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

STOPPING THE SPILL: THE FIVE-MONTH EFFORT TO KILL THE MACONDO WELL

---Draft---

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The effort to contain and control the blowout of the Macondo well was unprecedented. From April 20, 2010, the day the well blew out, until September 19, 2010, when the government finally declared it "dead," BP expended enormous resources to develop and deploy new technologies that eventually captured a substantial amount of oil at the source and, after 87 days, stopped the flow of oil into the Gulf of Mexico. The government organized a team of scientists and engineers, who took a crash course in petroleum engineering and, over time, were able to provide substantive oversight of BP, in combination with the Coast Guard and the Minerals Management Service (MMS).[1] BP had to construct novel devices, and the government had to mobilize personnel on the fly, because neither was ready for a disaster of this nature in deepwater.

The containment story thus contains two parallel threads. First, on April 20, the oil and gas industry was unprepared to respond to a deepwater blowout, and the federal government was similarly unprepared to provide meaningful supervision. Second, in a compressed timeframe, BP was able to design, build, and use new containment technologies, while the federal government was able to develop effective oversight capacity. Those impressive efforts, however, were made necessary by the failure to anticipate a subsea blowout in the first place. Both industry and government must build on knowledge acquired during the Deepwater Horizon spill to ensure that such a failure of planning does not recur.

[1] On June 18, 2010, Secretary of the Interior Ken Salazar ordered that the Minerals Management Service be officially renamed the Bureau of Ocean Energy Management, Regulation, and Enforcement. For consistency, throughout this paper, we will refer to the agency as the Minerals Management Service (MMS), its name at the time of the April 20, 2010 blowout.

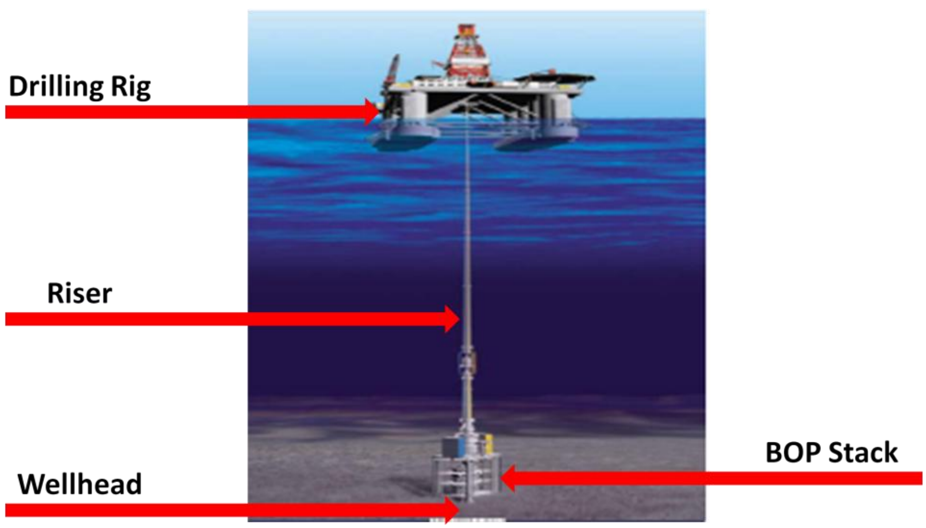
I. Emergency Response to the Blowout

Following the explosion on the Deepwater Horizon during the evening of April 20, 2010, while firefighting efforts were underway at the surface, Transocean and BP began working subsea to stop the flow of hydrocarbons from the Macondo well. Almost immediately, they started assessing the status of the 53-foot-tall blowout preventer ("BOP") stack, which stood atop the well.[2]

The Macondo well tapped into a reservoir more than 13,000 feet below the sea floor, containing roughly 110 million barrels of oil.[3] Extending upwards from the reservoir to the sea floor was a steel pipe called the "production casing." During production, this pipe was to contain the "production tubing," which would convey oil from the reservoir up to a vessel on the surface. The production casing was surrounded by other casings, which are integral to the drilling process and provide barriers between the production casing and the rock formation surrounding the well.[4] Each gap between casings, or between the outermost casing and the rock formation, is called an annulus.

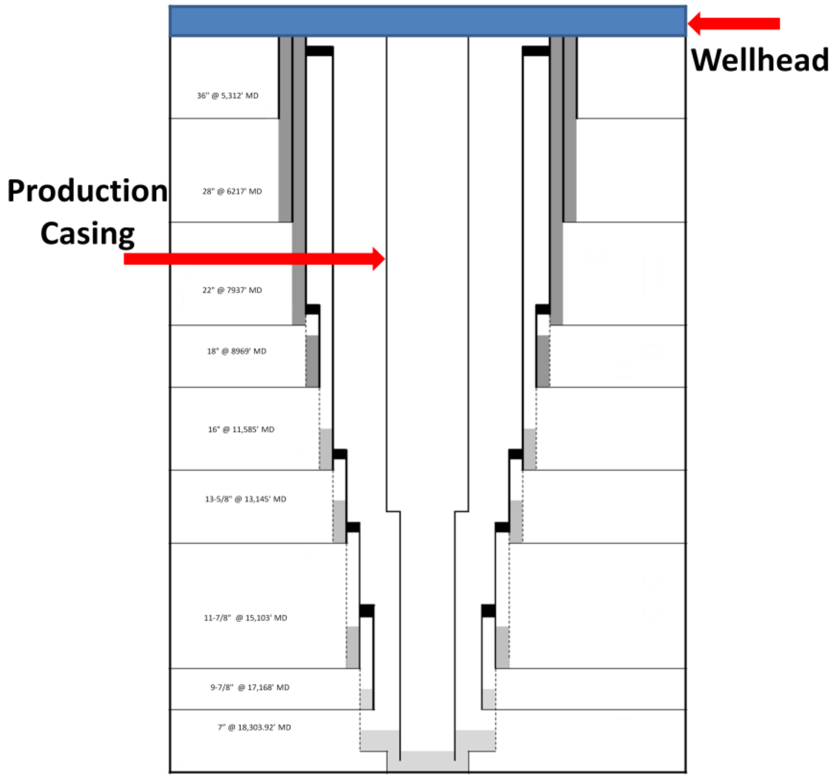
The production casing hung off a "casing hanger" in the "wellhead," or top of the well. The wellhead is a large, steel fitting that sits on the sea floor. Above the wellhead was the BOP stack. The drilling rig on the ocean's surface—the Deepwater Horizon—connected to the stack 5,000 feet below through a long steel pipe called a "riser." During drilling operations, the drill pipe (which has a bit at its end) passed from the rig through the riser and BOP stack, then down into the well.

Figure 1.A: Above the Sea Floor (Not to Scale)[5]



[2] Non-public Transocean document; Non-public BP document; Henry Fountain, *Focus Turns to Well-Blocking System*, N.Y. TIMES (May 10, 2010).
[3] Interview with government scientist.
[4] The bottom 1,136 feet of the production casing in the Macondo well was not surrounded by an outer casing, leaving it exposed to the reservoir.
[5] Image provided by BP.

Figure 1.B: Below the Sea Floor (Not to Scale)



A BOP stack is both integral to the drilling process and—as its name suggests—the last line of defense in preventing a blowout. The lower portion of the stack is often referred to simply as the BOP. The BOP on the Macondo well contained five separate closing devices, called "rams." The five rams were designed to serve different functions: for example, cutting drill pipe or casing, or sealing around drill pipe while leaving it intact. The "blind shear ram" was the only ram of the five with the ability to cut through drill pipe and completely shut in the well. In addition to the rams, the BOP had "boost," "choke," and "kill" lines, which were used to circulate fluids into and out of the well.

The top portion of the BOP stack is called the "lower marine riser package." On the Macondo well, that package contained two additional sealing mechanisms, called "annular preventers." Each preventer includes a hard rubber device in the shape of a tire that is designed to expand and seal around drill pipe or else seal the well entirely if drill pipe is not present.

BP's earliest containment efforts, undertaken with Transocean, focused on trying to close the rams and annular preventers within the BOP stack using remotely operated vehicles.[6] There are some indications that, even at this stage, BP was concerned about "well integrity"—i.e., the possibility that oil was flowing outside the production casing, and could flow sideways out of the

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[6] Non-public Transocean document; Non-public BP document; Henry Fountain, *Focus Turns to Well-Blocking System*. Before evacuating following the explosion on the evening of April 20, the Deepwater Horizon's crew had attempted to actuate the BOP stack and seal off the well. An ongoing forensic analysis of the BOP stack may fully explain the results of the crew's actions. For purposes of this paper, it is sufficient to recognize that the crew's efforts did not stop the flow of hydrocarbons.

well and into the rock formation if the well were shut in. According to Billy Stringfellow, a Transocean Subsea Superintendent, BP delayed interventions with remotely operated vehicles for approximately 20 hours because it was concerned that the pressure created by closing the BOP stack and shutting in the well might force hydrocarbons into the surrounding rock and "create an underground blowout."[7] Some of that delay may also be attributable to concerns about positioning surface ships operating the vehicles too close to the fire then consuming the Deepwater Horizon rig.[8] Remotely operated vehicles began working on the BOP stack at about 6:00pm on April 21.[9] The rig sank approximately sixteen hours later, on the morning of April 22.[10]

The earliest operations on the BOP primarily attempted to activate the blind shear ram.[11] During those attempts, officials from MMS were embedded in the operations centers at Transocean and BP headquarters in Houston. Those officials described themselves as observers, with on-scene personnel from BP, Transocean, and Cameron (the company that manufactured the BOP stack) making decisions.[12] According to the officials, there was no need for government approval of the early attempts on the BOP because of the ongoing emergency and because MMS was generally familiar and comfortable with the operations.[13] Starting on April 21, Secretary of the Interior Ken Salazar also received daily updates on source control activities through conference calls with BP's technical teams.[14] These calls would continue throughout the containment effort.[15]

Initially, the news was good: On April 23, Federal On-Scene Coordinator Admiral Mary Landry stated that, according to surveillance by remotely operated vehicles, the BOP stack, while "[i]t is not a guarantee," appeared to have done its job, sealing off the flow of hydrocarbons and preventing any leak.[16] That same day, senior management from BP, Transocean, Cameron, and Wild Well Control, a contractor to BP specializing in blowouts, met and concluded that, with

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[7] Testimony of Billy Stringfellow, Transocean, COAST GUARD/BOEM MARINE BOARD OF INVESTIGATION INTO THE MARINE CASUALTY, EXPLOSION, FIRE, POLLUTION, AND SINKING OF MOBILE OFFSHORE DRILLING UNIT DEEPWATER HORIZON [hereinafter COAST GUARD/BOEM BOARD OF INVESTIGATION] 408, 423-24 (Aug. 25, 2010).

[8] *See* Testimony of Daun Winslow, Transocean, COAST GUARD/BOEM BOARD OF INVESTIGATION 51-53 (Aug. 24, 2010) (discussing risk mitigation strategies employed to get ships close to the wellhead using water cannon curtains); Harry R. Weber, *Contractor: BP Interfered with Critical Efforts*, ASSOCIATED PRESS (Oct. 4, 2010) (describing precautions BP took to ensure that surface ships would not be harmed by the fire consuming the rig).

[9] Non-public Transocean document; Non-public BP document.

[10] Non-public Transocean document; Non-public BP document.

[11] Non-public BP document. On April 22, remotely operated vehicles tried to activate the blind shear ram in three separate ways: (1) by providing hydraulic pressure to the ram through the BOP's "hot stab" panel, which was specifically designed to be accessed by remotely operated vehicles; (2) by simulating the "Deadman," which was supposed to automatically actuate the ram if electric, hydraulic, and communication connections with the Deepwater Horizon were lost; and (3) by cutting the firing pin for the "Autoshear," which was designed to actuate the ram if the rig drifted out of position and disconnected the lower marine riser package from the BOP. *Id*; David Barstow et al., *Regulators Failed to Address Risks in Oil Rig Fail-Safe Device*, N.Y. TIMES (June 20, 2010); Testimony of Mark Hay, Transocean, COAST GUARD/BOEM BOARD OF INVESTIGATION 292 (Aug. 25, 2010).

[12] Interviews with MMS officials.

[13] Interview with MMS official.

[14] Non-public government document.

[15] *Id.*

[16] Leslie Kaufman, *Search Ends for Missing Oil Rig Workers*, N.Y. TIMES (Apr. 23 2010); *see also* Angel Gonzalez and Stephen Power, *Coast Guard Says Oil Leak Stopped*, WALL ST. J. (Apr. 24, 2010).

regard to the BOP stack, "[w]e have to take a noninvasive approach and not broach/risk what we have now in regards to stability of the well."[17] By mid-afternoon on April 23, however, remotely operated vehicles had discovered that oil was leaking from the end of the riser, which had broken off from the rig when it sank.[18] By the next morning, the vehicles had also discovered a second leak from a kink in the riser, located above the BOP stack.[19]

II. Early Containment Efforts

As it became clear that the initial efforts to actuate the BOP stack had been unsuccessful and that there were two separate leaks from the riser, BP began to consider other source control options. As early as April 21, BP started to discuss drilling a relief well to intersect the Macondo well at its source and stop the flow of oil.[20] Doug Suttles, Chief Operating Officer for Exploration and Production at BP, characterized a relief well as a standard industry technique for stopping a blowout, but said he believed at the time of the blowout that the drilling would take approximately 100 days.[21] Several experts from both industry and government described relief wells to Commission staff as the only accepted, high-probability solution to a subsea blowout, even though they take months to drill.[22] A relief well was the only source control option mentioned by name in BP's Initial Exploration Plan for the area that included the Macondo well.[23] Within days of the explosion, BP mobilized two rigs to drill separate relief wells, a primary well and a back-up insisted upon by Secretary Salazar.[24] After an expedited MMS permitting process, the first rig began drilling on May 2,[25] with the second beginning on May 17.[26]

Other than the lengthy process of drilling a relief well, BP had no available, tested technique to stop a deepwater blowout. Less than a week after the explosion, it embarked on what would become a massive effort to develop containment options, either by adapting shallow-water technology to the deepwater environment, or by designing entirely new devices. Different teams at BP's Houston headquarters focused on different ways either to stop the flow of oil or to collect it at the source.[27] Each team concentrated on a discrete containment effort, like actuating the BOP stack, developing near-term options to collect oil from the riser, or stopping the flow through a "top kill" procedure.[28] Each team also had what amounted to a blank check. As one contractor put it, "Whatever you needed, you got it. If you needed something from a machine

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[17] Henry Fountain, *Notes from Wake of Blowout Outline Obstacles and Frustration*, N.Y. TIMES (June 21, 2010).
[18] Non-public Transocean document.
[19] Non-public government document; Campbell Robertson, *Oil Leaking Underwater from Well in Rig Blast*, N.Y. TIMES (Apr. 24, 2010).
[20] Non-public government document.
[21] Interview with Doug Suttles, Houston, TX (Oct. 13, 2010).
[22] Interviews with MMS officials; Interview with well control expert.
[23] BP, INITIAL EXPLORATION PLAN, MISSISSIPPI CANYON BLOCK 252 (Feb. 23, 2009), http://www.gomr.boemre.gov/PI/PDFImages/PLANS/29/29977.pdf.
[24] Non-public government document.
[25] BP Press Release, *Work Begins To Drill Relief Well To Stop Oil Spill* (May 4, 2010), http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7061778.
[26] The White House, Ongoing Response Timeline (May 17, 2010), http://www.whitehouse.gov/blog/2010/05/05/ongoing-administration-wide-response-deepwater-bp-oil-spill.
[27] Interview with Doug Suttles.
[28] Interview with Richard Lynch, Houston, TX (Oct. 13, 2010).

shop and you couldn't jump the line, they bought the machine shop."[29] Several MMS officials agreed that, for BP, money was no object: If a team needed equipment, whether it was a ship, freestanding riser, or flexible hose, BP would buy it.[30] As Suttles pointed out, BP's parallel processing effort required enormous resources, and the size of its presence in the Gulf of Mexico was a big advantage.[31]

BP also sought help and advice from the oil and gas industry. One well control expert recalled a meeting in early May with at least 35 people, including representatives from the four companies in the world that specialize in well control; BP's major competitors, including ConocoPhillips, Exxon, and Shell; and academic petroleum engineering departments.[32] The expert remembered BP forthrightly admitting that it was seeking all of the help it could get.[33] According to Suttles of BP, nearly everyone in the industry recognized the magnitude of the emergency and answered BP's calls for assistance.[34]

MMS was the primary source of government oversight and expertise on source control operations, with the Coast Guard overseeing surface operations, vessel safety, and firefighting preparedness.[35] BP drafted detailed procedures describing the operation it wished to perform around the wellhead. MMS and Coast Guard officials in Houston participated in the drafting process to help identify and mitigate hazards. Once the procedures were finalized, the officials in Houston would approve and forward them to the Unified Area Command in Louisiana.[36] At Unified Command, Lars Herbst, MMS Gulf of Mexico Regional Director, or his deputy, Mike Saucier, would again review and approve the procedures, before the Federal On-Scene Coordinator, a Coast Guard Admiral, gave the final go-ahead.[37] This sign-off process remained in place throughout the containment effort.

MMS was the sole government agency charged with understanding deepwater wells and related technology, such as BOP stacks. Its supervision of the containment effort, however, was limited, in line with its established role in overseeing deepwater drilling more generally. Its staff did not attempt to dictate whether BP should perform an operation, to suggest consideration of other options, or to determine whether an operation had a significant likelihood of success.[38] Rather, MMS focused on minimizing the safety risks of operations BP proposed and ensuring conformity with MMS regulations.[39] In part, MMS's limited role stemmed from a lack of resources. At most, MMS had four to five employees in Houston trying to oversee BP's efforts.[40] One employee described his experience as akin to standing in a hurricane.[41] Despite

[29] Interview with well control expert.
[30] Interviews with MMS officials.
[31] Interview with Doug Suttles.
[32] Interview with well control expert.
[33] *Id.*
[34] Interview with Doug Suttles.
[35] Interviews with Coast Guard officials.
[36] Interviews with MMS officials.
[37] Interviews with MMS officials.
[38] Interview with Coast Guard official; Interview with MMS official.
[39] Interviews with MMS officials.
[40] Interview with MMS official.
[41] Interview with MMS official.

working more than 80 hours a week, this individual recalled having to miss more than half of the BP engineering team meetings he was supposed to attend each day.[42]

These resource constraints, however, do not fully explain MMS's role. Interviews of MMS staffers involved in the containment effort suggest that the agency viewed itself as neither capable of, nor tasked with, providing more substantive oversight. One MMS employee asserted that BP, and industry more broadly, possessed ten times the expertise that MMS could bring to bear on the enormously complex problem of deepwater containment.[43] Another pointed out that MMS has trouble attracting the most talented personnel, who are more likely to work in industry where salaries are substantially higher.[44] A third MMS employee stated that he could count on one hand the people from the agency whom he would trust to make key decisions in a source control effort of this magnitude.[45] Perhaps most revealingly, two MMS employees recalled high-level officials at the Department of the Interior asking what they would do if the U.S. Government took over the containment effort. Both said they would hire one of the major oil companies.[46]

It was in this environment—with BP deploying in-house and outside industry expertise to develop a containment strategy, while MMS and the Coast Guard provided limited procedural supervision—that the early containment efforts moved forward.

A. Attempts To Actuate the Blowout Preventer Stack

Even though the initial efforts had failed, BP thought that actuating the BOP stack remained its best chance to shut in the well quickly. After a two-day pause, BP restarted the attempts on April 25. It enlisted the help of other oil companies, including Shell, Exxon, Chevron, and Anadarko.[47] None of the attempts, however, stopped the flow of oil. Although several focused again on the blind shear ram, others were directed at different rams and at the annular preventers in the BOP stack, which were not designed to shut in the well completely where—as here—drill pipe was present. It appears that BP and Transocean were trying to use the BOP stack to reduce the flow of hydrocarbons, even if they were unable to stop the flow altogether.[48]

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[42] *Id.*
[43] *Id.*
[44] Interview with MMS official.
[45] Interview with MMS official.
[46] Interviews with MMS officials.
[47] Guy Chazan, *BP Seeks Help from Other Oil Companies*, WALL ST. J. (May 1, 2010).
[48] Non-public BP document; *see, e.g.*, Clifford Krauss, *Overhead and on the Ground*, *Waiting for a Potential Environmental Disaster to Hit*, N.Y. TIMES (Apr. 30, 2010) (quoting Suttles as indicating that one outcome of closing the annular preventer was "substantially reduc[ing] the flow of oil.").

Efforts to actuate the BOP stack were plagued by engineering and organizational problems. For instance, it took nearly ten days for a Transocean representative to realize that the stack's plumbing was not as it seemed and to inform the engineers attempting to actuate one of the BOP's rams through a "hot stab" panel that they had been misdirecting their efforts.[49] Without properly recording the change, Transocean had reconfigured the BOP stack; the panel that was supposed to control that ram actually operated a different, "test" ram, which was not designed to stop the flow of hydrocarbons from the well.[50] BP Vice-President Harry Thierens, who was BP's lead on BOP interventions, stated afterwards that he was "quite frankly astonished that this could have happened."[51] In contemporaneous notes, he wrote: "When I heard this news, I lost all faith in this BOP stack plumbing."[52] The inability of on-scene remotely operated vehicles to deliver enough hydraulic pressure may also have hindered attempts to close the rams.[53] At the very least, these problems delayed the closure efforts, while high-pressure hydrocarbons and sand wore down the BOP stack's components, making closure more difficult.[54]

In its accident report, BP indicated that it ceased trying to close the BOP stack on May 5.[55] By May 7, BP had concluded that "[t]he possibility of closing the BOP has now been essentially exhausted."[56] At the time, BP believed that various portions of the BOP had functioned: One ram had successfully severed the drill pipe, one or more of the other rams had closed, and the blind shear ram had partially closed, but not sealed the well.[57]

BP undertook gamma-ray imaging of the BOP stack, proposed by Secretary of Energy Steven Chu, in mid-May.[58] Although the imaging suggested that the blind shear ram had at least partially closed,[59] hydrocarbons continued to flow past it. According to BP's accident report, the blind shear ram could have failed to seal the well for a number of reasons, including the presence of a joint connecting two pieces of drill pipe where the ram attempted to make its cut, insufficient hydraulic pressure due to leaks in the stack, or degradation of the rams due to hydrocarbon flow and pressure conditions.[60] In September, BP retrieved the BOP stack from the sea floor.[61] The Coast Guard and MMS hired the Norwegian firm Det Norske Veritas to perform

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[49] Testimony of Harry Thierens, BP, COAST GUARD/BOEM BOARD OF INVESTIGATION 104 (Aug. 25, 2010).

[50] Fountain, *Notes from Wake of Blowout Outline Obstacles and Frustration*; Non-public BP document.

[51] Testimony of Harry Thierens, BP, COAST GUARD/BOEM BOARD OF INVESTIGATION at 106.

[52] *Id.* at 107.

[53] David Barstow et al., *Between Blast and Spill, One Last, Flawed Hope*, N.Y. TIMES (June 21, 2010); BP, *DEEPWATER HORIZON* ACCIDENT INVESTIGATION REPORT 169-71 (Sept. 8, 2010); Testimony of Billy Stringfellow, Transocean, COAST GUARD/BOEM BOARD OF INVESTIGATION at 397-99.

[54] Non-public government science advisor email. Billy Stringfellow of Transocean recently testified: "I think it's a well-known fact throughout the industry that abrasives can damage BOP components. . . . The quickest reaction time you can get is what you're looking for." Testimony of Billy Stringfellow, COAST GUARD/BOEM BOARD OF INVESTIGATION at 352.

[55] BP, *DEEPWATER HORIZON* ACCIDENT INVESTIGATION REPORT at 150.

[56] Non-public BP document.

[57] *Id.*

[58] Barstow et al., *Regulators Failed to Address Risks in Oil Rig Fail-Safe Device*; John M. Broder, *Energy Secretary Emerges To Take a Commanding Role in Effort To Corral Well*, N.Y. TIMES (July 16, 2010).

[59] Barstow et al., *Regulators Failed to Address Risks in Oil Rig Fail-Safe Device*.

[60] BP, *DEEPWATER HORIZON* ACCIDENT INVESTIGATION REPORT at 156-60.

[61] *Blowout Preventer May Hold Clues to Oil Spill*, CBS NEWS (Sept. 5, 2010).

forensic analysis, which may answer the question of why the Deepwater Horizon's BOP stack failed to seal the well.

B. Cofferdam

On April 25, as efforts to actuate the BOP stack continued, BP began to consider placing a large containment dome, also known as a cofferdam, over the larger of the two leaks from the broken riser.[62] At the top of the cofferdam, a pipe would channel hydrocarbons to the *Discoverer Enterprise*, a ship on the surface.[63] Although some initial reports indicated that BP would need as long as four weeks to install the dome,[64] BP was able to move more rapidly. Several cofferdams were already in existence, with BP having used them to recover oil from shallow-water leaks following Hurricanes Katrina and Rita.[65] By May 4, just ten days after first raising the possibility of using a containment dome, BP reported that it had finished modifying for deep-sea use a preexisting dome that was 14 feet wide, 24 feet long, and 40 feet tall.[66] Following an MMS inspection of the *Discoverer Enterprise*,[67] BP began to lower the 98-ton dome to the sea floor late in the evening of May 6 (see Figure 2).[68] BP planned to stage a second cofferdam on the sea floor in case the first dam failed.[69]

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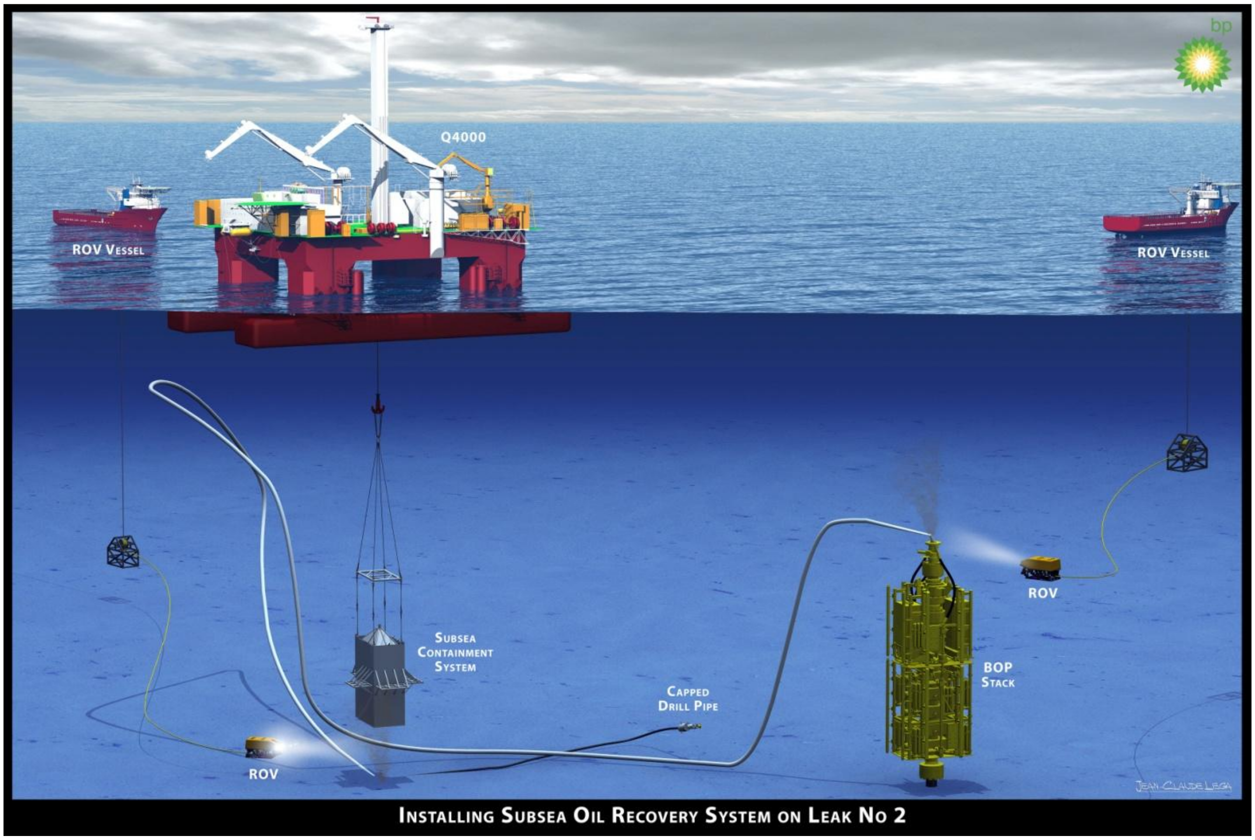
[62] Non-public government document; Campbell Robertson and Leslie Kaufman, *Oil Leaks Could Take Months To Stop*, N.Y. TIMES (Apr. 25, 2010). On April 28, BP discovered a third leak, located closer to the source than the kink leak. *See* Campbell Robertson and Leslie Kaufman, *Size of Spill in Gulf of Mexico is Larger than Thought*, N.Y. TIMES (Apr. 28, 2010). While BP was able to quickly stop that leak with a specially designed valve, this action did not reduce the amount of oil being released. *See* Sam Dolnick and Liz Robbins, *BP Says One Oil Leak of Three Is Shut Off*, N.Y. TIMES (May 5, 2010).
[63] Sam Dolnick and Henry Fountain, *Unable to Stanch Oil, BP Will Try To Gather It*, N.Y. TIMES (May 5, 2010); BP Press Release, *Work Begins To Drill Relief Well To Stop Oil Spill* (May 4, 2010), http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7061778.
[64] Guy Chazan and Ben Casselman, *Documents Show BP Opposed New, Stricter Safety Rules*, WALL ST. J. (Apr. 28, 2010); Ben Casselman, Stephen Power, and Ana Campoy, *Oil-Spill Fight Bogs Down*, WALL ST. J. (Apr. 30, 2010).
[65] Interview with Richard Lynch; Interview with Doug Suttles.
[66] Interview with Richard Lynch; BP Press Release, *Work Begins To Drill Relief Well To Stop Oil Spill*.
[67] The White House, The Ongoing Administration-Wide Response to the Deepwater BP Oil Spill (May 6, 2010), http://www.whitehouse.gov/blog/2010/05/05/ongoing-administration-wide-response-deepwater-bp-oil-spill.
[68] *Deepwater Team Attempts To Put 100-Tonne Box over Blown-out Well*, GUARDIAN (May 7, 2010).
[69] Non-public government document; Interview with Richard Lynch.

Figure 2[70]



From the beginning, the likelihood of collecting hydrocarbons with the cofferdam was uncertain. Suttles of BP publicly cautioned that a containment dome had only been used successfully in much shallower water.[71] In an interview, he told Commission staff that, according to BP engineers, the chance of success was at best 50 percent.[72] Bob Fryar, a senior BP engineer, warned, "This is new technology. . . . It has never been done before."[73] BP recognized that chief among the potential problems was the risk that methane gas escaping from the well would come into contact with sea water and form slushy hydrates, essentially clogging the cofferdam with hydrocarbon ice. BP planned to mitigate this concern once the dome had been installed by circulating warm water into the dome from the surface, so that hydrocarbons could flow up the riser unimpeded.[74] Notwithstanding these uncertainties, BP, in a presentation to the leadership of the Department of the Interior, described the probability of the cofferdam's success as "Medium/High."[75] Others in the oil and gas industry were not so optimistic: Experts have told Commission staff that it was widely understood within the industry that the cofferdam effort was very likely to fail due to hydrate formation.[76]

[70] Image provided by BP.
[71] Ian Urbina, Justin Gillis, and Clifford Krauss, *On Defensive, BP Readies Dome to Contain Spill*, N.Y. TIMES (May 3, 2010).
[72] Interview with Doug Suttles.
[73] Dolnick and Fountain, *Unable to Stanch Oil, BP Will Try To Gather It*.
[74] Non-public BP document.
[75] *Id.*
[76] Interview with well control expert; Interview with drilling expert.

BP's effort to capture oil from the Macondo well with the containment dome did not succeed. While BP had a plan to deal with hydrates once the cofferdam was in place, it had not planned to mitigate hydrate formation during the installation process itself.[77] When crews started to maneuver the cofferdam over the leak at the end of the riser on the evening of May 7, hydrates formed before the dam could be put in place, clogging the opening through which oil was to be funneled.[78] BP Vice President Richard Lynch, who oversaw the cofferdam effort, told Commission staff that BP did not anticipate hydrates forming this early.[79] Because hydrates are lighter than water, they also rendered the containment dome buoyant as it was still being lowered.[80] In the *New York Times*, Lynch recalled engineers telling him that they had "lost the cofferdam," which, after filling with highly flammable hydrates, had begun floating up toward the ship-covered ocean surface.[81] Engineers were eventually able to gain control of the 98-ton dome and move it to safety on the sea floor.[82] One high-level government official recalled Andy Inglis, BP's Chief Executive of Exploration & Production, saying "if we had tried to make a hydrate collection contraption, we couldn't have done a better job."[83]

The lack of an accurate flow-rate estimate may have hindered BP's planning for the cofferdam. Suttles told Commission staff that, at the time BP deployed the cofferdam, no one at BP believed the flow was greater than 13-14,000 barrels per day (bbls/day).[84] The government's then-current estimate of the flow rate was 5,000 bbls/day,[85] an order of magnitude lower than its now-current estimate of the flow in early May (approximately 60,000 bbls/day).[86] Government officials have told Commission staff that part of the reason for the quicker-than-expected formation of hydrates in the cofferdam was the large flow volume.[87] Moreover, BP had publicly predicted that the cofferdam would remove about 85% of the oil spilling into the sea.[88] But the ship BP planned to connect to the cofferdam, the *Discoverer Enterprise*, was capable of

[77] Interview with Richard Lynch.
[78] Campbell Robertson, *New Setback in Attempt to Contain Gulf Oil Spill*, N.Y. TIMES (May 8, 2010).
[79] Interview with Richard Lynch.
[80] *Id.*
[81] Clifford Krauss, Henry Fountain, and John M. Broder, *Acrimony Behind the Scenes of Gulf Oil Spill*, N.Y. TIMES (Aug. 26, 2010).
[82] *Id.*
[83] Interview with senior administration official.
[84] Interview with Doug Suttles.
[85] On April 28, the government announced a flow rate estimate of 5,000 bbls/day. Press Conference, Admiral Mary Landry and Doug Suttles, New Orleans, LA (Apr. 28, 2010), http://cgvi.uscg.mil/media/main.php?g2_itemId=843309. This remained the government's official estimate until May 27. Unified Command Press Release, Flow Rate Group Provides Preliminary Best Estimate of Oil Flowing from BP Oil Well (May 27, 2010), http://app.restorethegulf.gov/release/2010/05/27/flow-rate-group-provides-preliminary-best-estimate-oil-flowing-bp-oil-well.
[86] *See* Deepwater Horizon Incident Joint Information Center Press Release, U.S. Scientific Teams Refine Estimates of Oil Flow from BP's Well Prior to Capping (Aug. 2, 2010), http://app.restorethegulf.gov/release/2010/08/02/us-scientific-teams-refine-estimates-oil-flow-bps-well-prior-capping. While BP has not released its own flow-rate estimates, it has suggested that the government's estimate of the total amount of oil released from the Macondo well—4.9 million barrels—is overstated by 20 to 50%. Meeting with BP, Washington, D.C. (Oct. 22, 2010).
[87] Interview with senior administration official; Interview with MMS official; *see also* Interview with well control expert.
[88] Dolnick and Fountain, *Unable to Stanch Oil, BP Will Try To Gather It*.

processing a maximum of 15,000 bbls/day.[89] If even half of the government's now-estimated 60,000 bbls/day was then flowing, the containment dome could not have collected 85% of the oil from the Macondo well, putting aside the issue of hydrates.

It is unclear whether a more accurate sense of the cofferdam's likelihood of success would have enabled BP to proceed differently. At the time, other containment options had not yet been developed, and the cofferdam did not risk damaging the well or otherwise making the spill worse. Several BP executives indicated that the *Discoverer Enterprise* was the only collection ship available, suggesting that a better understanding of the flow volume would not have resulted in more processing capacity for the operation.[90] Nonetheless, BP modeled hydrate formation and assessed the cofferdam's collection abilities without an accurate estimate of the oil flow.

Government oversight of the cofferdam operation was similar to oversight of efforts to actuate the BOP stack. MMS and the Coast Guard formally approved proposed procedures, after working with BP to identify operational hazards.[91] Government officials did not substantively review BP's plan to mitigate hydrate formation or evaluate BP's predictions as to the cofferdam's likelihood of success.[92] More robust oversight, addressing such strategic and scientific issues, would not begin until late May.[93]

C. Riser Insertion Tube Tool

Following the failure of the cofferdam, BP began, on May 14, trying to install a smaller device termed the Riser Insertion Tube Tool (RITT) into the end of the broken riser, the site of the primary leak.[94] After two days of attempts and some modifications, BP installed the tool on May 16.[95] The tool was a four-inch-diameter tube that fit into the end of the riser and carried oil and gas up to the *Discoverer Enterprise* on the surface a mile above. According to Lynch, BP was able to avoid a buildup of hydrates because the tool was inserted far enough into the riser to only pull in oil and gas, rather than mixing hydrocarbons with seawater.[96] Over the nine days of

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[89] *See* Clifford Krauss and Michael Cooper, *Cap Slows Gulf Oil Leak as Engineers Move Cautiously*, N.Y. TIMES (June 5, 2010).
[90] Interview with Richard Lynch; Interview with Doug Suttles; Interview with Paul Tooms, Houston, TX (Oct. 13, 2010).
[91] Interviews with MMS officials.
[92] Interview with MMS official; Interviews with government science advisors; Interview with senior administration official.
[93] Interview with senior administration official; Interview with government scientist.
[94] Non-public government document.
[95] Non-public government document.
[96] Interview with Richard Lynch.

use, the riser insertion tool was able to collect approximately 22,000 barrels of oil.[97] BP executives had different recollections of the tool's highest instantaneous collection rate, ranging up to 12,000 bbls/day.[98]

Data from the riser insertion tool indicated that the flow rate was greater than the highest instantaneous collection rates. For the entire time the tool was in place, visible hydrocarbons were still escaping around it at the end of the riser.[99] Hydrocarbons were also still flowing from the second, smaller leak at the kink in the riser.[100]

BP could have expanded its capacity to collect hydrocarbons from the riser. It deployed additional riser insertion tools to the sea floor by May 23.[101] According to Lynch, these tools had a larger diameter and would have had greater collection capacity than the first.[102] BP did not use these extra tools because another source control operation that it had been planning simultaneously, the "top kill," was about to begin.

III. The Arrival of the National Labs and Science Advisory Teams, the Top Kill and Junk Shot, and the Move to Collection

The failure of the cofferdam seemed to highlight the shortage of viable options to control the Macondo well. Somewhat outlandish suggestions filled the void. For instance, in mid-May, a Russian newspaper suggested detonating a nuclear weapon deep within the well to seal off the flow of oil, as the former Soviet Union had done on a number of occasions.[103]

Perhaps prompted by the cofferdam's failure, the federal government increased its footprint in Houston. Facilitated by Deputy Secretary of the Interior David Hayes, scientists and engineers from three Department of Energy National Laboratories had started to help BP obtain diagnostic information about the well and BOP stack in early May.[104] National labs personnel would remain on site at BP headquarters for the remainder of the containment effort. On May 7,

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[97] Methods that Have Been Tried to Stop the Leak, N.Y. TIMES (Aug. 17, 2010), http://www.nytimes.com/interactive/2010/05/25/us/20100525-topkill-diagram.html.

[98] Interview with Richard Lynch (recalling a rate of 12,000 bbls/day); Interview with Paul Tooms (recalling a rate of 8,000 to 10,000 bbls/day). The government's Flow Rate Technical Group, in its May 27 press release, noted that "[o]n May 25, 2010, at approximately 17:30 CDT, the [riser insertion tool] logged oil collection at a rate of 8,000 barrels of oil per day, as measured by a meter whose calibration was verified by a third-party." Deepwater Horizon Incident Joint Information Center Press Release, Flow Rate Group Provides Preliminary Best Estimate of Oil Flowing From BP Oil Well (May 27, 2010), http://app.restorethegulf.gov/release/2010/05/27/flow-rate-group-provides-preliminary-best-estimate-oil-flowing-bp-oil-well.

[99] Interview with Richard Lynch; Interview with Paul Tooms.

[100] Meeting with BP (Oct. 22, 2010).

[101] Non-public government document.

[102] Interview with Richard Lynch.

[103] Jeremy Hsu, *Why Don't We Just Drop a Nuclear Bomb on the Gulf Oil Spill?*, CHRISTIAN SCIENCE MONITOR (May 13, 2010).

[104] Non-public government document; U.S. Department of Energy Press Release, Secretary Salazar and Secretary Chu To Meet with Scientists and Engineers at BP Houston Command Center (May 11, 2010), http://www.energy.gov/news/8976.htm; Interview with government scientist; Interview with senior administration official. The three national laboratories involved were Sandia National Laboratories, Los Alamos National Laboratory, and Lawrence Livermore National Laboratory. In Houston, this group was sometimes called the "tri-labs team."

Secretary Salazar asked Dr. Marcia McNutt, the Director of the U.S. Geological Survey who had traveled with him to the Gulf on May 4, to remain in Houston to oversee source control efforts.[105] Finally, on May 10, President Obama directed Secretary Chu to form a team of government officials and scientists to work with BP on source control.[106] On May 11, Secretary Chu called several prominent scientists and asked them to join him the next day for a 6:30am meeting with BP in Houston.[107]

The May 12 meeting signified the beginning of an oversight role for Secretary Chu and his team of science advisors. A winner of the 1997 Nobel Prize for Physics, Secretary Chu had been the Director of Lawrence Berkeley National Laboratory, where he focused on renewable energy technologies and atomic physics.[108] Secretary Chu's principal deputy for the containment effort was Dr. Tom Hunter, who arrived in Houston in early May and was about to retire from his position as Director of Sandia National Laboratories, where he had worked for 43 years, primarily on the nuclear weapons program.[109] Along with Dr. McNutt, Dr. Hunter served as a link between the on-site national labs personnel and Secretary Chu's science advisory team.

The advisory team included well-known scientists and engineers. Some, but not all, had prior oil and gas experience. For instance, Dr. Alexander Slocum, an MIT professor, holds more than sixty patents and had done some work on drilling design.[110] Dr. George Cooper had been the head of the Petroleum Engineering Program at the University of California at Berkeley and is a Senior Petroleum Engineer at Lawrence Berkeley National Laboratory.[111] Dr. Arun Majumdar is the Director of the Department of Energy's Advanced Research Project Agency—Energy.[112] Dr. Richard Garwin, who helped design the world's first hydrogen bomb, was involved in putting out the Kuwaiti oil fires following the first Gulf War.[113] Although the team members attended the May 12 meeting in person, the vast majority of their future participation in decision-making occurred via conference calls.[114]

The role of both the national labs personnel and Secretary Chu's advisory team took time to evolve from helping BP diagnose the situation to providing substantive oversight on containment. In part, this was because the Secretary of Energy, his team of advisors, and the national labs lacked a formal role within the Unified Command structure.[115] Their oversight was

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[105] U.S. Department of Energy Press Release, Secretary Salazar and Secretary Chu To Meet with Scientists and Engineers at BP Houston Command Center; Interview with senior administration official.
[106] U.S. Department of Energy Press Release, Secretary Salazar and Secretary Chu To Meet with Scientists and Engineers at BP Houston Command Center.
[107] Interviews with government science advisors.
[108] Bio, Secretary Steven Chu, Department of Energy, http://www.energy.gov/organization/dr_steven_chu.htm.
[109] Press Release, NNSA Honors Tom Hunter, Welcomes Paul Hommert as Director of Sandia Labs (May 13, 2010); Interview with government science advisor.
[110] Curriculum Vitae, Dr. Alexander Slocum, http://meche.mit.edu/documents/slocum_CV.pdf; Interview with government science advisor.
[111] Faculty Biography, George A. Cooper, University of California, Berkeley, http://www.ce.berkeley.edu/faculty/faculty_bio.php?name=Cooper/.
[112] Bio, Dr. Arun Majumdar, ARPA—E, http://arpa-e.energy.gov/About/Team/DrArunMajumdar.aspx.
[113] William J. Broad, *Physicist and Rebel is Bruised, Not Beaten*, N.Y. TIMES (Oct. 8, 1999); Interview with government science advisor.
[114] Interviews with government science advisors.
[115] Interview with Coast Guard official.

grafted onto the existing framework, which required MMS and the Coast Guard to sign off on BP's proposals. It also took some time for the national labs team to integrate itself into the command structure led by MMS and the Coast Guard. While MMS, the Coast Guard, and Dr. McNutt worked out of offices on the third floor of BP's Houston headquarters, the national labs team sat on the eighteenth floor.[116] One MMS staffer who was in Houston from late April through early July told Commission staff that he never interacted with the national labs team: They never reached out to him, and he had no idea on what they were working.[117] Perhaps as a result of these unclear lines of authority, BP's provision of data to the government was uneven.[118] Although BP gave information when asked, it did not proactively share, so government officials had to know what information they were seeking and ask for it specifically.[119] By mid-June, the government teams created a process by which the national labs engineers and science advisors could direct formal requests for information and action to BP.[120]

Finally, both the science advisors and the national labs team had to educate themselves on the situation, and on deepwater petroleum engineering more generally, before they could participate substantively in decision-making.[121] Thus, in mid-May, while the science advisors were learning the lay of the land, the national labs engineers focused on helping BP obtain diagnostic information through efforts such as gamma-ray imaging of the BOP stack.[122] Meanwhile, throughout May, BP set the strategy for trying to control the well, with limited government oversight.[123]

While the government science teams were getting up to speed over the course of May, BP was ramping up for its first major effort to stop the flow from the Macondo well: the "top kill" and "junk shot."

[116] Interview with Coast Guard official; Interviews with MMS officials; Interview with Paul Tooms.
[117] Interview with MMS official.
[118] Interview with senior administration official; Interview with Coast Guard official; Interview with government science advisor.
[119] Interview with senior administration official.
[120] Interview with government scientist.
[121] Interview with government scientist; Interview with government science advisor.
[122] Interview with government scientist; Interview with government science advisor.
[123] Non-public government document; Interviews with government science advisor; Interview with senior administration official.

A. Top Kill and Junk Shot

Top kills and junk shots are standard industry procedures for stopping the flow of hydrocarbons from a blown-out well.[124] Also known as a momentum or dynamic kill, a top kill involves pumping heavy drilling mud into the top of a well through the BOP's choke and kill lines, at rates and pressures significant enough to force escaping hydrocarbons back down the well and into the reservoir. A junk shot complements a top kill. It involves pumping bridging materials—including pieces of tire rubber and golf balls—into the bottom of a BOP through the choke and kill lines. Those bridging materials ideally get caught on obstructions in the flow path for hydrocarbons—such as pieces of drill pipe and partially deployed BOP rams—and further impede the flow. By slowing or stopping the flow of hydrocarbons, a successful junk shot makes it easier to execute a top kill.

BP's top kill team began its work in the immediate aftermath of the initial failed efforts to actuate the BOP stack.[125] Leading up to the operation, both BP and federal engineers modeled different scenarios based on different rates at which oil might be flowing from the Macondo well. Paul Tooms, BP's Vice President of Engineering, told Commission staff that BP hired a Norwegian company to model different outcomes depending on the flow rate of hydrocarbons.[126] He recalled that, given the planned pumping rates, the top kill was unlikely to succeed with oil flow rates greater than 15,000 bbls/day.[127] National labs engineers modeled the top kill based on the then-current flow-rate estimate of 5,000 bbls/day, concluding that mud would need to be pumped at greater than 20 barrels per minute to succeed.[128] Yet, surprisingly, a well control contractor involved in the top kill effort told Commission staff that the flow rate was not a factor in designing the top kill procedure or determining its likely success. According to this contractor, the top kill's likelihood of success depended on the area through which hydrocarbons flowed from the well, but would have been the same if the flow rate were only 10 bbls/day, instead of the actual rate.[129] Commission staff did not speak to anyone else in government or industry who shared this view.

Nonetheless, a senior administration official recalled being told by a BP engineer, on the day the operation began, that the top kill would not work if the flow rate was greater than 13,000 bbls/day.[130] The official responded that a government team was about to come out with a new

[124] Interview with well control expert.
[125] Interview with well control expert; Interview with Richard Lynch.
[126] Interview with Paul Tooms.
[127] *Id.* This estimate was apparently based on a mud pumping rate of 40-45 barrels per minute. In addition, a successful junk shot would have obstructed the flow path and reduced the flow rate. It therefore could have enabled the top kill to succeed even if the initial flow rate were greater than 15,000 bbls/day.
[128] Non-public government documents.
[129] Interview with well control expert.
[130] Interviews with senior administration official.

flow-rate estimate with a *lower bound* of 12,000 to 25,000 bbls/day.[131] BP's engineer replied that there could be some margin above 13,000 bbls/day at which the top kill might succeed.[132] In retrospect, according to the government official, if BP had devoted a fraction of the resources it expended on the top kill to obtaining a more accurate early estimate of the flow rate, it might have better focused its efforts on the containment strategies that were more likely to succeed.[133]

While the government had limited involvement in planning the top kill procedure, the science advisors had expressed concerns about the junk shot, both because junk could get stuck in the well and block the mud from pushing hydrocarbons back into the reservoir, and because junk could increase the pressure in and stress on the well and BOP stack.[134] Suttles of BP suggested that junk also had the potential to clog the choke and kill lines, which could interfere with future source control operations.[135] In the early morning of May 25, the day before the three-day top kill operation began, Tom Knox of BP assured the government science advisors, including Secretary Chu, that "[t]he junk shot is no longer on the flow sheet. It is not an option under consideration."[136] At some point, however, the junk shot was put back on the table, because BP did attempt it. Tooms suggested that this change was made after the failure of the initial top kill effort, which involved only mud (not junk).[137]

With the approval of Coast Guard Admiral Landry, the Federal On-Scene Coordinator, the top kill began on the afternoon of May 26.[138] Secretary Chu and some members of his science team were in the command center in Houston.[139] The top kill operation consisted of three separate attempts on three consecutive days. First, BP attempted to pump only mud at rates of up to 53 barrels per minute or more than 76,000 bbls/day.[140] Although initially pressures within the well began to drop, suggesting that hydrocarbons were potentially being pushed back into the reservoir, the pressure readings soon flattened out, indicating that the top kill was not making further progress.[141]

After a pause to analyze the results, BP made a second attempt on May 27, pumping mud at 25 barrels per minute or 36,000 bbls/day and firing fifteen different junk shots of bridging materials.[142] Again, the effort did not succeed. After another pause for analysis, BP undertook a third and final attempt on May 28. On that day, BP pumped mud at rates up to 80 barrels per minute or more than 115,000 bbls/day and fired two junk shots of bridging materials.[143] Even pumping at these higher rates, BP did not succeed. While Secretary Chu evidently had the

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[131] Interview with senior administration official.
[132] *Id*.
[133] *Id*.
[134] Non-public government science advisor emails.
[135] Interview with Doug Suttles.
[136] Non-public government science advisor email.
[137] Interview with Paul Tooms.
[138] The White House Blog: Deepwater Horizon Oil Spill (May 26, 2010), http://www.whitehouse.gov/blog/issues/Deepwater-BP-Oil-Spill?page=6.
[139] Interview with government science advisor.
[140] Non-public BP document.
[141] Interview with Doug Suttles.
[142] Non-public BP document.
[143] *Id.*; Interview with MMS official.

authority to call off the top kill at his discretion,[144] members of the science advisory team and BP executives recall that both BP and the government agreed to stop the top kill, concluding that it would not work after the failure of the third attempt.[145]

BP struggled with public communications surrounding the top kill effort. Internally, both BP and government officials were uncertain about the odds of success. Tooms recalled that, when Secretary Salazar asked a group of individuals who worked on the top kill about its likelihood of success, most said 70%.[146] One MMS employee involved in the procedure told Commission staff that, at the time, he estimated the chance of success as less than 50%.[147] Finally, a BP contractor who participated in the operation told Commission staff that, going into the top kill, he gave it a "tiny" chance to succeed.[148] Notwithstanding this uncertainty, BP CEO Tony Hayward stated publicly that "[w]e [BP] rate the probability of success between 60 and 70 percent."[149] Suttles told Commission staff that he was careful not to predict the top kill's chance of success and did not know what led Hayward to do so.[150]

B. Top Kill Analysis

Immediately following the top kill, BP teams in Houston met throughout the night of May 28 to assess the operation.[151] Some meetings occurred behind closed doors, without government participation. At one point, Lars Herbst of MMS and Coast Guard Admiral Kevin Cook, who had been dispatched by National Incident Commander Admiral Thad Allen to be his representative in Houston, entered a meeting and stated that they had a right to be present.[152] Apparently, government officials had not previously insisted on joining these types of meetings, and BP personnel were surprised by the interruption.[153] Asserting the right to be present for BP's top kill analysis was a turning point for the government team. After the failure of the top kill, the government significantly increased its oversight of the containment effort.[154]

Following the overnight meeting on the top kill, BP presented its assessment of why the operation failed. Understanding that analysis requires a brief digression on the Macondo well's design and, specifically, on the presence of "rupture disks" in the 16"-diameter casing within the well.[155] The 16" casing is the longest piece of pipe outside of the production casing. It forms the

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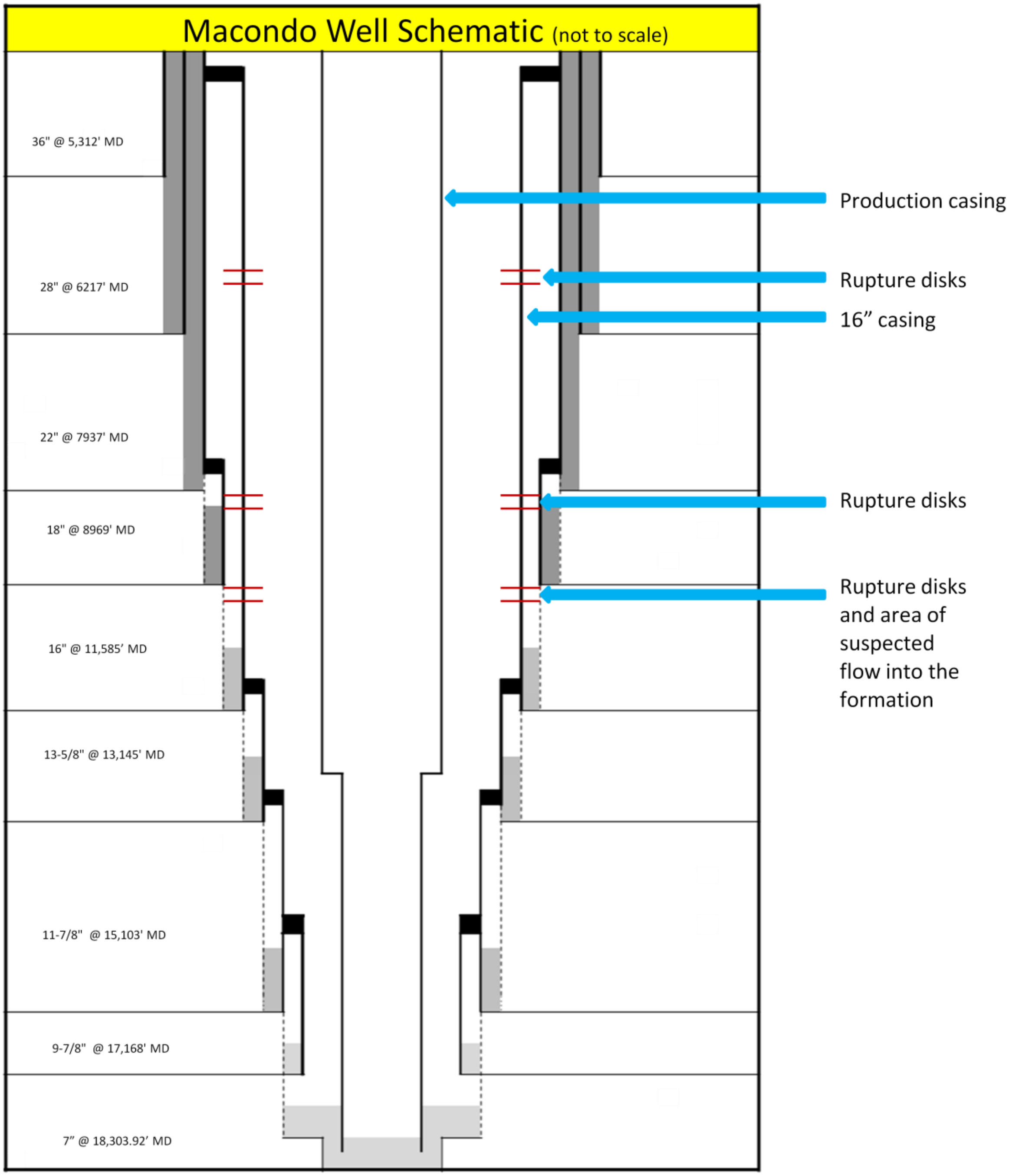
144 Interview with government science advisor.
145 Interview with government science advisor; Interview with Doug Suttles; Interview with Paul Tooms.
146 Interview with Paul Tooms.
147 Interview with MMS official.
148 Interview with well control expert.
149 Campbell Robertson, Clifford Krauss, and John M. Broder, *Oil Hits Home, Spreading Arc of Frustration*, N.Y. TIMES (May 24, 2010).
150 Interview with Doug Suttles.
151 Interview with Paul Tooms.
152 Interviews government officials.
153 Interview with government official.
154 Interview with government science advisor; Interview with senior administration official.
155 Technically, the 16" pipe is a "liner" rather than a "casing," because it hangs 160 feet below the wellhead. Casing runs all the way up to the wellhead, where it hangs from a "casing hanger." A liner does not run all the way up to the wellhead, and instead hangs from a "liner hanger" placed further down in the well. For simplicity's sake, and because individuals in the oil and gas industry often use the terms interchangeably, we nevertheless refer to the 16" pipe as a "casing."

outermost barrier between the well and the rock formation for more than 1,000 vertical feet at approximately 10,000 feet below sea level.[156] The casing was purposely fabricated with three sets of failure points, called rupture disks. Those disks were designed to relieve pressure buildup resulting from heat during production, before that buildup could cause a collapse of the production casing or the 16" casing itself.

The disks were engineered to rupture in two separate ways. First, if pressure between the 16" casing and the production casing reached 7,500 pounds per square inch (psi)—less than the 11,140 psi at which the production casing would collapse—the rupture disks would *burst outward*.[157] Second, if pressure outside of the 16" casing topped 1,600 psi—less than the 2,340 psi at which the 16" casing would collapse—the rupture disks would *collapse inward*.[158] Once ruptured, the disks would create small holes in the 16" casing to bleed off pressure into the surrounding rock formation.[159]

[156] Macondo Well Schematic.
[157] Non-public BP document.
[158] *Id.*
[159] Non-public BP document.

Figure 3



According to BP's analysis, several factors, including the pressures observed during the top kill attempt—initially dropping, then flat-lining—made it plausible that the rupture disks in the 16" casing had collapsed inward during the initial blowout.[160] If the blowout had resulted in flow of hydrocarbons up the annulus between the 16" casing and the production casing, the difference in pressure between the heavy drilling mud that remained outside the 16" casing from the drilling process and the light hydrocarbons within could have been greater than the 1,600 psi

[160] Interview with Paul Tooms; Non-public BP document.

at which the rupture disks would collapse inward.[161] At the time, BP concluded that the top kill likely failed because mud pumped down the well had gone out through the collapsed rupture disks and sideways into the rock formation, rather than remaining within the well and pushing the hydrocarbons back into the reservoir, as had been intended.[162] Based on a comparison of pressure readings across the three top kill attempts, as well as visual observation,[163] BP believed that it had pumped more mud down into the well during the top kill than had come back up. If that were true, the mud had to have traveled either all the way down to the bottom of the well, or through the rupture disks and out of the sides of the well into the rock formation.[164]

Although Tooms of BP emphasized to Commission staff that collapse of the rupture disks was one of several plausible theories to explain the results of the top kill,[165] BP presented it to the government as the most likely scenario, and found its likelihood sufficient to change strategy moving forward.[166] The government teams did not challenge the assumption that BP had pumped more mud into the well than had flowed back out, but they were skeptical of BP's analysis regarding where the mud went during the top kill.[167] The national labs team performed its own analysis and concluded that only a fraction of the mud pumped during the top kill could have escaped into the rock formation through the rupture disks.[168] The team found it more likely that mud had gone down the production casing and into the rock formation at the bottom of the well.[169] This scenario could also explain the top kill's failure, as follows: While mud traveled down the central production casing, hydrocarbons continued to flow up the annulus outside of the production casing, into the BOP, and out of the riser.[170]

Although the government and BP analyzed the flow of mud during the top kill differently, the government believed that BP's hypothesis of collapsed rupture disks was plausible, and that well integrity needed to be considered moving forward.[171] In retrospect, several members of the government science teams have told Commission staff that a more likely cause of the top kill's failure was the flow rate, which was many times greater than 5,000 bbls/day, the government's official estimate when the top kill commenced.[172] Because BP did not pump mud into the well at high enough rates to counter the actual flow, the hydrocarbons flowing from the well ejected the mud back up the BOP stack and out of the riser.[173]

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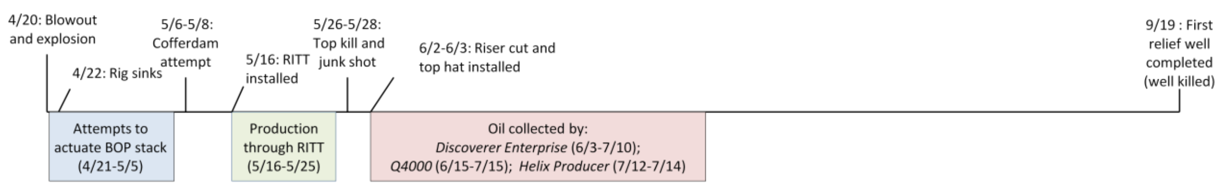
[161] Non-public BP document.
[162] Interview with Coast Guard official; Interview with MMS official; Interview with senior administration official.
[163] Non-public government document; Non-public BP documents.
[164] Interview with government scientist.
[165] Interview with Paul Tooms.
[166] Interview with Coast Guard official; Interview with MMS official; Interview with senior administration official.
[167] Interview with government scientist.
[168] Interview with senior administration official; Interview with government scientist; Non-public government document.
[169] Interview with government scientist; Non-public government document.
[170] Non-public government document.
[171] Interview with senior administration official.
[172] Interviews with government scientists; Interview with government science advisor; Interview with senior administration official.
[173] Interviews with government scientists; Interview with government science advisor; Interview with senior administration official.

Prior to the top kill, in separate presentations to Secretary Chu and Secretary Salazar, BP had indicated that, if the top kill failed, its next step might be to cut the riser, remove the lower marine riser package, and install a second BOP on top of the existing BOP to shut in the well.[174] The theorized collapse of the rupture disks, however, took capping the well off the table. If BP shut the well in and hydrocarbons were flowing up the annulus between the production and 16" casings—as would have been necessary to cause the rupture disks to collapse during the blowout—the hydrocarbons in this annulus would follow the path of least resistance. They would flow out the rupture disks and into the rock formation in what is called a "broach" or "underground blowout." From there, the hydrocarbons could rise through the layers of rock and into the ocean. Containment of hydrocarbons flowing directly from the sea floor, rather than from a single source like the top of a well, is nearly impossible. With BP emphasizing the possible collapse of the rupture disks and risk of broach, shutting in the well—via a second BOP or otherwise—was deemed not viable.[175] In the aftermath of the top kill, BP and the government therefore directed their efforts toward collecting the oil, rather than closing the well, with the relief wells still providing the most reliable avenue for killing the well completely.[176]

C. A Move to Collection



i. The Build-Out of Capacity

Because it had been developing multiple containment options in parallel, BP had a team ready to proceed with new collection efforts almost immediately.[177] On May 29, BP and the government announced that BP would attempt to cut off the portion of the riser still attached to the BOP stack and install a collection device in its place.[178] Like the riser insertion tool and the cofferdam, this new cap or "top hat" was to be connected via a riser to the *Discoverer Enterprise* on the surface.[179] To be prepared for different possible connection points, BP had, by this time, constructed seven different top hats.[180]

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[174] Non-public BP documents; *see also* BP, ANSWERS TO FOLLOW-UP QUESTIONS POSED BY PRESIDENTIAL COMMISSION STAFF (Nov. 2, 2010).

[175] Non-public BP documents; Interview with Doug Suttles. One government official told Commission staff that another concern with installing a second BOP was weight: The existing BOP stack was listing at 2 degrees from vertical, and there was a risk that adding weight to its top would lead to further damage or collapse. Interview with senior administration official.

[176] Non-public BP document; Interview with senior administration official; Interview with Doug Suttles.

[177] Interview with Richard Lynch.

[178] Ongoing Administration-Wide Response to the Deepwater BP Oil Spill (May 29, 2010), http://www.restorethegulf.gov/release/2010/05/29/ongoing-administration-wide-response-deepwater-bp-oil-spill; BP Press Release, Update on Gulf of Mexico Oil Spill (May 29, 2010), http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7062487.

[179] *Id.*

[180] *See* Clifford Krauss and Henry Fountain, *BP Funneling Some of Leaks to Surface*, N.Y. TIMES (June 4, 2010); Interview with Richard Lynch.

The top hat installation was largely successful. On June 1, BP used, through remotely operated vehicles, large hydraulic shears to cut the riser at a small distance from the top of the BOP stack.[181] On June 2, BP deployed a diamond riser saw, which was designed to cut the remaining portion of the riser more cleanly and closer to the top of the BOP stack. The saw, however, became stuck in the riser. BP then used the hydraulic shears to make a more jagged cut in the same area.[182] By 11:00pm on June 3, the top hat was in place and siphoning hydrocarbons to the surface.[183] BP had learned from its cofferdam experience and used methanol injections to prevent formation of hydrates within the top hat.[184] By June 8, the *Discoverer Enterprise* was collecting nearly 15,000 bbls/day through the top hat.[185]

As the top hat collection system ramped up, BP was also developing a system to bring hydrocarbons to the surface through the choke line on the BOP, which BP had used to pump mud and junk during the top kill. Dr. Garwin of the science advisory team first suggested collecting oil through the choke and kill lines on May 12.[186] Following the top kill, BP began to outfit the *Q4000*, a vessel involved in the top kill effort, with equipment including an oil and gas burner brought from France.[187] After some subsea build-out and testing, the *Q4000* system became operational just before 10:00pm on June 16.[188] Once up and running, the *Q4000* was able to process and burn, rather than collect, up to 10,000 bbls/day through the choke line.[189]

The final collection system that BP was able to deploy was the *Helix Producer*, a production ship that connected to the kill line on the BOP through a freestanding riser. The freestanding riser had the advantage of requiring less disconnect and reconnect time than the top hat and *Q4000* in case of a hurricane.[190] It was a key addition to BP's collection capacity, which BP envisioned would eventually reach 90,000 bbls/day.[191] BP began building the first freestanding riser system on May 15, and began building a second on June 7 in order to expand its collection capacity.[192] Nevertheless, the *Helix Producer* only became operational on July 12,[193] and collected hydrocarbons through the first freestanding riser for two days before BP shut in the well on July 15. BP never used the second freestanding riser system, which became unnecessary when the well was capped.[194]

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[181] Non-public government document.
[182] *Day 43: The Latest on the Oil Spill*, N.Y. TIMES (June 2, 2010); The Ongoing Administration-Wide Response to the Deepwater BP Oil Spill (June 3, 2010), http://www.restorethegulf.gov/release/2010/06/03/ongoing-administration-wide-response-deepwater-bp-oil-spill.
[183] Non-public government document.
[184] Interview with Richard Lynch.
[185] Non-public government document.
[186] Interview with government science advisor; Interview with senior administration official.
[187] Non-public government document.
[188] Non-public government document.
[189] Non-public government document.
[190] Letter from Doug Suttles, BP, to Admiral James Watson, FOSC (June 6, 2010).
[191] Letter from Doug Suttles, BP, to Admiral James Watson, FOSC (June 21, 2010).
[192] Letter from Doug Suttles, BP, to Admiral James Watson, FOSC (June 9, 2010).
[193] BP Press Release, Capping Stack Installed on MC252 Well (July 12, 2010), http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7063637.
[194] BP pursued at least one additional long term containment option that involved routing hydrocarbons from the Macondo well through subsea pipelines to either an abandoned well or existing pipelines nearby. Like the second freestanding riser, this containment option was never operationalized. Interview with Richard Lynch.

ii. Collection with Flow Rate as a Moving Target

The underestimates of flow rate that persisted through much of this period may have affected the urgency with which BP pursued additional collection capacity. BP, on occasion, was overly optimistic about the percentage of the oil it could collect with existing equipment. On June 1, Suttles of BP was quoted as saying that he expected the top hat, when connected to the *Discoverer Enterprise* with its 15,000 bbls/day capacity, to be able to collect the "vast majority of the oil."[195] Within days, it became apparent that the top hat and *Discoverer Enterprise* were inadequate.[196] BP made the same mistake with the *Q4000*: On June 6, BP's Hayward told the *BBC* that, with the *Q4000* in place, "we would very much hope to be containing the vast majority of the oil."[197] When the *Q4000* came online in mid-June, the 25,000 bbls/day joint collection capacity between it and the *Discoverer Enterprise* remained insufficient. Suttles has since stated that he was surprised when BP's 25,000 bbls/day capacity was not enough to collect all the oil.[198]

Nonetheless, it is unclear whether BP could have increased its collection capacity more rapidly than it did. Lynch of BP told Commission staff that the speed at which BP brought collection capacity online was limited solely by the availability of dynamically positioned production vessels.[199] One high-level Coast Guard official challenged BP's definition of availability: He told Commission staff that, prior to being pushed by the government, BP did not consider options such as procuring ships on charter with other companies.[200] Had BP obtained another production vessel sooner, it might have been able to collect oil through the BOP's kill line at a rate comparable to the collection rate of the *Q4000*.[201] At the very least, it seems fair to conclude that through the beginning of June, BP did not expect that 25,000 bbls/day of collection capacity would be inadequate. If additional production vessels had in fact been available, BP could have prepared itself for that contingency.

IV. The Science Team's Evolving Role, the Capping Stack, and Killing the Macondo Well

While the basic pieces of the federal oversight structure were in place by mid-May, the oversight process continued to mature throughout June.[202] By mid-June, the roles of different teams were better defined. MMS and the Coast Guard continued to focus on identifying hazards in BP's operational procedures; national labs and U.S. Geological Survey personnel provided

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[195] Helene Cooper and Peter Baker, *U.S. Opens Criminal Inquiry into Oil Spill*, N.Y. TIMES (June 1, 2010).
[196] *See* Clifford Krauss and John M. Broder, *Coast Guard Sees Cleanup of Spill Lasting Until the Fall*, N.Y. TIMES (June 6, 2010).
[197] *BP Captures '10,000 Barrels' a Day in U.S. Gulf*, BBC NEWS (June 6, 2010), http://www.bbc.co.uk/news/10248409.
[198] Interview with Doug Suttles.
[199] Interview with Richard Lynch. Dynamically positioned vessels have computer controlled systems that maintain the vessel's exact position and heading, despite external factors such as wind, waves, and current.
[200] Interview with Coast Guard official.
[201] *See* Letter from Doug Suttles, BP to Admiral James Watson, FOSC (June 9, 2010) (suggesting that with the *Clear Leader* attached to the kill line, BP could collect 5-10,000 bbls/day).
[202] Interview with Coast Guard official; Interview with senior administration official.

information and analysis to the science advisors and, upon request, BP; and the science advisors conducted their own independent analyses, gave "homework" to national labs personnel, and helped inform the government's ultimate decision-makers, including Secretary Chu, Secretary Salazar, Dr. McNutt, Dr. Hunter, Carol Browner, Director of the White House Office of Energy and Climate Change Policy, and Admiral Allen.[203]

Following the failure of the top kill, BP began presenting its source control plans for review by Secretary Chu's science advisors as well as the on-site scientists from the national labs and U.S. Geological Survey. The on-site scientists would then prepare their own analyses of BP's plans. Based upon those analyses, the science advisors would force BP to evaluate worst-case scenarios and plan for contingencies.[204] In essence, they played "devil's advocate," questioning BP's proposals to ensure that BP had fully considered and mitigated even low-probability risks.[205]

The government team saw this questioning of BP's assumptions and risk management as essential. A senior government official characterized BP's attitude prior to the increased supervision as "hope for the best, plan for the best, expect the best."[206] One of the science advisors told Commission staff that, before the science team stepped up its oversight, BP had failed to consistently consider worst-case scenarios.[207] Tooms of BP, on the other hand, expressed frustration to Commission staff about the nature of the science team's pushback, arguing that theoretical scientists consider risk differently than engineers, that BP had expertise in managing risk, and that the science team slowed the containment effort.[208] The government team, however, was skeptical of BP's risk management practices, given that BP's well had just blown out.[209]

In addition to challenging BP's containment ideas, the science advisors developed certain ideas of their own and asked the on-site government engineers to pursue them. Some of the ideas were good ones, as when Dr. Garwin suggested collecting oil through the choke and kill lines.[210] Other ideas required the on-site personnel to expend significant effort proving their lack of feasibility to the off-site science advisors.[211] Several members of the on-site team told Commission staff that, while the science advisors added substantial value in assessing BP's proposals, they could also be a distraction, forcing the on-site team to chase down ideas it found unhelpful and undermining its working relationship with BP engineers.[212]

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[203] Interview with Coast Guard official; Interviews with government scientists; Interview with government science advisor.
[204] Interview with senior administration official; Interview with government scientist.
[205] Interviews with government scientists.
[206] Interview with senior administration official.
[207] Interview with government science advisor.
[208] Interview with Paul Tooms.
[209] Interview with government scientist; *see also* Interview with senior administration official.
[210] Interview with senior administration official.
[211] Interviews with government scientists; Interview with senior administration official.
[212] Interviews with government scientists.

One example cited by multiple members of the national labs team involved the science advisors' interest in obtaining pressure readings from the top hat.[213] Because the top hat was a loose-fitting device, some members of the national labs team felt the data would not be especially useful.[214] In addition, according to an MMS official, inserting a pressure gauge could have hindered collection by blocking a back-up port for injecting methanol into the top hat.[215] At the direction of the science team, BP installed an analog pressure gauge that had to be read visually by a remotely operated vehicle. When this gauge failed, BP installed a second pressure gauge that was physically tethered to a remotely operated vehicle that reported its readings.[216] The vehicle took readings for several days, until lightning hit the *Discoverer Enterprise* on June 15, shutting down the ship's collection capacity for over an hour. After the lightning strike, the gauge recorded only a slight pressure change, even though the pressure in the top hat should have increased significantly due to lack of collection from the ship above.[217] The gauge was probably malfunctioning and, in retrospect, attempting to obtain data from it may not have been the best use of scarce resources (including the remotely operated vehicle that had to stay tethered to the gauge).[218] As one high-ranking government official summed up the effort: Three national labs had teams of scientists trying to make sense of a gauge that was likely clogged with hydrates and frozen in one position, reading nothing.[219]

Another significant change to the oversight structure occurred in mid-to-late June, when the government team began to seek more frequent advice from BP's industry competitors.[220] The government often sought this input through conference calls of thirty or more people, sometimes with BP's participation and sometimes without.[221] One senior government official noted that BP viewed its competitors as suffering from a conflict of interest and that at least some government officials agreed, taking the competitors' advice "with a grain of salt."[222] An industry participant recalled that the calls were fairly disorganized, with no pre-set agenda and people talking over one another.[223] He mentioned one instance when he was chagrined to learn he had been talking to Secretary Chu without realizing it.[224] This individual also explained that industry personnel were concerned about the legal ramifications of their participation, and may have been cautious in giving their opinions as a result.[225] Finally, he noted that he rarely had access to non-public data, which may have hindered his ability to offer informed opinions.[226] Although government personnel told Commission staff that they found the industry input helpful,[227] both the science advisors and industry participants thought that the government could

[213] Interviews with government scientists.
[214] Interview with government scientist.
[215] Interview with MMS official.
[216] Interview with government scientist.
[217] *Id*.; Interview with senior administration official.
[218] Interview with government scientist.
[219] Interview with senior administration official.
[220] Interview with government scientist; Interview with industry executive.
[221] Interview with government scientist; Interview with government science advisor; Interview with industry expert.
[222] Interview with senior administration official.
[223] Interview with industry expert.
[224] *Id.*
[225] *Id.*
[226] *Id*.
[227] Interview with government science advisor; Interview with senior administration official.

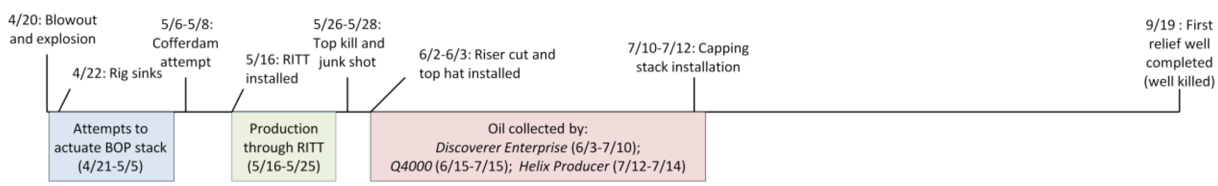
make more effective use of industry expertise in the future by addressing some of these concerns in advance.[228]

The extent of oversight by the science advisors continued to increase throughout June. On June 18, Secretary Chu sent an email to the advisory team, as well as some national labs scientists, describing their expanded role.[229] The next day, Admiral Watson, who had replaced Admiral Landry as the Federal On-Scene Coordinator, issued a letter to BP formalizing the more extensive government review process that had begun after the failed top kill.[230] Going forward, before BP took any action relating to containment, it had to "submit the pending decision"—including conceptual drawings and descriptions of the capabilities and limitations of any equipment and procedures—to the government "for review."[231]

The greater role of the government science teams came as the source control effort approached a critical phase. BP was well on its way toward installing a "capping stack" that could seal tightly over the top of the Deepwater Horizon's BOP stack. Once installed, the capping stack would allow BP to shut the well in completely.

A. The Capping Stack

i. Development, Analysis, and Installation



The capping stack was essentially a smaller version of a BOP.[232] Designed to connect to the top of the Deepwater Horizon's BOP stack, it contained three rams capable of shutting off the flow of hydrocarbons as well as its own choke and kill lines. The idea to install a capping stack was not new. Both Suttles and Tooms of BP told Commission staff that BP internally discussed the idea of a cap with a tight-fitting seal within a week of the blowout.[233] As noted above, BP and the government had shelved the idea of shutting in the well following the top kill, in part because of well integrity concerns relating to the rupture disks in the 16" casing. The government and BP had to consider those concerns when planning for use of the capping stack.

BP's planning for the capping stack operation began in earnest in mid-June, with the national labs providing guidance.[234] One key analysis, performed by BP with national labs support, concluded that the capping stack was not too heavy to be placed on the BOP stack, even

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228 Interview with industry expert; Non-public government science advisor email.
229 Interview with government science advisor.
230 Letter from Admiral James Watson, FOSC, to Doug Suttles, BP (June 19, 2010).
231 *Id*.
232 Interview with senior administration official.
233 Interview with Doug Suttles; Interview with Paul Tooms.
234 Interview with government science advisor; Interview with Richard Lynch.

though the latter was listing at two degrees from vertical.[235] The government also pushed BP to install two pressure sensors in the capping stack.[236] These sensors were accurate to plus or minus two psi; by contrast, the original BOP stack had only one pressure sensor, which was accurate to plus or minus 400 psi.[237] The accurate sensors in the capping stack later proved critical in generating wellhead pressure readings and a flow-rate estimate.

At the end of June or in early July, Dr. Hunter from the science team and James Dupree of BP traveled to Washington, D.C. to brief a group of high-ranking government officials, which included Secretaries Chu and Salazar, Secretary of Homeland Security Janet Napolitano, EPA Administrator Lisa Jackson, Browner, and Dr. Jane Lubchenco, Administrator of the National Oceanic and Atmospheric Administration.[238] The briefing presented the capping stack as the preferred course forward, and the high-ranking officials gave their approval.[239] The next day, Secretary Chu and Dr. Hunter briefed the President, who gave his approval as well.[240]

It appears that the government delayed installation of the capping stack for a few days to continue analyzing the significant risks associated with shutting in the well.[241] One key analysis was of the geology surrounding the Macondo well. Because the condition of the well was unknown, this analysis assumed the rupture disks in the 16” casing had collapsed and examined whether, if the well were shut in, hydrocarbons that escaped sideways into the rock formation would travel up into the ocean. The government’s Well Integrity Team, led by scientists from the national labs and the U.S. Geological Survey and supported by experts from industry, academia, and MMS, presented their findings on this question in a July 12 report.[242] The Team analyzed the geologic conditions near the most likely point of escape, and concluded that it would take a total of approximately 100,000 barrels flowing through the rupture disks for oil to create one or more paths up to the sea floor.[243] After initially preferring a more optimistic estimate—i.e., believing that a larger volume of escaping oil was necessary for oil to reach the sea floor[244]—BP appears to have accepted this analysis.[245]

The Well Integrity Team next examined whether—assuming that shutting in the well caused oil to flow through the rupture disks, into the formation, and up to the sea floor—the flow paths up to the sea floor would close or “heal” if BP reopened the capping stack. The Team’s conclusion, supported by a consensus of industry representatives who considered the question on a conference call, was that the path would heal *if* BP reopened the capping stack with sufficient speed.[246] Industry participants and the Well Integrity Team were most concerned that flow paths between the well’s steel casings and the surrounding rock would develop and remain open,

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[235] Non-public government document.
[236] Non-public government document; Interview with government science advisor.
[237] Interview with government science advisor.
[238] Interview with government science advisor.
[239] *Id.*
[240] *Id.*
[241] BP, ANSWERS TO FOLLOW-UP QUESTIONS POSED BY PRESIDENTIAL COMMISSION STAFF; Interview with Richard Lynch; Interview with Paul Tooms; Non-public government document.
[242] Non-public government document.
[243] *Id.*; Interview with government scientist; Non-public government science advisor notes.
[244] Interview with senior administration official.
[245] Non-public BP document.
[246] Interview with government scientist; Interview with industry expert.

resulting in an uncontrolled flow of oil to the sea floor.[247] The Team's final step was to consider what monitoring protocol would detect possible leaks into the rock formation in time to reopen the stack and to avoid creating a permanent flow path to the sea floor. The Team settled on a multi-tiered approach that involved visual, seismic, and sonar monitoring from ships and remotely operated vehicles, acoustic monitoring from a sensor at the wellhead, and wellhead pressure monitoring from gauges in the capping stack—all aimed at determining whether the well's integrity had been compromised and oil was flowing sideways into the rock.[248]

A second set of concerns related to closing the capping stack involved the risk that capping would increase the pressure inside the well and burst either the rupture disks (if they had not already collapsed) or the outermost casings between the top of the 16" casing and the wellhead.[249] BP and the government were worried that capping could cause pressure at the wellhead to reach 8,900 psi,[250] and pressures farther down the well to reach levels high enough to cause new ruptures.[251] One industry executive recalled discussing this issue on a conference call with the science advisors. On the call, he expressed concern with allowing pressure at the wellhead to climb above the pressures recorded during the top kill (about 6,300 psi).[252] In his view, that would be traveling in uncharted territory, with uncertain risks.[253]

In early July, as analysis of these concerns continued, BP prepared to install the capping stack. In a July 8 letter, Admiral Allen told BP that, going forward, it would need his approval before taking action on key "decision points."[254] The next day, he authorized BP to proceed with installation, but not to close the stack.[255] The operation began on July 10 and was extremely complicated. After removing the top hat from the top of the riser, remotely operated vehicles had to unbolt the stub of riser connected to the top of the BOP stack, remove this stub, assess whether pieces of drill pipe were sticking up through the top of the BOP stack, slide the capping stack into place, and bolt the capping stack to the top of the BOP stack. BP's Lynch told Commission staff that the installation team had closely examined each individual bolt that had to be removed with a subsea hydraulic wrench and determined the appropriate tool shape and torque to be applied.[256] BP had run through the entire operation on land. It had also practiced using remotely operated vehicles to remove bolts on the piece of riser lying on the seabed, which it had previously cut from the top of the BOP stack.[257] The capping stack was installed without

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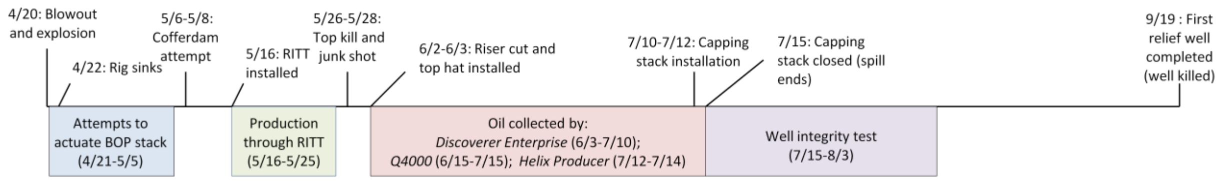
[247] Interview with senior administration official.
[248] Interview with government scientist.
[249] Interview with government science advisor.
[250] *Id.*; Non-public government document.
[251] Interview with government science advisor.
[252] Interview with industry expert; Non-public BP document.
[253] Interview with industry expert.
[254] Letter from Admiral Thad Allen, NIC, to Bob Dudley, BP (July 8, 2010). This appears to be the first directive issued by Admiral Allen to BP regarding its well control plans. From this point on, his personal authorization was necessary before major operations could commence.
[255] Letter from Admiral Thad Allen, NIC, to Bob Dudley, BP (July 9, 2010); Non-public government document.
[256] Interview with Richard Lynch.
[257] Interview with Richard Lynch; Interview with Doug Suttles.

incident by July 12.[258] Suttles described the installation process as the best source control operation of the entire containment effort.[259]

ii. Shut-In



After installation, BP prepared to temporarily shut the capping stack in a planned "well integrity test" to determine whether the well had been compromised and oil could flow sideways into the formation. Admiral Allen explained the need for the test in a public statement: "The measurements that will be taken during this test will provide valuable information about the condition of the well below the sea level and help determine whether or not it is possible to shut the well for a period of time, such as during a hurricane or bad weather, between now and when the relief wells are complete."[260] The test was to last anywhere from 6 to 48 hours, depending on the measurements observed.[261] In a July 12 letter, Admiral Allen formally authorized the test to begin.[262]

The well integrity test as authorized on July 12 never occurred. About two hours before it was to begin on July 13, the government team, including the science advisors, met with BP and industry representatives, including Exxon (in person) and Shell (over the phone).[263] Secretary Chu and Admiral Allen were both present in person.[264] According to Tooms of BP, participants in the meeting, especially Exxon, questioned the wisdom of the test.[265] The science advisors had asked industry representatives to identify potential risks for the government's consideration, and Exxon and Shell did so, raising new concerns about well integrity that had yet to be considered by BP or the government.[266] Because Secretary Chu and the science advisors believed that these risks required further consideration,[267] Admiral Allen delayed the well integrity test to allow for 24 hours of additional analysis.[268]

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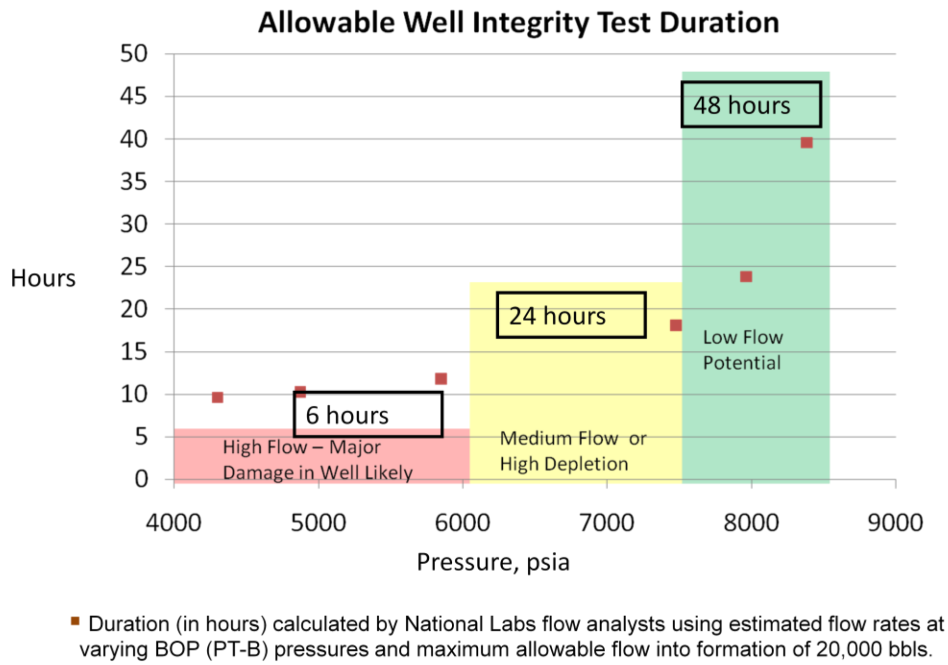
[258] Statement from National Incident Commander Admiral Thad Allen on Well Integrity Test (July 12, 2010), http://www.restorethegulf.gov/release/2010/07/12/statement-national-incident-commander-admiral-thad-allen-well-integrity-test.
[259] Interview with Doug Suttles.
[260] Statement from National Incident Commander Admiral Thad Allen on Well Integrity Test (July 12, 2010).
[261] *Id.*
[262] Letter from Admiral Thad Allen, NIC, to Bob Dudley, BP (July 12, 2010).
[263] Interview with government scientist.
[264] *Id.*
[265] Interview with Paul Tooms.
[266] Interview with government scientist; Interview with government science advisor; Interview with industry executive.
[267] Interview with government scientist.
[268] Statement from National Incident Commander Admiral Thad Allen on Well Integrity Test (July 13, 2010), http://www.restorethegulf.gov/release/2010/07/13/statement-national-incident-commander-admiral-thad-allen-well-integrity-test.

Overnight, the government science teams reached out to additional experts from industry and academia to evaluate the concerns that Exxon and Shell had raised.[269] By 10:00 the next morning, those experts had reassured the government that the risks were manageable.[270] With the government teams satisfied, Admiral Allen reauthorized the well integrity test.[271] Again the test was to last from 6 to 48 hours, and the government required BP to continuously monitor pressure, sonar, acoustic, and visual data as recommended by the Well Integrity Team.[272]

Reflecting the more rigorous oversight that followed the failed top kill, the government and BP developed a much more structured protocol for implementing the well integrity test than had existed for the top kill. Although the Well Integrity Team had calculated that it would take a total leak of approximately 100,000 barrels for hydrocarbons to reach the sea floor, the government determined that it would permit a leak of only 20,000 barrels before requiring the capping stack to be reopened.[273] Using this figure and an estimate for the expected pressure at shut-in derived from BP's modeling of the reservoir, the Well Integrity Team created guidelines for the test.[274] If the pressure at shut-in was less than 6,000 psi, major well damage was likely: BP would have to terminate the test within six hours and reopen the well.[275] If the shut-in pressure was greater than 7,500 psi, the risk of a leak was low, and the test could proceed for the full 48 hours.[276] Finally, if the shut-in pressure was between 6,000 and 7,500 psi, the risk of a leak was uncertain—either there was a medium-sized leak into the formation or the reservoir was highly depleted.[277] Under this scenario, the test could proceed for 24 hours.[278] These guidelines were condensed into a simple graphic, reproduced as Figure 4. As noted above, if the pressure was very high, there was also the risk of causing a new rupture.

[269] Interview with senior administration official.
[270] *Id.*
[271] Letter from Admiral Thad Allen, NIC, to Bob Dudley, BP (July 14, 2010).
[272] *Id.*; Interview with government scientist; Interview with senior administration official.
[273] Interview with government scientist; Interview with senior administration official; Non-public government document.
[274] Non-public government document; Interview with government scientist.
[275] Non-public government document.
[276] *Id.*
[277] *Id.*
[278] *Id.*

Figure 4[279]



After a 24-hour delay to repair a minor leak discovered in the capping stack, BP shut the stack and began the well integrity test at 2:25pm on July 15.[280] For the first time in 87 days, no oil flowed into the Gulf of Mexico. Initial wellhead pressure readings were just over 6,600 psi, squarely in the uncertain middle range, and rising slowly.[281] Later that afternoon, the science advisors, including Dr. McNutt and Dr. Hunter, met with Secretaries Salazar and Chu to consider the pressure data and whether to keep the well shut in. A member of the Well Integrity Team reported that, according to his original model, the shut-in pressure indicated a leak into the formation of about 3,500 bbls/day.[282] From there, discussion within the group appears to have turned firmly against keeping the well closed. Dr. Garwin, who had opposed even undertaking the well integrity test,[283] voiced the strongest opinion to that effect.[284] He argued that BP ought to stop the test immediately and wondered whether it was already too late.[285] Several participants were concerned that the monitoring systems might be unable to detect leakage.[286] No one at the meeting appears to have argued in favor of keeping the well shut in.[287] After an hour and a half, a consensus among the science advisors had developed: Oil was leaking into the

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[279] Derived from Non-public BP document.
[280] Campbell Robertson and Henry Fountain, *BP Says Oil Flow Has Stopped as Cap Is Tested*, N.Y. TIMES (July 15, 2010).
[281] Non-public government document; Non-public government science advisor notes.
[282] Non-public government science advisor notes.
[283] Interview with government scientist; Interview with MMS official; Interview with government science advisor. Dr. Garwin advocated continued surface collection as well as the immediate development of a subsea collection system, with oil-gas separation and storage capacity, for use if a hurricane required the evacuation of surface vessels.
[284] Non-public government science advisor notes; Interview with government science advisor.
[285] Non-public government science advisor notes.
[286] *Id.*
[287] *Id.*

formation, and the Coast Guard should order BP to reopen the capping stack and resume collecting oil from the well.[288]

BP evidently learned of this emerging consensus within the government to reopen the capping stack, and became concerned. Suttles called MMS Regional Director Lars Herbst to ask for his view of the well integrity test.[289] Herbst, who had not participated in the meeting with the science advisors, examined the pressure data and agreed with BP that the well should stay closed overnight.[290] BP apparently relied in part on Herbst's support in making its case to the government that the well should remain shut in.[291]

Following meeting with the science advisors, Admirals Allen and Cook, Browner, Secretaries Chu and Salazar, Dr. McNutt, and perhaps others had a series of conversations to determine how to proceed.[292] The stakes were high. Keeping the stack shut could cause an underground blowout and, in the worst case, loss of a significant portion of the 110 million barrel reservoir into the Gulf.[293] That risk had to be balanced against the need to stop the spill, an ongoing environmental disaster.[294] Participants in the conversations were aware of the importance and public impact of their decision: The public wanted the well shut in and the flow of oil into the Gulf stopped, but the risk of causing greater harm was real.[295]

According to interviews conducted by Commission staff, Admiral Cook made the argument that eventually prevailed. He reminded the others that, before the test began, BP and the government had considered the possibility of pressure measurements like those being observed. Both parties had agreed that, in such a case, the test should last 24 hours, with consultation between the parties prior to reopening the well.[296] One participant recalled general agreement that, while the data supported reopening the capping stack, under the guidelines established prior to shut-in, the stack could stay closed during the night.[297]

This additional time proved critical. Steve Hickman of the U.S. Geological Survey was in BP's Houston headquarters as pressure data started coming in during the afternoon and evening of July 15. Using the camera on his cellular phone, he took a picture of the initial "pressure curve," or plot of pressure readings during the shut in, and sent it to Paul Hsieh, another U.S. Geological Survey member of the Well Integrity Team who was then in Menlo Park, California.[298] BP had earlier sent an email to government and BP personnel indicating that the results of the well integrity test were "market sensitive," and warning against sharing data due to concerns about insider trading.[299] Although the email indicated that information about

[288] *Id.*
[289] Interviews with government officials.
[290] Interview with government official.
[291] *Id.*
[292] Interview with senior administration official; Non-public government science advisor notes.
[293] Interviews with government scientists.
[294] Interviews with government scientists.
[295] Interview with government scientist.
[296] Interview with Coast Guard official; Interview with senior administration official.
[297] Interview with government science advisor.
[298] Interview with senior administration official; Interview with government scientist.
[299] Non-public BP email.

how the test was progressing could be communicated to others if it was "strictly necessary for the procedure,"[300] Hsieh apparently relied on the data in the single cellular phone picture to model the reservoir.[301]

Overnight, Hsieh attempted to develop a model that explained the results of the well integrity test. The biggest question was why the pressure had climbed above 6,600 psi but not to the minimum expected shut-in pressure of 7,500 psi.[302] The answer was that the expectation had been based on an incomplete understanding of the reservoir's geometry and on pressure readings from a gauge at the bottom of the BOP, which was inaccurate and functioning only sporadically.[303] Using accurate pressure readings from the capping stack, along with a flow-rate estimate of 55,000 bbls/day and BP's estimate that the reservoir originally contained 110 million barrels of oil, Hsieh was able to generate a model of the depleted reservoir that predicted the observed shut-in pressures without having to assume a significant leak into the formation.[304]

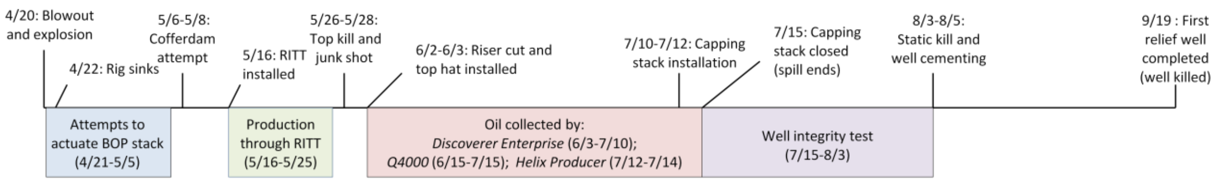
The next morning, the government principals and the science advisors—who had been convinced the night before that opening up the stack was necessary—hosted a meeting. BP presented its explanation of why pressures had built to the level observed and argued, in detail, that the well should remain shut in.[305] Hsieh also presented his model, demonstrating that there was a reasonable explanation for why the pressure was lower than expected.[306] Participants with whom staff spoke had different recollections as to whether BP's or Hsieh's presentation carried more weight.[307] The outcome of the meeting, however, was clear. The stack would stay shut, with government reevaluation of that decision every six hours.

Unrealized at the time, a critical point had passed: BP would not have to reopen the stack, and oil had finally stopped leaking from the Macondo well into the Gulf. Intense monitoring of the area around the wellhead continued and, on July 17, increased.[308] That day, the government brought in a sonar ship from the National Oceanic and Atmospheric Administration and doubled the number of seismic mapping runs over the site.[309] As more time passed, Hsieh was able to improve his model using seismic data. The model continued to predict the behavior of the well, and a leak into the formation became a less and less likely scenario.[310] Although the well integrity test had originally been scheduled to last a maximum of 48 hours, Admiral Allen began to extend it in 24-hour increments beginning on July 17.[311] With each

[300] *Id.*
[301] Interview with government scientist; Interview with senior administration official.
[302] Interview with government scientist.
[303] Interview with government scientist; Interview with government science advisor.
[304] Interview with government scientist; Interview with senior administration official; Non-public government document.
[305] Interview with Paul Tooms.
[306] Interview with government scientist; Interview with senior administration official.
[307] Interviews with government science advisors; Interview with senior administration official.
[308] Statement by National Incident Commander Admiral Thad Allen on Well Integrity Test (July 17, 2010), http://www.restorethegulf.gov/release/2010/07/17/statement-national-incident-commander-admiral-thad-allen-well-integrity-test.
[309] *Id.*
[310] Interview with government scientist.
[311] Statement by National Incident Commander Admiral Thad Allen on Well Integrity Test (July 17, 2010).

passing day, the government grew more certain of the well's integrity.[312] On July 24, in his daily press briefing, Admiral Allen stated that "our confidence [in the capping stack] is increasing and we have better integrity in the well than we may have guessed."[313]

B. Killing the Well



While the capping stack remained in place, with pressure inside it continuing to build, BP raised the possibility of killing the well before the relief wells were completed through a procedure called a "static kill" or "bullhead kill." Like the top kill, the static kill involved pumping heavy drilling mud into the well in an effort to push hydrocarbons back into the reservoir. Because the hydrocarbons were already static, however, the necessary pumping rates for the static kill to succeed were far lower than for the top kill. BP first publicly mentioned use of a static kill on July 19, in a letter from Bob Dudley, then heading BP's response in the Gulf, to Admiral Allen.[314] In a presentation dated July 21, BP made the case for the static kill to government scientists.[315] If successful, the kill would reduce or eliminate the pressure within the capping stack and hydrostatically contain the well during hurricane season.[316]

BP could not, however, immediately move forward with the static kill. The government and BP appear to have agreed that, before the static kill could begin, BP should finish running and cementing a casing in the first relief well, which was then only a few lateral feet from the Macondo well.[317] This avoided leaving an open well and potential flow path near a part of the

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[312] Interview with government science advisor. There were, however, at least two occasions when reopening the capping stack was a possibility. On July 18, a seep of methane was discovered some distance from the well; by the next day, however, it became clear that the seep was natural and not a leak from Macondo well. Letter from Admiral Thad Allen, NIC, to Bob Dudley, BP (July 18, 2010); Statement by National Incident Commander Admiral Thad Allen (July 19, 2010), http://www.restorethegulf.gov/release/2010/07/19/statement-national-incident-commander-admiral-thad-allen; Henry Fountain, *BP Considers New Plan To Permanently Seal Well*, N.Y. TIMES (July 19, 2010). On July 22, with Tropical Storm Bonnie bearing down on the Gulf, Admiral Allen, on the advice of Secretary Chu, decided to keep the well shut in while some of the ships monitoring the capping stack and well had to evacuate. Statement by National Incident Commander Admiral Thad Allen on Tropical Storm Bonnie (July 22, 2010), http://www.restorethegulf.gov/release/2010/07/22/statement-national-incident-commander-admiral-thad-allen-tropical-storm-bonnie; Henry Fountain, *Storm Threat Forces Ships To Leave Oil Spill Site*, N.Y. TIMES (July 22, 2010).
[313] Press Briefing by National Incident Commander Admiral Thad Allen and NOAA Administrator Dr. Jane Lubchenco (July 24, 2010), http://www.restorethegulf.gov/release/2010/07/24/transcript-press-briefing-national-incident-commander-admiral-thad-allen-and-noaa.
[314] Letter from Bob Dudley, BP, to Admiral Thad Allen, NIC (July 19, 2010).
[315] Non-public BP document.
[316] *Id.*
[317] *Id.*; Press Briefing by National Incident Commander Admiral Thad Allen (July 21, 2010), http://www.restorethegulf.gov/release/2010/07/21/transcript-pressbrief-national-incident-commander-admiral-thad-allen-july-21-2010.

Macondo well where there had been well integrity concerns.[318] With Tropical Storm Bonnie approaching, the *Development Driller III*, which was drilling the first relief well, had to leave the drill site before its crew could run and cement the casing.[319] Although the rig was able to return and restart work by July 25,[320] the work was delayed by debris that had accumulated in the well,[321] and BP was not able to finish running and cementing the casing until August 2.[322]

Aside from the relief well, the government's major concern with the static kill was the pressure it would put on the Macondo well. The science advisors discussed with industry experts whether it was wise to increase the pressure on the well beyond what the shut-in had indicated the well could hold.[323] On July 28, BP received an unsolicited letter from Pat Campbell, a Vice-President at Superior Energy Services, which owned BP contractor Wild Well Control, recommending in no uncertain terms that the static kill not proceed.[324] Campbell, who had worked with legendary well control expert Red Adair and had been profiled in the *New York Times* prior to the top kill,[325] reiterated the concerns that had been expressed to the science team by industry—namely, that the only pressure the well could withstand for certain was the shut-in pressure, approximately 6,920 psi at the time he wrote the letter.[326] According to Tooms, Campbell privately assured BP that, through the letter, he was only hoping to limit his company's exposure to liability if the static kill went awry.[327] Commission staff have not been able to corroborate Tooms's recollection of the letter through interviews with individuals outside BP.[328]

Despite Campbell's concern, by the time the *Development Driller III* had finished cementing the casing in the relief well, the government team had approved the plan for the static kill.[329] BP would have to abort the kill if the pressure at the wellhead exceeded 8,000 psi, significantly less than the capping stack's pressure rating.[330] A mud injection test began on August 3, and pressure at the wellhead increased by only approximately 35 psi before beginning

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[318] Press Briefing by National Incident Commander Admiral Thad Allen (July 21, 2010), http://www.restorethegulf.gov/release/2010/07/21/transcript-pressbrief-national-incident-commander-admiral-thad-allen-july-21-2010.
[319] Press Briefing by National Incident Commander Admiral Thad Allen (July 23, 2010), http://www.restorethegulf.gov/release/2010/07/23/transcript-press-briefing-national-incident-commander-admiral-thad-allen-july-23-.
[320] Press Briefing by National Incident Commander Admiral Thad Allen (July 25, 2010), http://www.restorethegulf.gov/release/2010/07/25/transcript-press-briefing-national-incident-commander-admiral-thad-allen.
[321] Press Briefing by National Incident Commander Admiral Thad Allen (July 23, 2010), http://www.restorethegulf.gov/release/2010/07/30/transcript-press-briefing-national-incident-commander-admiral-thad-allen.
[322] Non-public government document.
[323] Interview with industry expert.
[324] Letter from Pat Campbell, Superior Energy Services, to Richard Lynch, BP (July 28, 2010).
[325] *See* Henry Fountain, *Expert is Confident about Sealing Oil Well*, N.Y. TIMES (May 24, 2010).
[326] Letter from Pat Campbell.
[327] Interview with Paul Tooms.
[328] Interview with well control expert.
[329] Press Briefing by National Incident Commander Admiral Thad Allen (Aug. 2, 2010), http://www.restorethegulf.gov/release/2010/08/02/transcript-press-briefing-national-incident-commander-admiral-thad-allen.
[330] *Id.*; Non-public government document.

to drop.[331] Based on these positive results, BP began slowly pumping more heavy drilling mud into the well later that day and, at 11:00pm, achieved hydrostatic control of the well.[332] On the evening of August 4, Admiral Allen authorized BP to follow the mud with cement,[333] a process that BP completed the next day.[334] Finally, on August 8, Admiral Allen reported that BP had pressure-tested the cement, which was holding.[335]

BP proceeded to finish drilling the first relief well to finally kill the Macondo well. On September 19, 152 days after the April 20 blowout, Admiral Allen announced the end of the source control effort:

> After months of extensive operations planning and execution under the direction and authority of the U.S. government science and engineering teams, BP has successfully completed the relief well by intersecting and cementing the well nearly 18,000 feet below the surface. With this development, which has been confirmed by the Department of the Interior's Bureau of Ocean Energy Management, we can finally announce that the Macondo 252 well is effectively dead.[336]

V. Issues for Commission Consideration

There were many success stories in the effort to control the Macondo well, including, but not limited to, the ultimate successes of capping and killing it. The operation of numerous ships and remotely operated vehicles, in close proximity to one another and to gushing hydrocarbons, with no significant accidents was a credit both to BP's controls and to the Coast Guard and MMS officials who reviewed BP's procedures. BP's efforts to develop multiple source control options simultaneously were herculean. And the speed with which government scientists, with little background in deep-sea petroleum engineering, established meaningful oversight was truly impressive. The hundreds of individuals who spent the spring and summer of 2010 working to stop the spill, under enormous pressure and conditions of great uncertainty, have much in which to take pride.

These remarkable efforts were necessary, however, because of a lack of advance preparation by industry and government. The story of source control during the Deepwater Horizon spill therefore suggests the following potential findings and lessons for Commissioner consideration.

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[331] BP Press Release, Static Kill Injectivity Testing Commences on MC252 Well (Aug. 3, 2010), http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7064164; Non-public government document.
[332] BP Press Release, Well Reaches Static Condition; Well Monitoring Underway (Aug. 4, 2010), http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7064173.
[333] Statement by National Incident Commander Admiral Thad Allen (Aug. 4, 2010), http://www.restorethegulf.gov/release/2010/08/04/statement-national-incident-commander-admiral-thad-allen.
[334] Non-public government document.
[335] Face the Nation, CBS NEWS (Aug. 8, 2010), http://www.cbsnews.com/htdocs/pdf/FTN_080810.pdf.
[336] Statement from Admiral Allen on the Successful Completion of the Relief Well (Sept. 19, 2010), http://www.restorethegulf.gov/release/2010/09/19/statement-admiral-allen-successful-completion-relief-well.

First, beyond attempting to close the BOP stack and drilling a relief well, at the time of the blowout on April 20, there were no proven options for source control in deepwater. Although BP was able to develop new source control technologies in a compressed timeframe, the containment effort would have benefited from prior research and development, preparation, and contingency planning. The Deepwater Horizon experience suggests that deepwater operators should be required to create detailed source control plans that demonstrate their ability to respond to blowouts. The Commission may wish to recommend subjecting those source control plans to review by agencies with relevant expertise as well as outside experts.

Second, at the time of the blowout, the government was unprepared to oversee a deepwater source control effort. After the spill began, the public expected such oversight, but neither MMS nor the Coast Guard had the expertise to supervise BP's decisions. An effective oversight structure was not in place until late May. The delay may have contributed to a public impression that BP was running the source control effort. This experience suggests that, to provide meaningful supervision, the government needs access to sufficient expertise in deepwater drilling and containment—through the Department of the Interior, the national labs, outside scientists, or otherwise. Thus, the Commission may wish to recommend that the government develop and maintain additional in-house expertise in petroleum engineering, as well as formalize procedures to make the best use of outside industry experts during an incident.[337]

Third, underestimates of the flow rate appear to have impeded planning for source-control efforts like the cofferdam and, especially, the top kill. These underestimates may also have led BP to misinterpret the top kill's failure as evidence of a well integrity problem. Dr. McNutt recently stated that, if a similar blowout occurs in the future, the government will be able to quickly and reliably estimate the flow rate using the oceanographic techniques that eventually provided an accurate estimate of the flow from the Macondo well.[338] This suggests that the government and responsible party should prioritize accurate estimation of flow rate early in a well control effort.

Fourth, the lack of reliable diagnostic tools—such as accurate pressure gauges at the wellhead and a means of understanding the position of the BOP's rams—complicated the containment effort. The government and BP expended significant resources on attempts to collect data, like gamma-ray imaging of the BOP stack and inserting pressure sensors in the top hat. The lack of reliable data suggests that the government should require industry to equip BOP stacks with diagnostic tools that would provide more information in the case of a blowout.

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[337] On November 2, 2010, Secretary Salazar proposed to establish an Ocean Energy Safety Institute, to be housed at the Department of the Interior. Through partnerships across government agencies, with industry, and with the scientific and academic communities, the Institute intends, among other things, to develop "an expertise base useful both for preventing and responding to accidents," as well as "a larger cadre of technical experts who can oversee or otherwise participate in deepwater drilling-related activities." Department of the Interior Press Release, Salazar Proposes Ocean Energy Safety Institute (Nov. 2, 2010). Because this proposal is at an early stage, it is as yet unclear to Commission staff whether the Institute will be a source of the government expertise needed to oversee a deepwater source control effort and a vehicle to access industry expertise during such an effort.

[338] Transcript, Deepwater Blowout Containment Conference (Sept. 22, 2010), http://www.doi.gov/news/video/Deepwater-Blowout-Containment-Conference.cfm.

Fifth, in designing the Macondo well, BP does not appear to have considered how its use of rupture disks would impact the integrity of the well during a post-blowout source control effort.[339] Concerns about integrity—focused primarily, but not entirely, on the rupture disks—significantly complicated the process of controlling the Macondo well. By highlighting the problem of the rupture disks, Commission staff do not intend to suggest that use of such disks is inappropriate. Staff have been told that rupture disks may play an important role in relieving annular pressure under certain circumstances.[340] The Deepwater Horizon experience, however, raises a larger concern. As one BP well control contractor told Commission staff, it is not standard industry practice to consider, at the well design phase, what would happen if an operator were to lose control of the well.[341] The drawn-out effort to control the Macondo well suggests that this practice should change: Operators and government regulators should consider the potential need for post-blowout source control at the well design stage.

Sixth and finally, because BP is one of the world's largest companies, it had the resources to bankroll and implement a massive containment effort—and still needed 87 days to stop the flow of oil into the Gulf. All deepwater operators do not have BP's resources. The Commission may wish to consider recommendations aimed at requiring smaller deepwater operators to demonstrate the capacity to respond to a disaster of this magnitude, whether through bonding or insurance, membership in industry consortia focused on well control, or otherwise.

[339] Interview with Doug Suttles. On October 14, Commission staff asked to speak in more depth about well design with a representative of BP. As of this writing, staff has not received a response.
[340] Interview with Paul Tooms.
[341] Interview with well control expert.