The Next Generation of Planning for Offshore Oil Spill Response

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ABSTRACT 2017-333:

In 2014, the Bureau of Safety and Environmental Enforcement (BSEE) commissioned a study to inform an update of Oil Spill Response Plan (OSRP) regulations for offshore oil and gas facilities and pipelines at Title 30, Code of Federal Regulations, Part 254. The study, *Oil Spill Response Equipment Capability Analysis*, was conducted by a team led by Booz Allen Hamilton (Booz Allen), with support from RPS Group (formerly ASA Sciences), Environmental Research Consulting (ERC), and SEA Consulting. In close coordination with BSEE, the Booz Allen team reviewed eleven worst case discharge (WCD) scenarios in the Gulf of Mexico, Alaska, and Pacific Outer Continental Shelf (OCS) Regions. The study, which involved literature reviews, oil spill modeling, and benchmarking against foreign and domestic regulatory regimes, concluded in February 2016, and highlighted many areas for improving the requirements for response capabilities in the OSRPs.

This paper focuses on the key spill modeling methodologies, observations, and results in the *Oil Spill Response Equipment Capability Analysis* study, and its use of a concept of operations (CONOPS) for the application of various oil spill countermeasures in response to a WCD. The modeling results provided both new insights and reaffirmed many principles that have long guided oil spill response operations. The CONOPS systematically rolls them up into an offshore-based construct for employing multiple countermeasures in ways that will most effectively reduce oil contact with the environment. This effort did not attempt to quantify environmental impacts or provide guidance on applying countermeasures based upon a net environmental benefits analysis (NEBA) or spill impact mitigation analysis (SIMA). Decision-making for implementing the CONOPS will still require an additional overlying comparative analysis that evaluates the environmental, cultural, social and economic tradeoffs in order to find the preferred balance of spill countermeasures for a given planning scenario or incident. Regardless, the use of the construct (or CONOPS) as outlined in the study offers sound improvements for response planning involving very large spills in the offshore environment.

STUDY METHODOLOGIES

Oil Plume, Fate and Transport Modeling

The study *Oil Spill Response Equipment Capability Analysis* uses computer modeling to simulate 11 WCD scenarios to explore the application of different oil removal countermeasures and compare the outcomes for oil contact with the ocean surface and shorelines. Nine hypothetical discharge locations were selected for modeling: six in the Gulf of Mexico, one in the Pacific off the coast of California, and two in the Arctic off the coast of Alaska. The arctic scenarios were modeled with starting times both early in the open water season (no sea ice), and later in the season when sea ice was present for part of the simulation. The 11 scenarios were designed to investigate potential oil spill trajectories and response efforts across a variety of distances from shore, geographic locations, oil types, water depths, and discharge volumes.

Table 1. WCD Model Scenario Characteristics

Lease Block	Water Depth (ft.)	Distance from Shore (NM)	WCD Daily Flowrate (bbls/day)	Oil Name/°APIGravity[b]
Gulf of Mexico OCS Region				
Mississippi Canyon (MC807)	3,030	46	449,000	South Louisiana Crude / 34.5
West Delta (WD28)	35	5.6	97,000	
West Cameron (WC168)	42	25	26,400	South Louisiana Condensate / 57.5
High Island East (HIA376)	334	112	77,000	South Louisiana Crude / 34.5
Keathley Canyon (KC919)	6,940	217	252,000	
DeSoto Canyon (DC187)	4,490	101	241,000	
Pacific OCS Region (Southern California Planning Area)				
Santa Maria (SM6683)	1,073	8	5,200	Point Arguello Light Crude / 30.3
Alaska OCS Region (Chukchi Sea Planning Area[a])				
Posey (P6912)	150	60	25,000	Alaskan North Slope Crude / 30.9
Alaska OCS Region (Beaufort Sea Planning Area[b])				
Flaxman Island (FL6610)	120	1 to 4	16,000	Prudhoe Bay Crude / 24.8

[a] For each of the two Arctic locations, there are two seasonal scenarios – one early and one late season, the latter of which may involve ice.

[b] An alternative measure of density of oil; the higher the °API, the lighter the oil.

The fate and transport of the WCDs were modeled in two phases: the subsea release of oil was modeled with the OILMAPDeep^{TM} model, and the surface transport of oil was modeled with the SIMAP^{TM} model. Both models were developed by project team member RPS. OILMAPDeep modeled the oil and gas jet and described the behavior of the resulting plume of oil, gas, and water produced during a subsea blowout. The results obtained from this “near-field” plume analyses were used as the starting conditions for the subsequent “far-field” modeling of the oil transport in SIMAP. SIMAP modeled the transport and weathering of oil based on the oil properties and metocean conditions that were specific to the site and seasonality of each WCD scenario. Additionally, SIMAP estimated cumulative environmental exposure outcomes by tracking and quantifying the surface area swept by floating oil of varying thicknesses, the fate and concentrations of oil in the water column, and the location and quantity of oil stranded on shorelines.

Spill Response Countermeasures Modeling

Information was collected on the availability of spill response equipment in each OCS region to generate inputs for the modeling of spill response efforts. Surveys of major offshore Oil Spill Removal Organizations (OSROs) and other operator-owned response equipment were conducted to catalogue the types, quantities, and mobilization times for existing response equipment, including mechanical recovery skimmers, vessels for skimming and in situ burning, source control devices, and aircraft and dispersant stockpiles for dispersant application. The survey assumed that sufficient numbers of trained personnel and adequate arrangements for secondary temporary storage units were in place to support the identified equipment inventories. Daily oil removal rates were calculated for each major response system using the National Atmospheric and Oceanic Administration (NOAA) In Situ Burn Calculator, the NOAA Dispersant Mission Planner 2, and the Estimated Recovery System Potential (ERSP) Calculator (Genwest, Inc, 2016). The oil removal rates that were estimated by the calculators factored in each system's potential to encounter oil, and in the case of mechanical recovery systems, their ability to also store and offload oil. For source control**,** companies were surveyed to identify the location and quantity of well capping devices, as well as provide realistic estimates for mobilization and deployment times.

Following the collection of information on quantities and types of response equipment, model assumptions were developed to guide the application of the different oil removal countermeasures. Countermeasure operations were assumed to occur during daylight hours only (12 hours per day), with the exception of mechanical recovery systems with remote sensing capabilities, which were allowed to operate for longer periods (up to 18 hours).

As weathering and emulsification processes occur, oil becomes more viscous (by as much as 1,000 times) and increases in water content to about 70% (Fingas 2001, 2011a, 2011b). Within the SIMAP model, operating thresholds for weather conditions and oil viscosity were established. Above these thresholds, simulated response operations were suspended. The viscosity threshold for dispersants was 20,000 cST. The emulsion water content threshold for in situ burning was 60%. Most skimmers work less efficiently (if at all) on emulsified, viscous oil; however, some systems work well with more viscous oils up to point. Table 2 lists the various thresholds for skimming operations that were employed. Skimmer Groups A, B, and C represent different types of skimming devices that function optimally at different oil viscosities. The maximum upper limit for skimming operations was 15,000 cST. The oil removal rates for each of the countermeasures were also discounted to address other weather-induced operating restrictions that were not specifically included in the SIMAP model.

Table 2 Threshold Limits Applied to Mechanical Recovery Systems in the SIMAP Model

Factor	Equipment Type	Threshold Value		
		GOM	Pacific	Arctic
Oil Viscosity	Skimmer Group A	15,000 cST	15,000 cST	15,000 cST
	Skimmer Group B	2,000 cST	2,000 cST	2,000 cST
	Skimmer Group C	80 cST	80 cST	80 cST
Winds	Skimmer All Groups	30 kts	30 kts	30 kts
Wave Height	Skimmer All Groups	1.0 to 3.5 ft	1.0 to 3.5 ft	1.0 to 3.5 ft
Current Velocity	Skimmer All Groups	0.7 kts	0.7 kts	0.7 kts
Oil Thickness on Surface	Skimmer All Groups	8.0 µm	8.0 µm	8.0 µm
Daylight Operation Restriction	Skimmer All Groups	12 hours	12 hours	12 hours
Other Weather Restrictions*	Skimmer All Groups	21%	21%	62.5%
***Other Weather Restrictions would include other factors not specified above that would impede recovery operations such as low visibility, fog, extreme cold, the presences of ice, etc.**				

For each WCD scenario, a "no response" baseline simulation was run in which the discharge continued, without response efforts, until a relief well could be drilled. Up to six additional simulations were run for each WCD scenario using expanding suites of countermeasures, including temporary source control devices, mechanical recovery, surface dispersants, in situ burning, and subsurface dispersants (as appropriate). Table 3 shows how different response methods were combined in the simulations depending upon how many methods were being used simultaneously.

Table 3 Response Countermeasure Combinations Modeled for Each WCD Scenario

1 Response Method	2 Response Methods	3 Response Methods	4 Response Methods	5 Response Methods
Source Control (SC)	Source Control Mechanical Recovery (SC+MR)	Source Control Mechanical Recovery Surface Dispersant (SC+MR+D)	Source Control Mechanical Recovery Surface Dispersant In Situ Burning (SC+MR+D+ISB)	Source Control Mechanical Recovery Surface Dispersant In Situ Burning Subsurface Dispersant (SC+MR+D+ISB+SubD)

Offshore Response Concept of Operations (CONOPS)

Many of the operational lessons learned from the response to the Deepwater Horizon oil spill were used to realistically model the simultaneous use of multiple oil spill countermeasures. Modeled response countermeasures were assigned to discreet geographic areas of operation (referred to as "response divisions"), based upon the location of the initial surfacing of the discharge and the subsequent spreading, weathering, and transport of the oil (that was observed in the baseline "no response" simulation). This system of organized geographical response divisions, for the purposes of this paper, will be referred to as an "Offshore Response Concept of

Operations" or CONOPS. Within SIMAP, polygons were developed for each countermeasure to define the boundaries of each response division (see Figure 1).

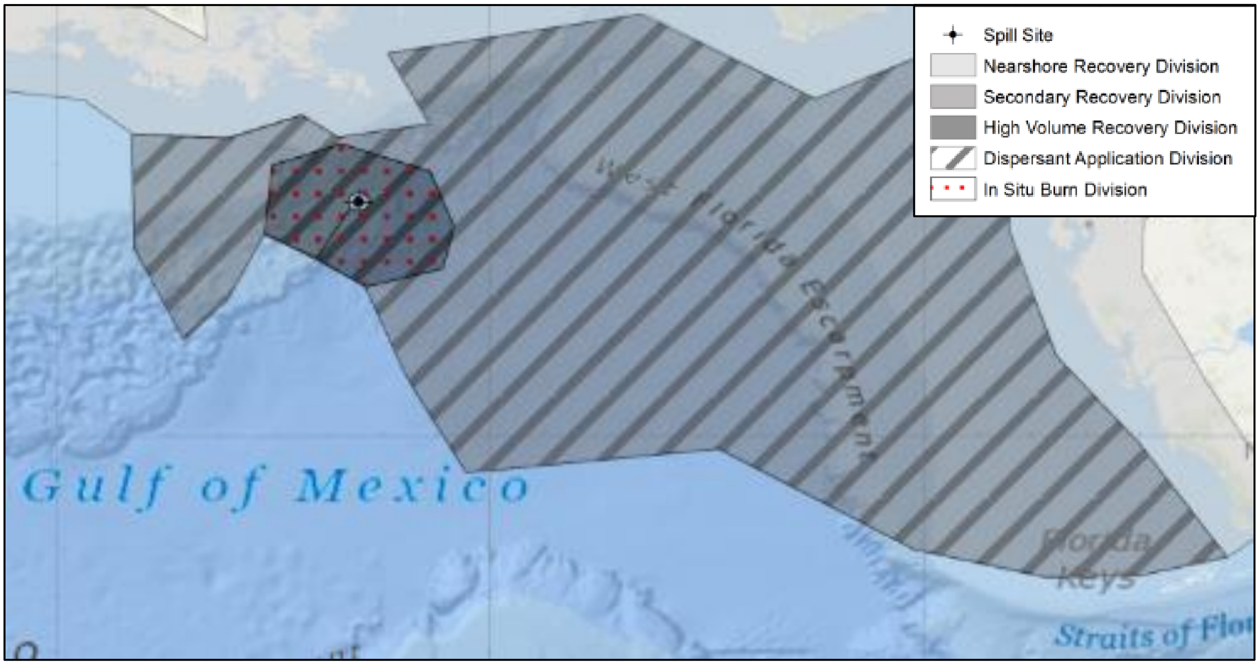

Figure 1. Illustration of Surface Oil Countermeasure Response Divisions

The oil removal rates for each of the response systems within each division were summed to create potential oil removal rates for each type of countermeasure in each division. These calculated removal rates were then applied for the response systems onsite for each time step throughout the simulation, whenever conditions were within the operating parameters of the response systems and there was removable oil available within the response division. Response divisions were created for each of the following countermeasures:

Source Control Exclusion Zone - Each WCD scenario simulated an exclusion zone around the wellhead, similar to the exclusion zone that was created during the Deepwater Horizon oil spill response for source control operations. These zones varied between 0.5 and 5 miles in diameter around the wellhead, depending upon the nature of the source control activities that were necessary to secure the discharge. If subsea dispersants were employed as a response countermeasure for a WCD response simulation, the dispersants were injected at the point of the oil discharge from the wellhead and all associated operations were conducted within the confines of the exclusion zone.

High Volume Recovery Division – High volume mechanical recovery operations were employed adjacent to the source control exclusion zone to capitalize on the highest possible encounter rate of thick, low viscosity oil.

In Situ Burning Division – In situ burning operations were assigned to the same geographical areas as the high volume mechanical recovery operations adjacent to the source control exclusion zone area. In situ burn operations require surface oil to be present at higher thickness levels for successful ignition and sustained burning operations to occur. In situ burning was not used in outlying areas as more thinly spread oil requires significantly more effort to collect in quantities thick enough to burn, and the oil was also likely to be too weathered and emulsified to ignite.

Secondary Recovery Division – Secondary mechanical recovery operations were used to remove oil that was not previously removed in the high volume recovery division. The high viscosity, patchy, thinly spread oil in this area requires more maneuverable, faster skimming arrangements and vessels to effectively locate, chase and recover discontinuous, small patches of weathered oil.

Nearshore Recovery Division – Nearshore mechanical recovery operations were used to remove oil from the surface of the water before it was stranded on shorelines.

Dispersant Application Division – Surface applied dispersants were employed in both the high volume and secondary recovery areas, due to the ability of these application systems to quickly move between, encounter, and treat widely-scattered areas of oil slicks.

Aerial Surveillance and Remote Sensing – The simulated oil removal rates for each surface-based countermeasure were developed based on the assumption that aerial surveillance and remote sensing capabilities would be present to efficiently locate the oil and guide removal operations for the response systems within each division. Environmental constraints on the use of surveillance and remote sensing were factored into the study analysis as part of the "Other Weather Restrictions" that were applied to various removal operations (ex: see Table 2).

STUDY RESULTS

Key Subsea Oil Plume, Fate and Transport Observations

Across all the simulations, the modeling results showed that the origins and behavior of the plume of oil, water, and gas generated at the point of discharge has a profound effect on the ultimate fates and transport of the discharged oil. Depending on the site-specific circumstances of the discharge and the subsequent behavior of the plume, oil may surface immediately above the wellhead, or remain submerged for an extended period and surface far away. The behavior of the subsea oil plume is largely dependent on the size of the oil droplets, which is a function of the turbulence of the water and hydrocarbon jet at the wellhead.

Among the modeled scenarios evaluated in this study, oil plumes reached the surface with rise times that ranged from less than 1 hour up to 5 days later (see Table 4). Oil surfacing locations ranged from immediately above the wellhead to more than 30 miles away at times. Proportions of the discharged oil mass that surfaced ranged from 55% to 100% of the discharge. Generally, discharge scenarios with small oil droplet sizes and greater water depths resulted in less of the overall oil mass surfacing, surface expressions in locations further away from the wellhead, and in longer oil droplet rise times.

Table 4. Comparisons of Oil Plume Behavior Between Six WCD Scenarios

	MC807	WD28	HIA376	KC919	DC187	SM6683
Water Depth (ft)	3030	35	334	6940	4490	1075
Median Droplet Size (microns)	211	227	985	695	689	1811
Trapping Height (ft)	1759	0	2	4268	3143	508
% of Oil Mass to Surface	63%	93%	100%	55%	63%	97%
Rise Time – % Mass	5 days	<1 hr	<1 hr	28 hrs	26 hrs	7 hrs

Key Surface Oil Fate and Transport Observations

The characteristics of the spilled oil changed as it was transported and mixed by currents and waves, and was weathered by various physical, chemical, and biological processes. High energy conditions on the surface (wind and waves) increased oil emulsion (and viscosity), geographic dispersion, and the entrainment of oil droplets into the water column. The model also simulated surface ice at various coverage rates, which sheltered the oil from the wind and waves. The changes in the distribution, thickness, and viscosity of the oil are critical factors in determining where the different countermeasures will be successful, and in the case of mechanical recovery, what types of skimming equipment must be present. In many of the model scenarios, within the first few days of surfacing, the oil spread out and/or emulsified and increased in viscosity to a point where it could no longer be effectively dispersed or recovered (i.e., > 20,000 cST). Figure 2 below illustrates oil weathering that occurred in the first nine days of the DC187 WCD scenario in the Gulf of Mexico. As the oil was transported away from the discharge site by winds and currents over many days, the oil's progression of increasing viscosity is clearly visible.

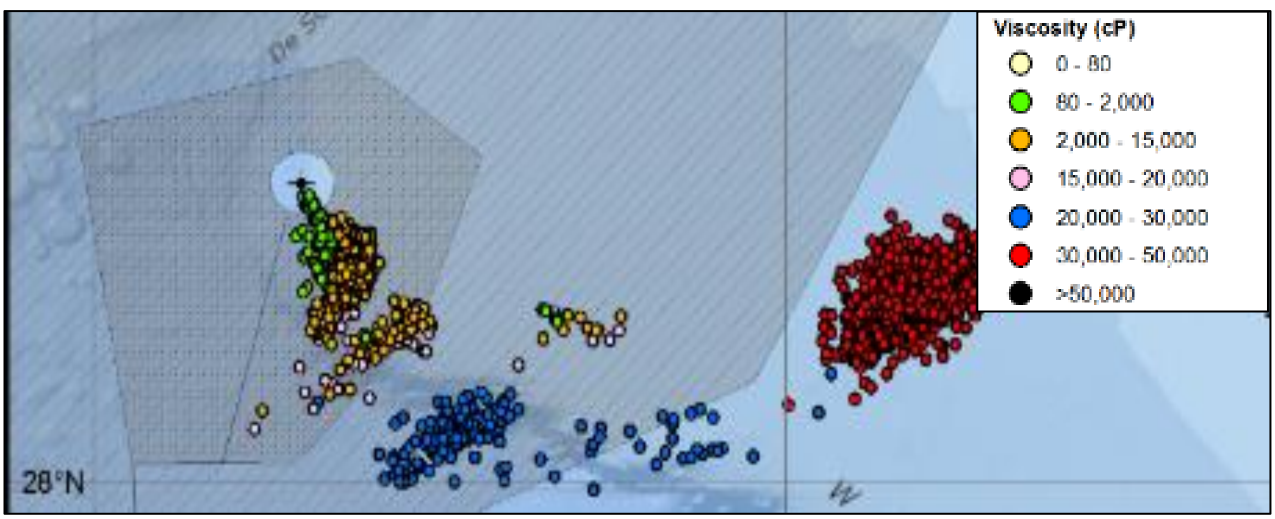

Figure 2. Example of Oil Viscosity Maps Demonstrating Weathering Behavior of Surface Slicks During Transport Processes for DC187 Scenario

Countermeasures Modeling Summary Results

The following section provides a summary discussion of some of the critical results observed for the many response countermeasure simulations that were modeled for the WCD scenarios. The *Oil Spill Response Equipment Capabilities Analysis* report available on BSEE's agency website (BSEE, 2016) contains extensive and detailed write-ups on the results and outcomes of each response countermeasure simulation for all of the WCD scenarios.

Temporary Source Control: The implementation of a temporary source control countermeasure was simulated for all the WCD scenarios. As expected, the modeling results showed that temporary source control actions are likely to be the most effective means of reducing the volume of an oil spill and its contact with the environment. Figure 3 shows the percent of the WCD volume prevented through a temporary source control action, such as well capping, versus the drilling of a relief rig for each of the modeling scenarios and the Deepwater Horizon oil spill (Macondo).

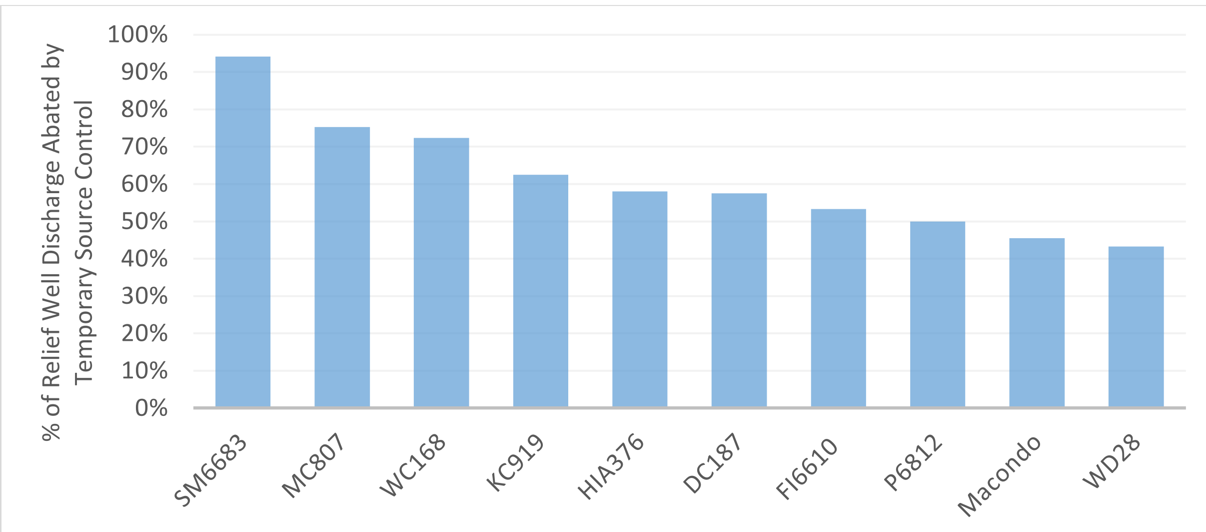

Figure 3. Comparison of Deepwater Horizon Oil Spill (Macondo) to Modeled Scenarios for Percentage of Oil Discharge Prevented by Source Control as Compared to When Drilling A Relief Well

The simulated times required to complete the temporary source control actions were estimated for each scenario based on factors such as the distance between the WCD site and available source control equipment, and information contained within representative OSRPs and Regional Containment Demonstration plans. Temporary source control times ranged from 14 to 45 days. While temporary source control actions took 87 days to stop the flow of oil in the Deepwater Horizon oil spill, subsea source control technologies are now better developed and readily available, and it is anticipated that in most scenarios, the time to implement a temporary source control action in the future is likely to be shorter than what was experienced with the Deepwater Horizon oil spill. Regardless, both the Deepwater Horizon incident and the modeling studies suggest temporary source control measures are a critical capability that can significantly reduce the impact from a WCD oil spill scenario.

Mechanical Recovery: Mechanical recovery equipment was assigned to different geographical areas of operation within each WCD scenario and their effectiveness was tracked based on location and equipment type (each type having a defined viscosity range for operating at targeted efficiency levels). The results highlighted that changes in oil slick thickness and viscosity will significantly affect the success of the mechanical recovery operations. Model results showed that the concentrated, fresh oil near the wellhead was readily recovered, and it was critical to deploy high volume skimming systems capable of sustained recovery operations in close proximity to the discharge site. Table 5 shows that in the 11 modeled scenarios, the vast majority of oil that was recovered occurred in the high volume recovery divisions.

Table 5. Percentage of the Total Oil Mechanically Recovered That Occurred in High Volume Division

Scenario	Percentage of Total Oil Mechanically Recovered That Occurred in the High Volume Division
MC807	77%
WD28	99%
WC168	100%
HIA376	100%
KC919	99%
DC187	88%
SM6683	78%
P6912 Early	97%
P6912 Late	100%
FL6610 Early	92%
FL6610 Late	88%

The model simulations showed that the effectiveness rates for the response countermeasures in the high volume recovery division were sensitive to the size of the source control exclusion zone. Larger exclusion zones around the wellhead usually meant lower oil removal totals for equipment in the adjacent high recovery divisions; decreasing the size of the exclusion zone usually resulted in greater amounts of oil being recovered.

As the oil spreads and is transported away from the source, it becomes thinner and patchy in its surface footprint, as well as more viscous, making mechanical recovery operations more difficult. The modeling strongly suggests that skimming devices in outer divisions must be selected purposely to suit the range of thicknesses and viscosities that will be encountered where they will be working.

Overall, the effectiveness of mechanical recovery countermeasures employed in the WCD scenarios varied widely, ranging from 5% to 56% (see Figure 4). Scenarios with consistently favorable weather conditions for offshore skimming (HIA 376 and WD28) resulted in very high oil removal rates, demonstrating the significant potential for very effective recovery operations under the right circumstances. Most scenarios, however, had a mixture of favorable and poor conditions during the simulation periods, and the removal percentages were typically less than 20% despite having significantly more mechanical recovery capacity employed when compared to the volume of the daily oil discharge flowrate. The results clearly demonstrated that the success rates of mechanical recovery systems were very closely tied to the onsite weather conditions that were experienced during removal operations.

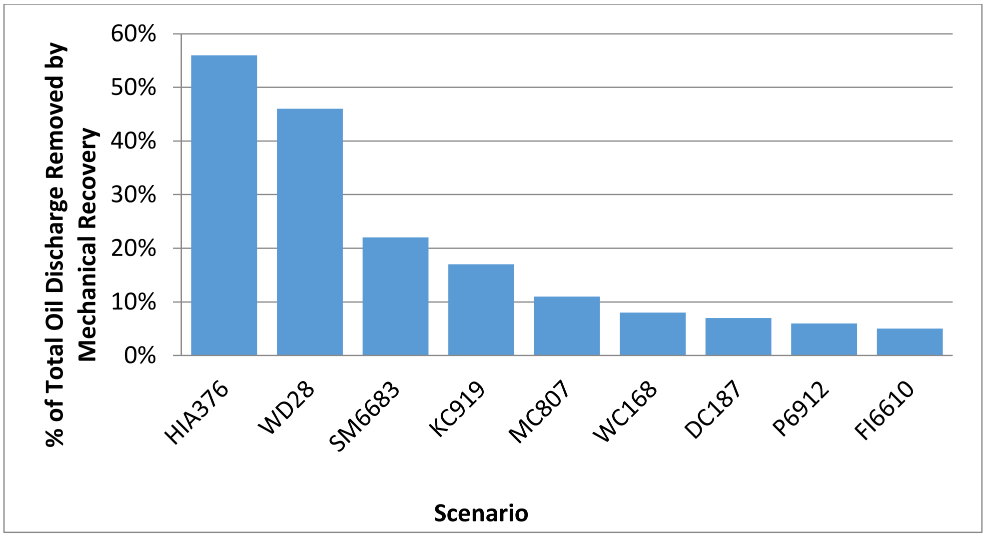

Figure 4. Percentage of Total Volume of Oil Discharge Removed by Mechanical Recovery

Dispersant Operations: The total amounts of dispersants available for simulated applications were calculated based on current industry supplies and the predicted ability to manufacture and deploy additional product. In some WCD scenarios, dispersant stockpiles were not sufficiently available to apply to all treatable surface oil. The WCD scenarios modeled for the Gulf of Mexico simulated the application of about 1 million to 2.5 million total gallons of surface dispersant. This compares closely with the amount of dispersant applied on the surface in the Deepwater Horizon oil spill response. The amount of oil dispersed by surface applications employed in the scenarios varied widely, ranging from 0% (WC 168 condensate WCD) to 10%.

For three WCD scenarios in the Gulf of Mexico (MC807, KC919, and DC187) and two WCD scenarios in the Arctic OCS (P6912 and F6610), the use of dispersants was modeled both on the surface and subsurface at the wellhead. In the Gulf of Mexico, the results ranged from 6-10% of the total oil discharged being dispersed through the combined surface/subsea use of dispersants, which is similar to the 8% that is estimated to have been dispersed during the Deepwater Horizon oil spill. For these GOM WCD scenarios, dispersant stockpiles were generally insufficient to sustain the long term use of simultaneous surface applications and subsea dispersant injection at their full capacities; as a result, stockpiles had to be rationed and strategically apportioned between the two methods, with subsurface injection normally taking precedence once it was operational. In the two Arctic OCS scenarios (late season in the Chukchi and Beaufort Seas), 85,000 and 116,000 total gallons of dispersants were injected at the wellhead, and in each case, subsurface injection achieved between 15 and 22% dispersion of the total volume discharged. In these two cases, the subsurface injection of dispersants into the discharged oil plume became the most effective response countermeasure that was modeled, likely due to the significant environmental constraints that limited the effectiveness of the surface-based spill countermeasures in the Arctic.

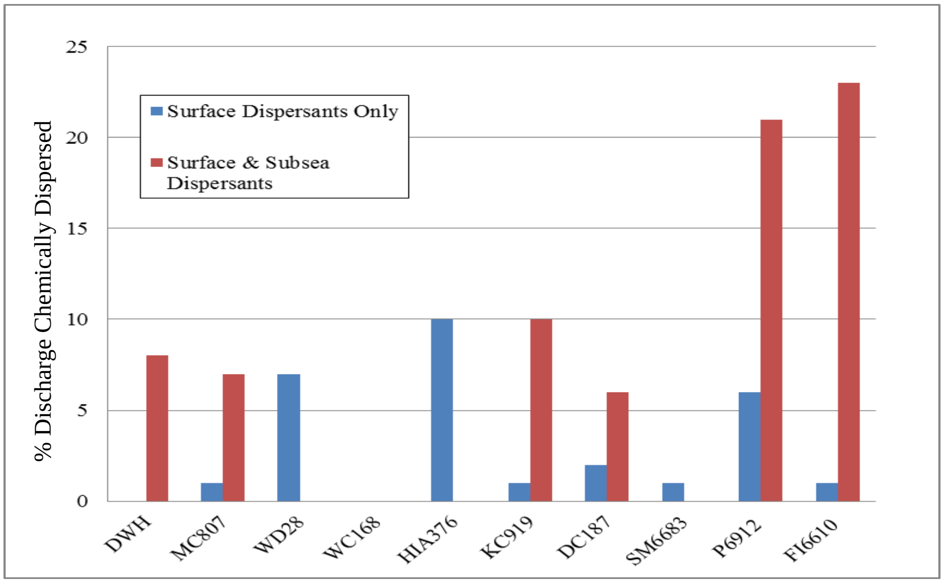

Figure 5. Comparison of Deepwater Horizon Response to Modeled Scenarios for the Percentage of the Total Oil Discharged that was Chemically Dispersed

All the WCD scenarios tested showed a significant reduction in shoreline and surface oiling when dispersant applications were used in conjunction with mechanical recovery systems. The model results, like the Deepwater Horizon Federal On-Scene Coordinator (FOSC) Report, support the conclusion that dispersants are an effective way to disperse oil and reduce the amount of oil that contacts sensitive resources on the surface and shorelines. While dispersants reduced the amount of oil that contacted shorelines, they also reduced the amount of oil that was mechanically recovered on the surface and increased the amount of oil that was biodegraded in the water column.

In Situ Burning: In situ burning was modeled in areas close enough to the discharge point that the oil slicks would be sufficiently thick and fresh to burn, but far enough away that they would not interfere with ongoing source control actions at the wellhead. The amount of oil removed with in situ burning in the WCD scenarios ranged from about 0.5% to 2% of the total oil discharged, which is lower than the 5% estimate for the amount of oil burned in the Deepwater Horizon oil spill response. While the modeling results suggest that in situ burning is an effective way to remove spilled oil in a WCD, however, the volumes of oil that are likely to be removed by burning are smaller than other countermeasures due to the limited inventory of burn booms available and the long lead times needed to remanufacture additional stocks.

Using Multiple Response Countermeasures: The simultaneous use of multiple countermeasures consistently provided greater reductions in surface and shoreline oiling. Significant oiling reductions could readily be seen in the larger spill scenarios when surface-applied dispersants, and as appropriate, the subsurface injected dispersants, were applied in addition to mechanical recovery efforts (see Figures 6 and 7). The smaller WCD scenarios had similar results, with comparable trend lines on a much smaller scale.

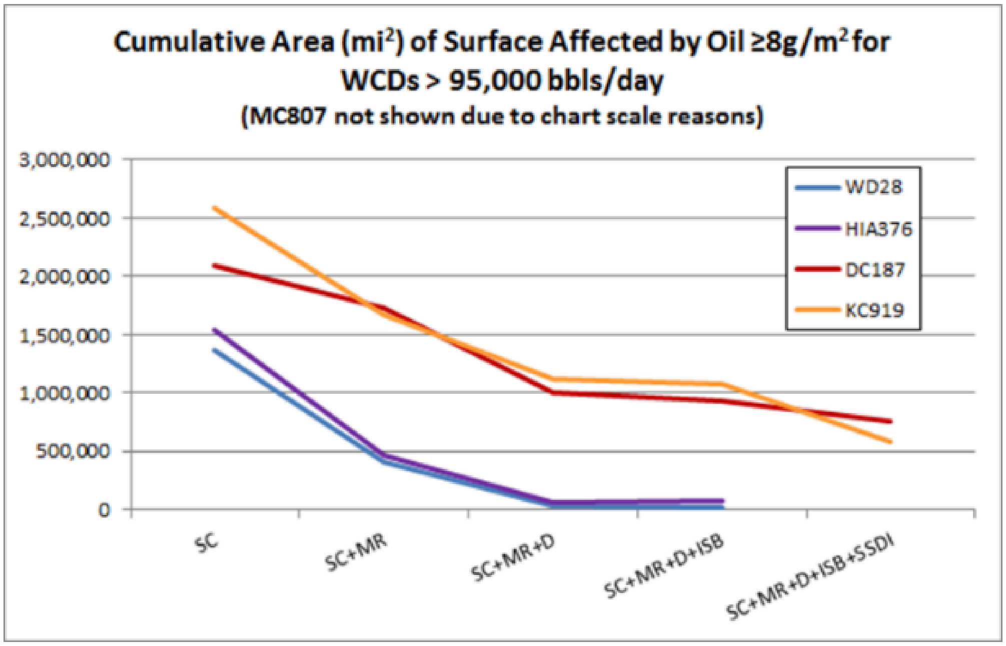

Figure 6. Comparison of Environmental Exposure Outcomes Between Simulations Using Different Combinations of Countermeasure Capabilities

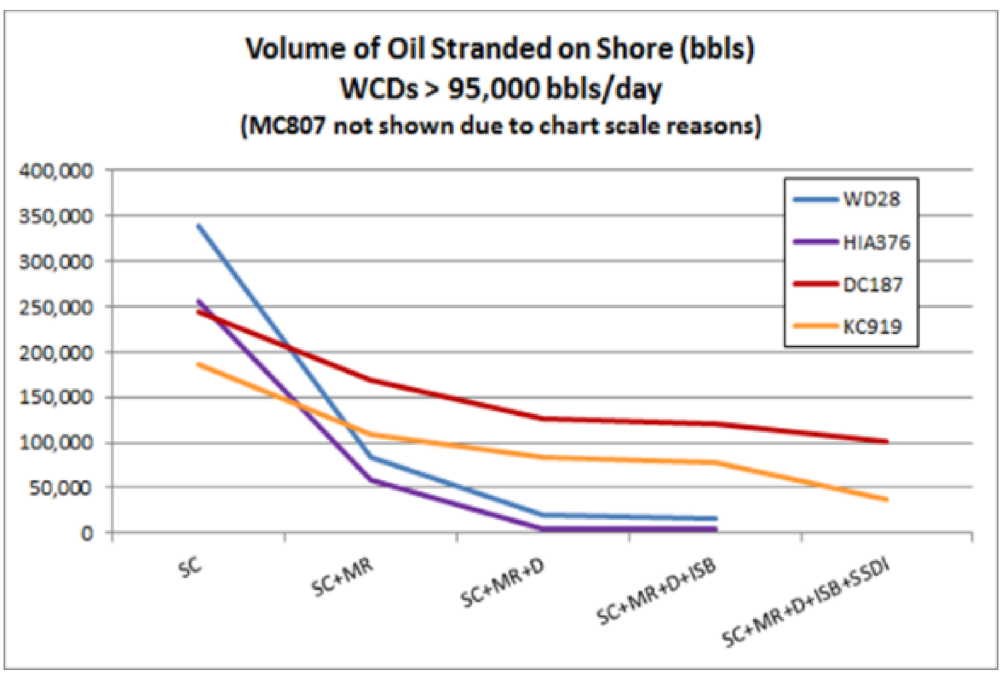

Figure 7. Comparison of Environmental Exposure Outcomes Between Simulations Using Different Combinations of Countermeasure Capabilities

Additional Mechanical Recovery: The response countermeasures modeling for each WCD scenario reflected the existing equipment inventories currently available to OSROs. To determine the degree to which employing additional mechanical recovery equipment might increase oil removal amounts and decrease surface and shoreline oiling, four scenarios (MC807, WD28, P6912 -early season, and P6912-late season) were selected for additional simulations using increased mechanical recovery equipment levels. Each of these WCD scenarios were modeled with 25%, 50%, and 75% increases in mechanical recovery capacity.

The simulations showed a positive relationship between using increased mechanical recovery resources and increased oil removal, as well as reductions in surface and shoreline oiling. In the WD28 scenario, significant reductions in surface and shoreline oiling did occur, likely due to conditions that were generally favorable for mechanical recovery success. The other three scenarios involved less favorable conditions for recovery operations, and the modeling results showed a pattern of diminishing returns for reduced oiling when additional mechanical recovery resources were applied. What was more remarkable were the reductions in surface and shoreline oiling that occurred with the addition of dispersants to the original baseline amount of mechanical recovery equipment (see Figure 8 and Figure 9 for examples). In almost every case, the addition of dispersants to the original baseline of mechanical recovery equipment resulted in significantly less oiling on the ocean surface and shorelines than was achieved through the addition of substantially more mechanical recovery capabilities. These results, however, should not be interpreted to suggest that this combination of countermeasures will naturally result in the greatest net environmental benefit. While that is altogether possible, such determinations must be made through a more detailed comparative analysis of the expected impacts to the affected habitats and species of concern for a specific spill scenario.

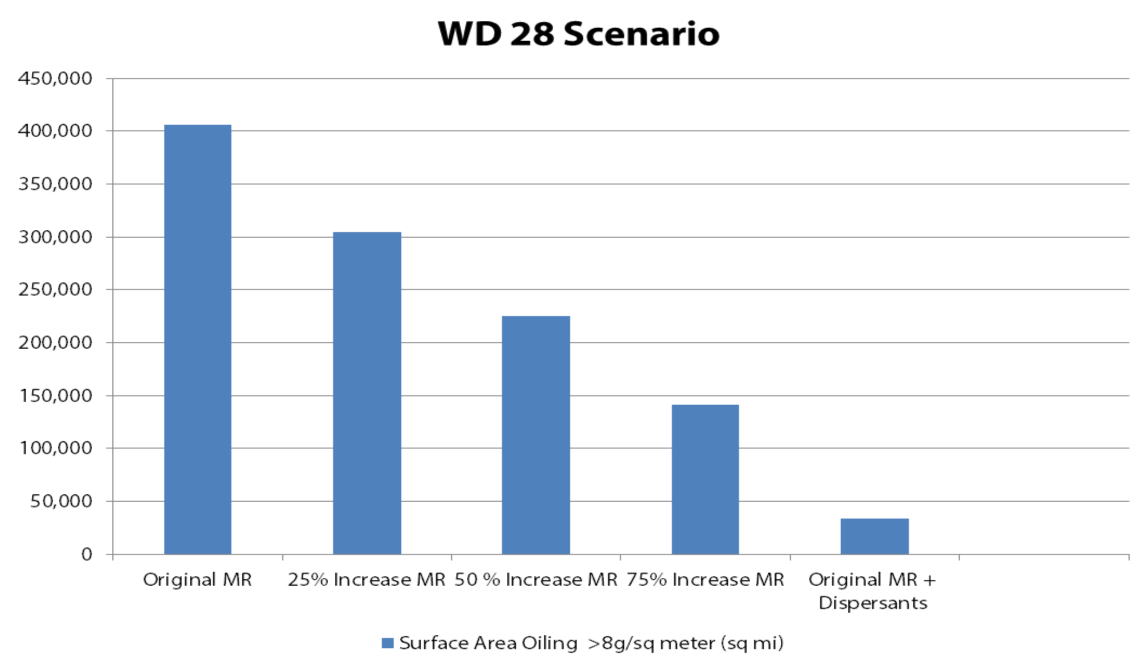

Figure 8. Comparison of Environmental Exposure Outcomes With Additional Mechanical Recovery and the Use of Dispersant Capabilities

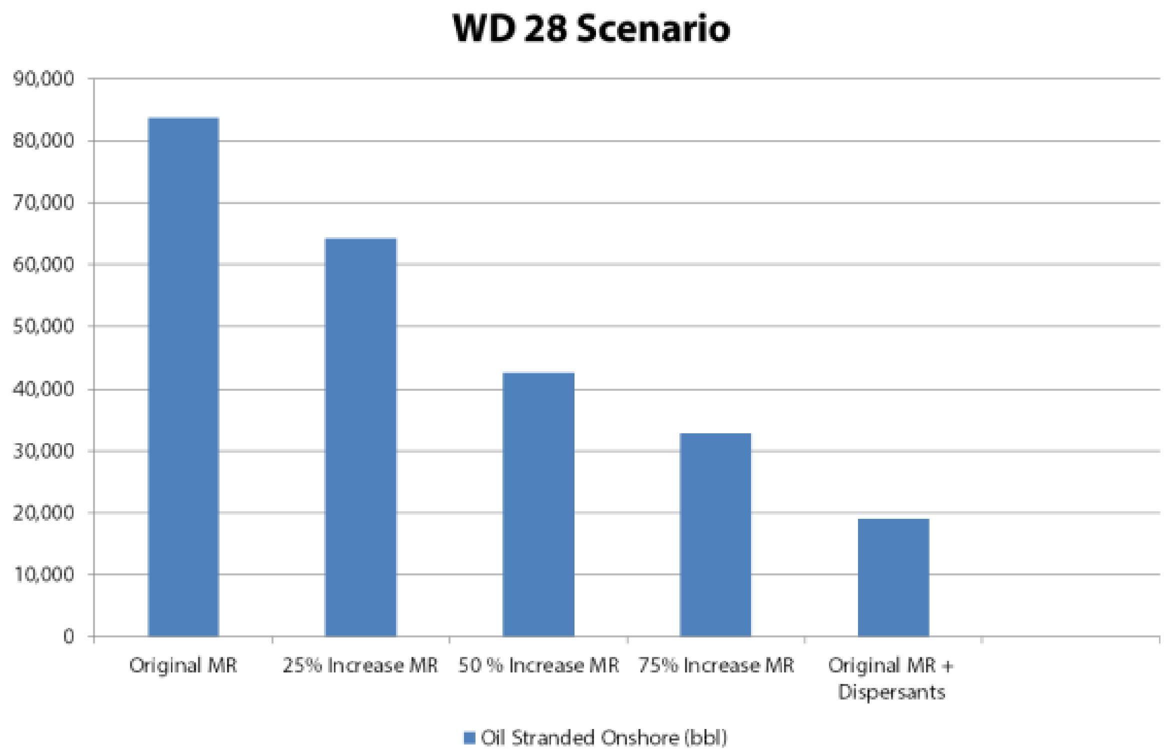

Figure 9. Comparison of Environmental Exposure Outcomes With Additional Mechanical Recovery and the Use of Dispersant Capabilities

RECOMMENDATIONS FOR FUTURE OFFSHORE SPILL RESPONSE PLANNING

Enhanced oil spill modeling plays a critical part in planning for a response to a WCD scenario in the offshore environment. This modeling can be effectively used to develop an offshore response CONOPS that optimizes the use of all available countermeasures based on their various system capabilities and the expected behavior of the spilled oil. The following is a short summary of some of the key points outlined within the *Oil Spill Response Equipment Capabilities Analysis* that should be factored into the next generation of offshore oil spill response planning:

- Planners should use scenario-based trajectory modeling and analysis in developing their OSRPs for responding to their WCDs. The modeling should track the fate and transport of the oil as it rises through the water column for subsurface releases, and/or as it moves away from the discharge site on the water's surface. This modeling should be supported by characterization data that incorporates the physical and chemical properties of the oil specific to the WCD scenario that is being modeled.
- Response planning should account for the time it will take for the oil to rise to the surface, the locations where the oil will first emerge, and the proportion of the oil that will reach the

surface. This information is necessary to effectively plan the timing, scaling, and allocation of response countermeasure resources.

- The scenario-based modeling should predict changes in viscosity and thickness of the oil on the surface over time and space in order to estimate the geographic extent of the oil spill, and develop response divisions that match response capabilities to the geographical areas where they will be effective. The resultant offshore response CONOPS should be readily adaptable to the dynamic nature of ambient conditions and resultant changes to the oil's fate and transport throughout the area of operations.
- The rapid deployment of temporary source control measures is one of the most critical and effective response countermeasures available. Planning for the mobilization and deployment of these systems should be an integral part of an OSRP. Efforts should continue to develop the technology and service arrangements that would be necessary to shorten deployment times as much as possible. Exclusion zones developed to support the implementation of these source control measures should be kept as small as possible to enhance the effectiveness of nearby high volume oil removal operations.
- Planners should use response calculators, such as Estimated Recovery System Potential (ERSP), Estimated Dispersant System Potential (EDSP), and Estimated Burn System Potential (EBSP), to estimate the oil removal potential of the countermeasures employed. The calculators should evaluate the ability of the countermeasure's component parts to work together as an oil removal (or dispersant) system, including those components that determine the rate at which a system can encounter oil.
- High volume, efficient removal systems should be assigned to areas of concentrated, fresh oil, typically close to the source of the discharge.
- A critical factor for skimming systems in the high volume recovery division is the availability of both primary and secondary temporary storage, as well as efficient offloading pumps and transfer arrangements, due to the high encounter rates that are possible in these areas.
- Maneuverable systems that can be adapted to remove more viscous oil will be better suited to secondary or nearshore areas where the oil has been broken up into weathered streamers and patches.
- When dispersants are planned to be applied both subsea at the point of discharge and on surface oil slicks, a dispersant management plan that effectively allocates the use of the dispersant stockpiles between the application methods is highly recommended, especially for large WCD spill scenarios.
- Every division must be supported with aerial surveillance and remote sensing to ensure that the best oil encounter rates possible are achieved for the removal systems that are employed.
- The simultaneous use of multiple response countermeasures during an offshore oil spill response, in particular the combination of mechanical recovery and dispersant application systems, will maximize the potential to reduce surface and shoreline oiling in the environment. While additional mechanical recovery resources are likely to reduce environmental oiling, the combination of mechanical recovery and dispersant countermeasures is likely to yield an even greater reduction in overall surface and shoreline oiling.

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