How Much is Enough? Planning Standards, Preparedness Research, and New Planning Tools for Measuring Response Equipment Capabilities

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Introduction

We have long wrestled with the question of "How much (response equipment) is enough?" In the wake of the Exxon Valdez spill, a planning metric was developed for the mechanical recovery of oil called effective daily recovery capacity (EDRC). U.S. agencies used this metric to estimate the daily recovery rates of skimming equipment, and then to compare and match it with the volume of a worst case oil discharge (WCD) in a contingency plan. This paradigm was highlighted during the BP Deepwater Horizon Oil Spill as a major shortcoming in oil spill response planning.

The Bureau of Safety and Environmental Enforcement (BSEE), responsible for regulating offshore oil and gas in the United States, recently completed a study that modelled simulated responses to a number of large WCD spills. The results demonstrated that the performance of equipment stockpiles and the ability to minimize environmental oiling are highly susceptible to overriding factors often beyond the control of responders. One can surmise from the study that even very large stockpiles of equipment do not result in a complete removal of the spilled oil, or guarantee that the oiling of the environment will be totally prevented; any expectations of such based on matching the size of the equipment stockpiles with discharge volumes are ultimately doomed to failure. It's time to stop perpetuating false hopes and expectations as a result of how we apply our planning standards.

Despite these unfortunate realities, there are new planning metrics that can dramatically enhance our ability to evaluate our equipment capabilities that are contained within a contingency plan. BSEE has developed a set of planning calculators to estimate the "potential" of different response systems to recover, burn, or disperse oil. These new preparedness tools factor in many of the critical elements of a response system that affect is spill removal or mitigation capabilities. While the calculators still can't tell us "How much is enough?", they do allow us to better understand "How much potential capability do I really have?", and "How can I improve the systems I already have?"

Volume-Based Equipment Metrics and Planning Standards

After the Exxon Valdez spill in 1989, the Oil Pollution Act required US regulatory agencies to develop requirements for oil spill response plans for vessels and facilities handling oil in bulk. This included developing metrics for measuring the response capabilities of oil removal equipment, as well as setting planning thresholds for required equipment stockpiles. As mechanical oil recovery was viewed as the backbone of any response at the time, the metric that was ultimately adopted was based on the maximum daily throughput of a skimmer and pump to recover oil (de-rated for conditions such as sea state), and is referred to as a skimmer's effective daily recovery capacity (EDRC). The planning thresholds for the required equipment stockpiles that was adopted typically matched the daily throughput capacity of the skimmers listed in a plan with the volume of the worst case discharge for the vessel or facility. In overly simplistic terms, "having a barrel of EDRC for each barrel of oil that could be spilled" became the de facto equipment stockpile planning standard.

There are many problems with using this combination of EDRC rates and discharge volumes as the primary basis for evaluating the adequacy of the response equipment in a plan. The EDRC metric focuses on only a single aspect of the recovery system (throughput capacity), and neglects to consider other factors such as operating environment limitations, recovery efficiencies, oil encounter rates, and storage and offloading capabilities. The EDRC metric also assumes that these skimmers will always be operating in concentrated thick oil; however, oil spills rapidly spread out, evaporate, and naturally disperse into the water; as a result, they become thinner in thickness and break up into widely distributed and discontinuous patches of oil. While skimmers are usually tested and rated for their throughput capacity when operating in a thick pool of oil, during a spill they will often be operating in much thinner collected pockets of oil.[1] The limiting factor for the performance of a response system is not going to be its throughput rating, but rather is often going to be its encounter rate with oil, as well as other aspects of the system such as its storage capacity. The areal footprints of spills are likely to exceed the areal coverage capabilities of the response equipment to collect oil. This areal component of the response is often overlooked when using volume-based equipment metrics and stockpile planning standards; however, it is likely to be a more critical factor in determining the effectiveness of a response. Summing and matching the de-rated throughput ratings of skimming equipment against the WCD volume listed in a plan will likely result in overestimating recovery abilities and underestimating the size of the stockpile that will be necessary.

Planning Standards and Public Expectations

The average person generally understands little about how response equipment works or what actually happens to the oil during an spill. When regulators compare volume-based equipment recovery numbers to WCD spill volume in a plan, the public can develop uninformed expectations about the environmental outcomes of any response conducted under that plan. Matching numbers wrongly leads one to believe that these equipment levels will be sufficient to remove all the oil that is spilled. The presumption that equipment stockpiles with EDRC ratings that meet or exceed the WCD volume will be adequate to remove *all* the spilled oil (and also prevent *any* environmental damage from occurring) is almost always doomed to fail in the case of a large WCD oil spill. What follows will likely be condemnation of the spiller's plan, and intense scrutiny for the regulators who approved it.

This pattern of public expectation played out during the BP Deepwater Horizon Oil Spill. A seemingly unprecedented quantity of skimmers, boom, and other types of spill response equipment were cascaded in from across the United States, as well as from other nations, resulting in a massive amount of offshore mechanical recovery capability that was used during the response. Despite this effort, significant oiling of wildlife and shorelines occurred across the Gulf of Mexico. The public concluded that the response was a failure, and the equipment used was inadequate to the task. Government and industry after-action reports identified the performance of skimming systems and the effectiveness of the EDRC planning standard as a focal point in their observations and findings. The BP Deepwater Horizon Incident Specific Preparedness Review (ISPR) points out that the total recovery ratings for the equipment used far exceeded BP's WCD-based requirements for equipment stockpiles, and this extensive armada of equipment was also seemingly ineffective in removing oil in quantities that came anywhere near their aggregated recovery values.[2] The BP oil spill response plan was widely criticized by the public as being inadequate, and people openly questioned why the regulators involved had approved the plan.

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[1]BSEE research has indicated the oil recovery rates for skimmers can be expected to significantly decrease as the oil thicknesses they are operating in decrease. McKinney, K., Caplis, J., Devitis, D., Dyke, K.V., 2017, Evaluation of Oleophilic Skimmer Performance in Diminishing Oil Slick Thicknesses.

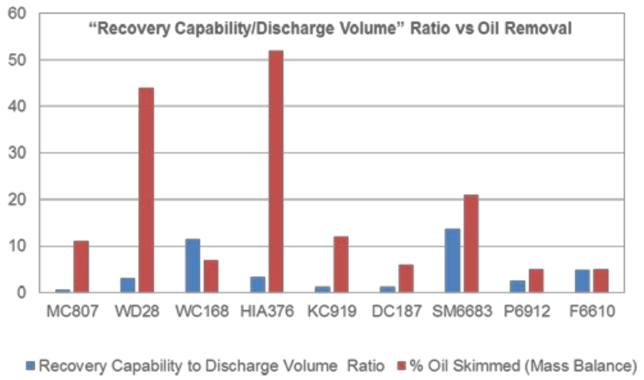
[2] The ISPR reported that the WCD for the Macondo well was approximately 162,000 barrels of oil per day, the actual discharge was estimated at closer to 65,000 barrels per day, and the response equipment contained in the BP's regional oil spill response plan was listed at 492,000 barrels of EDRC. The BP DWH Oil Spill ISPR, 2011.

Worst Case Discharge Response Modelling

In 2016, BSEE completed the study, *Oil Spill Response Equipment Capability Analysis*[3], which modeling the responses to nine different subsea blowout WCD scenarios in order to explore the application of different removal countermeasures and the outcomes for oil contact with the ocean surface and shorelines. 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 the release has a profound effect on the fate and transport of the spilled oil. Depending on the site-specific circumstances of the release (flow rate, orifice size, gas to oil ratio, water depth) and their effects on the subsequent behavior of the plume, oil may surface immediately above the wellhead, or remain submerged for an extended period and surface far away. Among the modeled scenarios, oil plumes reached the surface with rise times that ranged from less than 1 hour up to 5 days later. Oil surfacing locations ranged from immediately above the wellhead to more than 30 miles away at times. Proportions of the spilled oil mass that reached the surface ranged from 55% to 100% of the discharge. All these factors had a dramatic effect on the areal footprint and thickness of the oil spill on the surface.

The characteristics of the spilled crude oil also changed rapidly 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 changes in the distribution, thickness, and viscosity of the oil were critical factors in determining where (and to what degree) the different countermeasures were effective, and in the case of mechanical recovery, what types of skimming equipment must be present. In many of the WCD modeled scenarios, within the first few days of the oil surfacing, the spill had spread out and/or emulsified, increasing in viscosity to a point where it could no longer be effectively dispersed or efficiently recovered (i.e., > 20,000 cST). The results definitely showed that there are limited spatial and temporal windows of opportunity for effectively removing, dispersing, or burning oil, all which are driven by the properties of the oil and onscene weather conditions, in addition to the capabilities of the equipment being deployed.

The effectiveness of the mechanical recovery countermeasures employed in the WCD scenarios varied widely, ranging from 5% to 56% of the spilled oil being removed. The results did not show a consistent relationship between the amounts of oil removed and the “mechanical recovery capacity to daily discharge volume” ratio.



The results do suggest that the success rates for the amounts of oil removed were more closely tied to the weather conditions experienced during removal operations. A few scenarios with consistently

[3] The *BSEE study, Oil Spill Response Equipment Capability Analysis,* is publically available and can be downloaded at https://www.bsee.gov/what-we-do/oil-spill-preparedness/worst-case-discharge-scenarios-for-oil-and-gas-offshore-facilities-and-oil-spill-response.

favourable weather conditions for offshore skimming 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 favourable and poor conditions during the simulation periods, and the oil removal percentages were typically less than 20% despite having significantly more mechanical recovery capacity employed when compared to the volume of the oil discharged each day.

The simulations showed an overall positive relationship between using increased mechanical recovery stockpiles and increased oil removal, as well as corresponding reductions in surface and shoreline oiling. In several of the scenarios, significant reductions in surface and shoreline oiling did occur with the addition of more mechanical recovery capacity. These outcomes were likely the result of weather conditions in these scenarios that were generally favorable for mechanical recovery throughout the simulation. The other scenarios tested with less favorable conditions showed a pattern of diminishing returns for reducing oiling when applying additional mechanical recovery stockpiles. What was more remarkable were the reductions in surface and shoreline oiling that occurred when dispersant capabilities were used in conjunction with the mechanical recovery equipment. In almost every case, the addition of dispersants to the baseline of mechanical recovery equipment resulted in significantly less oiling on the ocean surface and shorelines than when substantially more mechanical recovery capabilities were employed without the use of dispersants. The results suggest that an offshore response strategy that employs both mechanical recovery and dispersant equipment stockpiles in a complementary fashion (see the offshore concept of operations in the BSEE study) will provide the greatest reductions in oil contact with the environment.

In all cases (regardless of the size of the equipment stockpiles employed), it should be expected that a large amount of the oil spilled will be lost to the environment due to natural weathering processes, and oiling will occur, whether on the surface, in the water column, or on shorelines, in the aftermath of a large WCD spill. The success of the countermeasures and strategies employed should only be judged by their abilities to remove or disperse that portion of the spilled oil that is available to be addressed by responders, and the degree in which those countermeasures applied reduce the amount of oiling that occurs.

Systems-Based Metrics and Planning Calculators

In response the lessons learned from the BP Deepwater Horizon Oil Spill, BSEE, in collaboration with Genwest Systems, Inc., developed an improved set of metrics and associated planning calculators for mechanical recovery (ERSP), *in situ* burning (EBSP), and surface-applied dispersants (EDSP) countermeasures.[4] These tools provide a much more holistic assessment of how each system's components can affect its overall capabilities, and offer insights on how their performance on a large WCD spill may be improved. While these calculators provide estimates of how much oil can be removed, they also include data on system's areal coverage and oil encounter rate. The ERSP, EBSP, and EDSP calculators are intended as planning tools for estimating the potential of different oil spill response systems to mitigate (recover, burn or disperse) discharged oil relative to one another. These planning tools are NOT intended to be used for predicting system performance during an actual spill. While ERSP is a significantly improved metric over EDRC, regulators and planners should not simply switch from one metric to the other. We must also rethink how they are going to be used when evaluating equipment stockpiles. The metrics, when used in conjunction with rigid planning thresholds, can generate unrealistic expectations for success, setting the stage for failure in the court of public opinion, even in the aftermath of what should be considered an effective response given the limitations of what is possible in a large WCD oil spill.

[4] The ERSP, EBSP, and EDSP Calculators and User Manuals are publically available and can be downloaded at https://www.bsee.gov/what-we-do/oil-spill-preparedness/response-system-planning-calculators.

Conclusions

When planning for a large WCD spill offshore, there is no single right answer to the question "How Much is Enough?" It is trick question. There will never be enough equipment to recover *all* the spilled oil. There will also never be enough equipment, in most cases, to ensure that oiling of the environment never occurs. We need to start educating the public that in almost all oil spills, much of the oil will be lost to the environment due to natural weathering processes, and at least some portion of the environment will get oiled as a result of how oil spills behave in nature. We also need to educate people on the limited temporal and spatial windows that exist for effectively using response countermeasures, and the fact that weather conditions can drastically alter what our expectations of success should look like for any size stockpile on a given spill. An equipment stockpile may be very successful at removing oil one week, yet achieve very poor results the next week. There is no silver bullet, no simple answer to "How much is enough?" One might ask then, how should we evaluate the equipment and strategies that are listed in a spill response plan? Recent BSEE research provides some helpful best practices:

- Use a systems-based approach to evaluate the potential capabilities of the response equipment. A system will only be as effective as its most limiting factors. The ERSP, EDSP, and EBSP calculators are excellent resources for evaluating the system limitations and overall potential for mechanical recovery, dispersant application, and on-water in situ burning.
- Consider evaluating response times, anticipated periods of down time, and the areal coverage capabilities of equipment to encounter oil when determining the size of the stockpiles that will be required. The ERSP, EDSP, and EBSP calculators provide estimates of a response system's areal coverage and oil encounter rates. Since the areal footprint of a spill increases with time, areal coverage rates become especially important if there will be delays in the arrival of equipment, or conditions are likely to result in periods of down time when countermeasures can not be employed due to operational constraints. Improvements or supporting capabilities that increase the oil encounter rates of response systems are strongly encouraged and should be employed whenever possible during offshore oil spills.
- When evaluating equipment types and amounts, consider how changing oil properties due to weathering will impact the effectiveness of the response systems being used. Characterizing the properties of the oil and completing weathering studies as part of an oil spill response plan can significantly inform the development of response strategies and the employment of response equipment. They can also be used to increase the public's understanding of oil fates and manage their expectations for recovery and mitigation during a spill.
- When considering stockpile levels for mechanical recovery equipment, BSEE modelling research suggests that significantly more removal capabilities will be required than the WCD volume in a plan in order to achieve a desirable recovery outcome in most cases. Stockpile levels will need to be capped at some point, however, due to economic considerations. Regulators must work with stakeholders and the oil industry to determine what levels of equipment will constitute a viable response capability that can be maintained in a constant high state of readiness, rapidly deployed, and effectively employed to achieve an acceptable level of mitigation for the oiling that will occur during a large WCD spill.
- BSEE research indicates that using equipment stockpiles and strategies that employ complementary response countermeasures will provide greater amounts of oil removed or mitigated, and will also be more successful at minimizing the levels of environmental oiling that will occur. This was especially the case when mechanical recovery equipment stocks are augmented by dispersant application systems.
- Once stockpiles types and levels have been agreed upon and established, it then becomes the regulator's primary role to verify that an operator is trained and ready to deploy, support, and operate the equipment, the equipment is properly maintained, and that spill managers employ well-crafted strategies to mitigate the impacts of the spill to the maximum extent possible.

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