a reader into believing that BP engineers assumed unrealistic conditions in the well system.

Dr. Wilson also demonstrates a lack of understanding of specific features of at least one model he discusses, the OLGA model. Dr. Wilson assumes that when Dr. Lockett (one of the senior members of the flow assurance group) reported on May 14, 2010, that some of Dr. Lockett's modeling was showing "values [that] are not credible" when compared with visual observations, Dr. Lockett is stating that specific flow rates for the Well were unrealistically low.[47] Dr. Lockett was not, however, reporting on a continuous discharge rate from the Well; he was commenting on whether his visual observations were consistent with the instantaneous momentum of fluids that could be predicted by a specific option in the OLGA model called "slug-tracking." Based on my knowledge of OLGA, the OLGA model was likely producing results that seemed not credible because the slug-tracking option was not accurately depicting the instantaneous momentum of fluids in an unconventional system like the Well that Dr. Lockett visually observed in the oil plume.

Finally, with respect to the May 3, 2010 "best estimate" work by Dr. Lockett, Dr. Wilson's report presents a significantly inaccurate account of Dr. Lockett's work.[48] Dr. Lockett was examined at great length on his use of hydraulic models at his deposition in 2012. As he explained, through May 2010, BP had limited information from which it could model flow from the Well.[49] For example, Dr. Lockett testified that information was not available on the flow path, inflow performance of the well, restrictions in the BOP stack, the degree of restriction posed by the kink, and whether there had been any collapse of the formation.[50]

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[47] Wilson Report, p. 21.

[48] See note 32 above.

[49] Lockett Tr. at 84:9-85:8.

[50] Lockett Tr. at 84:9-85:8. Dr. Wilson's report also does not deal accurately with Dr. Lockett's testimony in other respects. Wilson Report, pp. 29-30 (discussing Dr. Lockett's skepticism about Dr. Rygg's use of a 5,000 bopd discharge estimate in pre-Top Kill modeling). As Dr. Lockett explained at his deposition, when he initially reviewed Dr. Rygg's pre-top kill modeling, Dr. Lockett incorrectly believed that Dr. Rygg had only conducted simulations using the 5,000 bopd case. Lockett Tr. at 269:14-25. Dr. Lockett did not know the origin of the 5,000 bopd estimate which, as he testified, was why he was skeptical of the estimate. Lockett Tr. at 269:14-25. Dr. Lockett also testified that a 5,000 bopd estimate could have been valid based on another estimation method. Lockett Tr. at 270:17-271:23. Based on my review of the relevant materials, I have concluded

Neither Dr. Lockett nor any other member of the flow assurance team believed that they could reliably estimate daily discharge rates from the Well using hydraulic models in April and May 2010.[51]

3. Production Engineering Team

Dr. Wilson's excerpts from the work of another group of engineers that he calls the "Production Engineering Modeling" team[52] demonstrates the point that in April and May 2010, hydraulic modeling could not reliably estimate the flow rate from the Well. For example, Figure 11 in the Wilson Report is taken from a large parametric study that varied several different potential (and unknown) conditions in the Well system in a scenario in which the restriction on flow attributed to the BOP and riser in early May 2010 would be lost.[53] The outputs from this single excerpt from the parametric study range from 21,000 to 82,000 bopd when the BOP is present, and from 24,000 to 96,000 bopd when the BOP is not present. The only claim that the modelers could make from their outputs is, not surprisingly, that a loss of the BOP and the restrictions on flow that it and the riser created would increase flow from the Well.[54] Dr. Wilson reads another document that he

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that the estimate of 5,000 bopd, announced earlier in the Macondo response at the Unified Area Command ("UAC") headquarters in Louisiana, was not based on hydraulic modeling. For that reason it is not surprising that Dr. Lockett, a hydraulic modeler based at BP's offices in Sunbury in the United Kingdom, was unfamiliar with the origins of the 5,000 bopd estimate announced at UAC headquarters. Dr. Lockett's concern was that Top Kill should be modeled against a broader range of flow rates than just 5,000 bopd -- which is what Dr. Rygg did. Lockett Tr. at 272:3-11; AE-HZN-2179MDL00132194.

[51] Tooms Tr. at 319:4-9 (no attempt by flow assurance team headed by Mr. Tooms to estimate daily discharge rates until July 2010).

[52] Wilson Report, p. 21.

[53] The presentation by the Production Engineering Team is contained in Exhibit 9156. As explained above, (see note 29), the modelers may have been asked to assume that a particular source control option would have required removal of the BOP and riser, or that the BOP and riser would otherwise separate from the wellhead.

[54] The intent of the study that Dr. Wilson is discussing was to try to predict the percentage increase in flow if the wellhead experienced a significant drop in

attributes to the "Production Engineering Modeling" team in a manner intended to discredit what he considers low estimates of flow from the Well. Referring to Figure 13 of his report, Dr. Wilson asserts that a 5,000 bopd estimate could be produced by the Production Engineering Modeling team only by using hydraulic models that posited what Dr. Wilson calls "low" permeability, a "minimal" reservoir thickness, and a "large skin."[55] Dr. Wilson's background is in hydrology. He asserts no expertise in reservoir engineering. I am unaware of any opinion offered by Transocean that conclude the conditions depicted in Figure 13 of Dr. Wilson's report were unrealistic at the time when the modeling was performed. Based on my review, Dr. Wilson does not appear qualified to determine "minimal" reservoir thickness, "large" skin, or any other feature of the well system to which he would apply a qualitative value in the absence of relevant data.

4. Hydraulic Modeling by Other Parties

Dr. Wilson's review of hydraulic modeling by BP contractors warrants a brief response. Dr. Wilson devotes attention to the hydraulic modeling performed using the OLGA suite of models, which he claims in one scenario to have "yielded a flow rate of 146,000 BOPD," while another (according to his report) resulted in a "blowout rate" of 37,000 to 87,000 bopd.[56] But Dr. Wilson does not address the testimony by Dr. Rygg, the individual who was performing the OLGA modeling, stating that it was impossible for Dr. Rygg to reliably predict or estimate the flow rate for the Well with the information available to him during the response.[57]

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pressure. This is made clear on one slide in Exhibit 9156 that Dr. Wilson omits. See Ex. 9156, BP-HZN-2179MDL04808634 ("Flow increases by 13-31% when wellhead pressure drops from 3800 psi to 2270 psi.").

[55] Wilson Report, p. 13. The 37,000 to 87,000 bopd range was generated from simulations for "worst case dynamic kill requirements." (See note 30 above.)

[56] Wilson Report, p. 17.

[57] Rygg Tr. at 191:16-19 ("[I]n all my calculations and modeling, I found that there was too many unknowns to -- to precisely estimate from the simulations any flow rate."); 211:23-212:8 (" . . . But there was -- there were too many unknowns, that the model could give me any exact numbers on flow rates."). As elsewhere in his report (see note 46 above) Dr. Wilson does not explain the meaning of the orifice sizes in hydraulic modeling, in this case making it appear that Dr. Rygg used an unrealistically "small 0.73 orifice" in his modeling with a version of the OLGA hydraulic model.

Dr. Wilson's other references to specific modeling by third parties are merely illustrations of what I term above "assumed studies" (see p. 16). Stress Engineering[58] assumed a specific set of discharge rates and did not calculate a flow rate.[59] Dr. Wilson's discussion of Halliburton's use of a proprietary hydraulic model[60] only shows that BP did not interfere with Halliburton's decision to use an assumed flow rate of 30,000 bopd, in cement work that was never undertaken.[61]

D. Applications of Hydraulic Modeling to Top Kill

[redacted] In addition to that other expert's analysis, it is worth noting that the hydraulic modeling performed by Dr. Rygg, which indicated that momentum kill would not work at conditions that Dr. Rygg translated to 15,000 bopd, assumed near worst case conditions in the Well system for purposes of the momentum kill. Specifically, Dr. Rygg chose a deep choke and annular flow, both of which would have made it more difficult for momentum kill to overcome pressures in the Well system.[64] This worst case condition approach is consistent with many other modeling exercises during the response.

[redacted]

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[58] Wilson Report, pp. 11-12.

[59] See note 34 above.

[60] Wilson Report, pp. 25-26.

[61] Wilson Report, pp. 25-26; Expert Report of Iain Adams, May 10, 2010 pp. 8-9 (explaining that the addition of the junk shot portion of the Top Kill procedure increased the likelihood of success at potential flow rates in excess of 15,000 bopd).

[62] [redacted]

[63] [redacted]

[64] Ex. 8537.

[65] [redacted]

[redacted]

III. Conclusion

The opinions that I have expressed in this report are based on my education, training, and experience, and my review of materials in connection with this proceeding. While I have done my best to review materials in this matter as they have become available, I reserve the right to supplement my opinions based on my review of additional information or reports.

Adam L. Ballard, Ph.D.

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66 [redacted]

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Current Position: BP – GoM DWP – Special Projects

- 7/2012-10/2012 – BP – GoM – Legal – **30(b)(6) Company Witness**. BP representative in regards to Flow Rate Estimates from the Macondo Well. Prepared with Legal team for 2 day deposition from Department of Justice, States, and Companies involved in Macondo Civil Trial.
- 5/2009-1/2013 – BP – GoM DWP – Thunder Horse – **Engineering Manager / AESTL**. Managed a multi-discipline team (23 BP – 13 contract) to perform all engineering of Production, Utilities, and Marine systems. Accountable for process safety, operability, and compliance of the Thunder Horse field (wells, subsea, and topsides). Responsible for delivering and maintaining operation philosophy, strategy, and procedures of each production system.
- 1/2008-5/2009 – BP – GoM DWP – Thunder Horse – **Lead Flow Assurance Engineer**. Accountable for all multi-phase operability, production chemistry, and internal corrosion and erosion of the Thunder Horse field. Duties include leading a multi-discipline team to deliver all Flow Assurance monitoring and readiness associated with Thunder Horse base project, temporary first-oil system, tie-back opportunities, and water injection system. Responsible for delivering operation philosophy, strategy, and procedures of each production system. Project Manager for Thunder Horse intelligent pigs ($16mm program and fully delivered).
- 1/2007-12/2007 – BP – GoM DWP – Thunder Horse – **Flow Assurance and Subsea Systems Coordinator**. Duties include coordination of all Flow Assurance and Subsea activity associated with Thunder Horse base project, temporary first-oil system, and tie-back opportunities.
- 7/2005-12/2006 – BP – GoM DWP – Thunder Horse – **Facility/Subsea/Flow Assurance Engineer**. Duties included support of facilities, subsea flow assurance, and start-up operations.
- 2004-2005, BP – GoM DWP – JV/Pompano – **Offshore Operations Engineer**. Duties included process optimization, integrity management, and on-site operations support in fighting daily issues.
- 2003-2004, BP – EPTG – Base Management – **IAM/Flow Assurance Engineer**. Duties included full field Integrated Asset Modeling (IAM) and transient gas lift analysis. Wrote *BP Hydrate Plug Remediation Guidelines* for safe removal of hydrate plugs in pipelines, wells, risers, and equipment. Wrote *Subsea Tie-Back Hydrate Risk and Cost Analysis* for evaluating hydrate risk in design of subsea flowlines.
- 2002-2003, BP – EPTG – Facilities and Topsides – **Flow Assurance Engineer**. Duties included steady-state and transient simulation studies for flowline and riser insulation selection (thermal performance), slugging, shut-down, start-up, well clean-up, and hydrate management and mitigation.
- 1998-2002, **Research Assistant** for Dr. E.D. Sloan, Jr. in the Center for Hydrate Research at the Colorado School of Mines
- 2001, **Consultant** for Dr. E.D. Sloan, Jr. in the preparation of flow assurance short course
- 2001, **Consultant** for Shell in state-of-the-art methods for detection of plug location

- 2000, **Consultant** for ABB Consulting in power cycles involving natural gas hydrates
- 1999, Produced **commercial software (CSMGem)** used for the prediction of natural gas hydrate equilibria
- 1998, **Consultant** for Arco Exploration and Production in the modeling of a natural gas mixture in preparation for conducting hydrate equilibrium data experiments
- 1998, **Consultant** for Mobil Oil in the mathematical modeling of propylene glycol for the inhibition of natural gas hydrates
- 1997-1998, **Taught** Chemistry Lab and Fortran programming course at Colorado School of Mines

EDUCATION:

- **Ph.D. Chemical Engineering**, Colorado School of Mines March 2002
  Research area: Thermodynamics of Phase Equilibria involving Natural Gas Hydrates
  Minor: Applied Mathematics Tracks: Thermodynamics, Transport Phenomena
  GPA 4.0/4.0

- **B.S. Mathematics,** Willamette University, Salem, OR December 1996
  2^{o} Studies: Chemistry, Physics
  Research interest: Optimization Theory, Hyperbolic Geometry
  GPA 3.5/4.0

Self-financed 100% educational expenses

RELEVANT COURSES AND TRAINING:

- BP Managing Operations (Cadre 16 - July 2011)
- BP Engineering Management (EM6 - February and December 2010)
- BP Projects and Engineering the BPWay (April 2009)
- Ariel Compressor School (2005)
- University of Ohio CO_2 Corrosion in Multiphase Flow (2005)
- Petroleum Experts Training (PROSPER, GAP, MBAL) (2003)
- Risk, Optimization, and Options (2003)
- Production Engineering (2002)

Complete Listing of Courses Available Upon Request

COMPUTER SKILLS:

Programming Languages:
Visual Fortran Visual Basic Visual C++ Matlab

Thermodynamic Software:
CSMGem Multiflash PVTsim GUTS
HWHydrate DBRHydrate

Multi-Phase Flow Software:
OLGA2000 Pipesim2000 WellCat ASPEN
PROSPER GAP MBAL HYSYS

Other Software:
AutoCad MSOffice MSProject MSAccess

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17. Ballard, A.L., Shoup, G.J., & Sloan, E.D. (2010) Industrial Operating Procedures for Hydrate Control. Natural Gas Hydrates in Flow Assurance, Edited by E.D. Sloan, C. Koh, and A.K. Sum, Elsevier, 145-162
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PATENTS:

- Joint Inventor for "*Subsea Pressure Relief Devices and Methods*." Franklin, Oldfield, Pabon, Ballard, Gulgowski. #13/470,793. 5/14/2012
- Joint Inventor for "*Marine Subsea Free Standing Riser Systems and Methods*." Shilling, Kennelley, Franklin, Corso, Ballard, Thethi, Nguyen, Hatton. #13/156,258. 6/8/2011
- Joint Inventor for "*Marine Subsea Assemblies*." Shilling, Gulgowski, Kennelley, Greene, Franklin, Corso, Maule, Oldfield, Ballard, Steele, Wilkinson, Thethi, Nguyen, Hatton. #13/156,224. 6/8/2011

- Primary Inventor for "*Method for Remediating Flow-Restricting Hydrate Deposits in Production Systems.*" Ballard, McMullen, Shoup. #12/082,742. 4/14/2008

HONORS and RECOGNITION:

- Overall Winner of the *2009 BP Tallow Chandler's Award for Excellence in the Innovation and Application of Technology*

PRESENTATIONS:

- April 2011, BP GoM Hydrate Workshop, Houston, TX
- 2007, 2005, 2003, 2002, BP Flow Assurance Network Forum, Houston, TX
- March 2007, NACE Corrosion Conference and Expo, Nashville, TN
- May 2006, OTC, Flow Assurance Special Session, Houston, TX
- February 2004, ASME/API/ISO Gas Lift Workshop, Houston, TX
- October 2003, PIPESIM User Group Meeting, Houston, TX
- September 2003, PennWell Flow Assurance Forum, Galveston, TX
- 1998-2002, semi-annual presentations to Colorado School of Mines hydrate consortium of 10 oil companies, Golden, CO
- May 2001, 9th International Conference on PPEPPD, Kurashiki, Japan
- November 2001, AIChE Meeting, Los Angeles, CA
- June 2000, 14th Symposium on Thermophysical Properties, Boulder, CO
- July 1999, 3rd International Conference on Gas Hydrates, Salt Lake City, UT

PROFESSIONAL ACTIVITIES:

Industry

- Article Reviewer for Journal of Petroleum Science and Engineering (2007-present)
- Deepstar Flow Assurance Committee Chairman (2008-2010)
- Member of SPE Projects, Facilities, and Construction Advisory Committee (2006-2012)
- Member of SPE Distinguished Lecturer Committee (2007-2008)
- Advisor to API E&P Standards Committee for developing Best Practice Recommendations for the Application of Dynamic Simulation Techniques - **API RP 19G11** (2007-2011)
- Member of American Chemical Society (11 years), American Institute of Chemical Engineers (10 years), Society of Petroleum Engineers (10 years), NACE (3 years)

BP Specific

- Coordinator and Instructor of Gulf of Mexico Flow Assurance Course (2007-2008)
- Instructor on Hydrates at PE Advanced Development Program School (2006-2011)
- Co-Chair BP Flow Assurance Network Forum session on Subsea Tie-Back Risks, September 2003

OTHER ACTIVITIES/AFFILIATIONS:

- Volunteer Sunday School Teacher for Grace Fellowship UMC (4 year olds, 3 year olds)
- Willamette Varsity Football: 4 year starting guard, two-time All-Conference, All-American
- Finisher of 2010 Houston Marathon
- Alumnus of Sigma Alpha Epsilon (ΣΑΕ)

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Appendix B: Materials Considered

AE-HZN-2179MDL00059940
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LAL137-015769
LNL083-000351
NOA016-001452
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ORL003-006587
PNL001-032329
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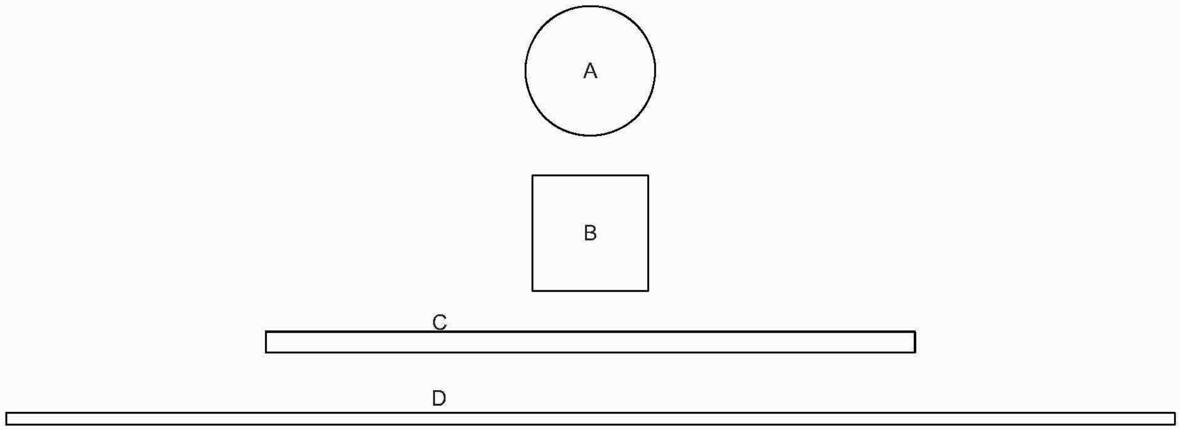
MDL 2179 Deposition Exhibit 9175

Appendix C -- Use of Circular Orifices in Hydraulic Modeling

The hydraulic modeling used by the "workgroups" described in Dr. Wilson's reports often employed circular shaped orifices to account for assumed restrictions in the Well system. These restrictions were not known with any degree of specificity in April and May 2010. The "orifice sizes" reported or calculated in the modeling work cited by Dr. Wilson do not reflect the actual system created by the Well, simply because the Well system's restrictions were not articulated as perfect circles. Thus, when Dr. Wilson compares "large" and "small" orifices and uses specific units of measure (such as fractions of an inch) in discussing the modeled systems, he is providing little or no insight into real conditions in the Well.

A simple example will illustrate the point. The modeling performed during the *Deepwater Horizon* response involving orifices assumes a perfectly circular hole in the middle of a thin plate, with the plate being placed in the flow path. This is important to understand because a circle has a low circumference to area ratio. The circumference, which is the part of the orifice (i.e., its edge) that actually touches the fluid as the fluid flows through, is what causes total pressure loss in the system. Therefore, for a given flow area (and therefore, a given velocity at a constant volumetric flowrate), the larger the circumference of the orifice shape, the larger the pressure drop across it hence a circle is the ideal shape giving the least pressure drop. Conversely, for a given pressure drop across an orifice, the larger the circumference to area ratio, the lower the rate through the orifice. To put this into practical terms, consider the following set of figures, which consists of four figures having an identical surface area: (A) circle, (B) square, (C) long rectangle, and (D) thin rectangle.



The circumference to area ratio for the four figures is as follows: (A) 1.0, (B) 1.1, (C) 3.3, and (D) 5.8. In other words, shape (D) above has approximately 6 times as much resistance to flow as shape (A) and would encounter a much higher pressure drop than the circle (shape A). As these comparisons show in a very simple way, the orifice sizes reported in the modeling surveyed by Dr. Wilson provide no insight into the realism of the model's results, because they are based on perfect circular orifices (among several other simplifying assumptions), and the actual restrictions geometry in the Well were much more complex.