BAYOU PEROT AND THE UNUSUAL SITUATION OF STRANDED OIL ADHERED TO MUD FLATS

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ABSTRACT

The Environmental Sensitivity Index ranks Sheltered Mud Flats as a 9 on a scale of 1 to 10 (with 10 being the most sensitive of habitats). Mud flats are very soft substrates that will not support even the lightest of foot traffic by cleanup workers. Conventional wisdom suggests that oil that strands on a mud flat during low water will lift and float free during the next high water event. Afterwards, the flat will generally appear free of oil. It is very unusual for stranded oil to form a strong adhesive bond to the wet substrate such that during high water events, water flows over the oil, and the oil doesn’t resurface and float away. When the water level drops, the oil remains. This unusual process was one of the problems facing responders during the Bayou Perot Oil Spill in Southern Louisiana in January, 2007. The spill was reportedly caused by a vessel striking a small platform and wellhead. The incident resulted in an uncontrolled, wild well release that lasted for nearly five days. During that time, more than 7000 bbls of crude oil and production water emulsion were thought to have been released into the environment. Several thousand of those barrels became stranded in an adjacent wetland with most of the oil stranded on mud flats and in shallow canals with little to no water. The water levels were very low at the time of the event. Subsequent tidal and wind-driven water level changes failed to significantly free the oil. Most of the emulsified oil remained adhered to the mud flats. The question and response challenge became, “How do you clean mud flats adjacent to sensitive marsh habitat without causing unacceptable collateral damage?” Field tests were conducted using several types of sorbents (snare, sweeps, and bagasse), a solidifier, squeegees, and burning. The outcome, based on these tests, was to use “Airboat-deployed Vacuum Recovery Systems. This paper provides a case study of an unusual, and challenging, oiling event that required a series of field experiments to develop a practical cleanup strategy.

INTRODUCTION

Marine casualties may occur at any time. If you are a spill responder, you’re probably convinced that they happen more often at night and on weekends. The Bayou Perot incident was one such incident. Shortly after midnight on Saturday, 20 January, 2007, a local fishermen reported oil blowing out of the water in Bayou Perot just south of the Gulf Intercoastal Waterway (GICW). Reportedly, a tug with barge tow had collided with a small well platform and left the scene. The allision had completely collapsed the platform and sheared the well control structure (Christmas tree), resulting in an uncontrolled release of crude oil condensate, formation water, and gas. The cause of the incident was unknown until later in the response. This case study focuses only on the unique and difficult shoreline cleanup challenges created by spilled emulsified oil that stubbornly adhered to sheltered tidal flats in an adjacent fragmented marsh. Greater than 20 acres of mud flats were heavily oiled requiring mitigation due to the risk to wildlife. This paper provides background information on the incident and outlines the process used to develop and test different techniques for shoreline cleanup. The cause of the incident and any follow up investigations related to the incident or Natural Resource Damage Assessment are outside of the scope of this paper.

ADDITIONAL BACKGROUND INFORMATION

Location

The location of the release was reported as 29° 40.89' N Latitude and 090° 10.26' W Longitude. This position places the release approximately 35 nautical miles south of New Orleans, Louisiana, and just southeast of where the GICW passes between Lake Salvador and the entrance to Bayou Perot. The area is remote and there are no roadways to the spill area. Much of the shoreline in this area is characterized by fresh to brackish salinity marshes. The shoreline of Lake Salvador is mostly freshwater marsh, but there is a change in salinity within the watershed to the south toward Barataria Bay. Like much of Louisiana, this area has exhibited significant land loss due to subsidence and erosion, and many of the marsh areas are fragmented. Particularly on the western portion of Bayou Perot, there are numerous shallow man-made canals
cut through the marshes as well. This area also included extensive sheltered tidal flats (or mud flats).

The habitat provides essential nursery grounds for numerous finfish and shellfish as well as a habitat for birds, such as wading birds and ducks. Marsh rails, such as the Clapper Rail (Rallus crepitans), were particularly at risk since they often transit and feed at the margins of the marsh and tidal flats. Federally protected Brown Pelicans (Pelecanus occidentalis) are not uncommon in the open bayou areas and the American alligator (Alligator mississippiensis) is found throughout the intermediate to freshwater marshes. Both species are protected under the Endangered Species Act of 1973 and are listed as federally threatened species.

**Hydrology and Water Levels**
The water level within the adjacent marsh and associated bayous and canals was a key element in the stranding of oil and subsequent cleanup difficulties. During much of the response, the problem was a lack of water in the marsh. The Bayou Perot area is microtidal and nearly at the maximum extent of the regional tidal prism. The movement of water between Lake Salvador and Bayou Perot is controlled by winds, tides, and the drainage of rainwater from the upper watershed. This system is not connected to the Mississippi River, and winds often dominate water levels. North winds generally push (or blow) water out of both Lake Salvador and Bayou Perot. Both systems are relatively shallow. Lake Salvador is larger of the two systems with respect to surface area, but Bayou Perot connects through Little Lake to Barataria Bay. Sustained southerly winds will tend to push and focus water up and into Lake Salvador as well as adjacent marshes. The net result of sustained winds, either north or south, is that water in Lake Salvador either increases or decreases. When northern winds subside, the water level in Lake Salvador will relax, resulting in water flowing in the opposite direction through the pass between Lake Salvador and Bayou Perot. This also results in the lake water level returning to an equilibrium condition. Tidal currents that are in phase and in the same direction of wind dominated flow will increase predicted velocities and water levels. Tides that are out of phase (moving water in the opposite direction of the drainage flow) will retard currents in the pass. To further complicate the hydrology, the GICW crosses the pass between the two water bodies. While this seems relatively complex, for the purposes of the response and this case study, it is most important to simply understand that winds in the region are dominated by cold fronts with strong northerly winds. This resulted in exposed tidal flats during most of the response.

**INITIAL SPILL RESPONSE ACTIONS**
Initially, the source of the release was unknown. But based on the observation of a spray of oil extending some 40 feet into the air from below the water surface (see Figure 1), the source was believed to be a well blowout. The initial response efforts for containment were under federal control while the actual source and operator were researched and identified by the United States Coast Guard (USCG) and the Louisiana Oil Spill Coordinator’s Office (LOSCO). Through the use of the State of Louisiana’s Strategic Online Natural Resources Information System (SONRIS) database maintained by the Louisiana Department of Natural Resources (LDNR), it was determined that the location corresponded to a newly developed well (see references for SONRIS website address). The well was the only one owned by the company and although it was completed, it was not yet in service for oil production. Once notified, the company responded immediately and continued the effort as part of a Unified Command. The response objectives were straightforward:

- Contain the oil at or near the source;
- Control the source by killing the well;
- The safety of the public and response personnel;
- Prevent oil from again entering the GICW; and
- Protect adjacent sensitive habitat and natural resources.

While these priorities are not ranked, the overriding objective and priority was safety of the public and response personnel.

The initial release occurred with southerly winds and an approaching cold front. During the night into the first day of the response, oil moved though the pass into Lake Salvador. Oil was also observed in the GICW. As the cold front approached, the winds clocked around to the north and moved the oil to the south toward Little Lake. The response tactic was to “put a box around the problem.” Two boxes in fact: one immediately around the source at a safe distance (due to the gasses and volatile hydrocarbons being continually released), and the other containing the oil in the open western portion of Bayou Perot. This second “box” would prevent oil from entering the complex marshes adjacent to the release site, the commercially important GICW, and the sensitive habitats further to the south. This was to be conducted while preparations were being made for securing the uncontrolled release by a wild well control contractor and while conducting on-water recovery operations. At this stage, it was a typical oil spill response with challenges typical of oil spill responses, such as managing vessel traffic on a major commercial waterway during the response and cleanup.

To assist in on-water recovery, a large on-water skimming system, developed primarily for offshore use, was secured and deployed on-scene. This platform, identified as the response contractor’s High Volume Open Sea Skimming System (or HOSS), served several critical roles. Not only was it a major skimming asset, the HOSS provided a base for forward operations with communications and a helicopter pad. Even though the shallow water restricted the mobility of the barge within Bayou, the HOSS barge was able to recover more than 1600 bbls of oil on Day 5 of the response.

Day 5 was a critical day in the response. First, the well was effectively controlled by “bull heading” the well with a heavy brine solution. Several thousand bbls of oil had been effectively contained near the source in a series of ring booms. The weather forecast predicted a cold front to pass through the area that evening with northeast winds in excess of 35 mph. Under such conditions, any unrecovered oil would be lost and blown into the adjacent bayous, canals, and marsh. Although the barge skimming system was able to significantly reduce the amount of free oil before the front passed, in the end, there was still oil on the water. Containment and protection booms set for shoreline protection were expected to have little effect given the predicted severe weather. The following day, the oil that wasn’t recovered or that had escaped containment, was stranded mostly in shallow canals and mud flats.

**OIL CHARACTERIZATION AND DELINEATION OF STRANDED OIL**

The oil observed spraying from the well was yellow in color and determined to be a mixture of oil and formation water. A sample collected early in the response indicated a water concentration of 67% by weight when analyzed. For practical purposes, the percentage of water was estimated as between 60 and 70%. The oil was characterized as a waxy condensate crude oil with an API gravity of 35. Once the oil separated from the water, it was a deep reddish color. Although estimates of more than 7000 bbls were used as a working value for planning and response, the true volume of oil released will never be known because it was an uncalibrated release from an open bore hole. By the end of the response, more than 8,000 bbls of oily liquids had been recovered (most of which was oil and emulsified oil). The oil spill impacted more than 37 miles of shoreline dominated by fringing marsh, canal banks, scarps, tidal flats, and riprap. Any overall mass bal-
 ance estimations would only be a guess, given the uncertainty of the release volume.

By chance, a National Oceanic and Atmospheric Administration (NOAA) Cessna Citation II aerial photography mission was being conducted near the spill site and diverted to acquire digital imagery of the spill area. The yellow, orange, and red oil contrasted easily with the water and marsh habitat. After processing the digital photography data and classifying the oiling with ground truth surveys, a digital map was created to assist the responders in planning cleanup operations. Based on this imagery, it was estimated that 3,330 bbls of emulsified oil was observed in the environment on 7 February. Most of the observed oil was in shallow canals or stranded on tidal flats. It was the stranded oil that created the next series of challenges for the responders.

CONVENTIONAL WISDOM FOR CLEANING OILED TIDAL FLATS

NOAA ranks the Environmental Sensitivity Index for Sheltered Mud Flats as a 9 on a scale of 1 to 10, with 10 being the most sensitive of habitats. As such, these areas are second only to the marsh itself relative to oil impacts from response and cleanup activities. Mud flats are very soft substrates that will not support even the lightest of foot traffic by cleanup workers. Even if the tidal flat is relatively compact, trampling will move oil from the surface into the sediments. Conventional wisdom suggests that oil that strands on a mud flat during low water will lift and be transported away during the next high water event. Afterwards, the flat will generally appear free of oil. The tactic is to set up collection boom and recovery resources adjacent to the flat and collect the oil after it naturally flushes during subsequent tides.

It is very unusual for stranded oil to form a strong adhesive bond to the wet substrate such that during high water events, water flows over the oil, and the oil doesn’t resurface and float away. The stranded, emulsified oil on the tidal flats in Bayou Perot created such a situation (see Figure 2). The cause was thought to be associated with the high organic content of the mud flat, and a simple case of waxy emulsified crude sticking to the organic mud. The cool temperatures of winter seemed to enhance the adhesion. On the few warm days during the response, the emulsions would begin to break and free, relatively pure oil would run off the intertidal flats and float. This oil could be collected by conventional approaches using containment boom and small drum or brush skimmers. The conventional approach would have required that the cleanup wait for spring, warmer weather, and higher water levels. The chronic threat to wildlife by leaving the oil till spring was not acceptable. Booms were deployed to contain the oil that did migrate, maintaining the strategy of keeping a “box” around the problem.

CLEANUP ENDPOINTS

All operations require a measure for success and criteria for determining that the task is completed. For shoreline cleanup, these endpoints should be balanced with environmental trade-offs: the cleanup should not cause more environmental damage than simply leaving the oil in place (the “do no more harm than good” approach). In addition, cleanup techniques should be selected or developed to meet the desired outcome, not the reverse. For the Bayou Perot Oil Spill, the following general endpoint criteria were established and approved by the Unified Command:

- Oiled shorelines should be free of bulk oil and not produce appreciable sheen under all weather conditions;
- There should be no appreciable floating or stranded oiled debris that can be removed by hand;
- Oil stain or sporadic coat on vegetation and large immobile debris that does not produce sheen and is judged not to be an appreciable contact risk to wildlife may be left in place and allowed to weather and degrade naturally; and
- Some oil stain or coat may still be present if, in the best professional judgment of the Environmental Unit/SCAT, it is determined that further treatment will not result in environmental benefit.

Evaluation and Testing of Cleanup Options

The NOAA Scientific Support Coordinator, as part of the Planning Section, was tasked to lead an assessment of cleanup options for the tidal flats. This process included small-scale tests of various cleaning alternatives to evaluate effectiveness in meeting the cleanup endpoints. The process of evaluation and testing was conducted jointly with the Planning Section and Operations. As previously stated, the nature of the oil was such that many conventional cleanup technologies were not highly effective with the weathered, emulsified residues that readily adhered to and didn’t easily release from tidal flats (an unusual phenomena). Oil stranded on mud flats are particularly difficult to collect. In fact, there may be no viable option that would not result in severe damage to the flat and adjacent marsh habitat (conventional wisdom). During most oil spills, oil easily refloats from intertidal flats during tides and migrates to an area that allows collection and recovery. The flats adjacent to marsh are of concern relative to wildlife exposure since many bird species utilize these areas for feeding.

Technical Approach

The NOAA job aid, Characteristic Coastal Habitats: Choosing Spill Response Alternatives, was used as a preliminary guide to assess possible cleanup options. Figure 3 provides a scanned copy of page 53 for evaluating Sheltered Tidal Flats. The guide was developed to characterize possible negative environmental impacts rather than the true effectiveness of cleanup options. Note that every oil spill situation is different, and such guidance must be used with the understanding that oil spill cleanup is a continual learning experience. Responders continually build on past experiences, but such guidance documents are a proper place to start. After discussions with the Regional Response Team (RRT 6), several cleanup options were selected for testing. These included Manual Oil Removal using rakes and squeegees; Synthetics or Polysorbents such as pads, sweep, round sorbents (boom), and snare (pom-poms); Natural Sorbets such as bagasse (a byproduct of sugarcane refining); Solidifiers; In-Situ Burning; and vacuum systems. Options such as Flooding and Low Pressure Ambient Water Flushing were considered not applicable because of access and concerns for mixing oil into the sediments. Tides provided a similar function with relatively little oil mobilization except on relatively warm days.

Testing would include small bench-scale experiments (backyard experiments) at the Command Post and field level demonstrations. The focus of the testing was the selection of methods that were effective, operationally feasible, protective of wildlife concerns, and that would minimize collateral impacts, such as trampling of vegetation and removal or disturbance of sediments. A small test site on the northwest shoreline of Bayou Perot was selected for field-testing. The site was logistically easy to access and had a number of small pockets of stranded oil typical of the larger problem being evaluated. Cane poles and flagging tape were used to delineate the study area. Documentation for the study included marking specific study areas with cane poles and GPS coordinates and photographing the testing before, during, and after application/treatment. To assist in evaluation, study areas were sometimes swept with a sorbent pillow that was used as a type of wildlife exposure indicator. If oil adhered to the pillows when dragged through a site, wildlife (particularly birds) would also be exposed and oiled.
RESULTS AND DISCUSSION

Manual Oil Removal
Airboats were used to access positions directly adjacent to the stranded oil. Although rakes were relatively ineffective, squeegees were effective at moving the oil around on the tidal flat. To be most effective, the blade on the squeegee needed to be reversed, since squeegees are principally designed as push, not pull tools. The problem with manual techniques was recovery. Pulling the oil toward the airboat was only one element of cleanup. What do you then do with the oil? There was just too much oil to consider using a small shovel to fill plastic bags.

Synthetic or Polysorbents
Conventional sorbents such as pads, sweep, round sorbents (boom), and pom-poms (or snare) were evaluated. In general, these were ineffective because the semi-solid, emulsified oil would only adhere to the outside of the pads, sweep, and boom. The waxy emulsified oil was not fluid enough for significant penetration, especially on cold days. The outer surface would collect some emulsified oil, but most of the capacity of the sorbent was wasted. These products worked effectively with the non-emulsified oil, but the emulsified oil was the problem requiring a solution. Snare, which is often highly effective for sticky heavy fuel oils (black oils), was ineffective.

Natural Sorbents
There was interest in what type of benefit natural sorbents might provide to assist recovery or possibly create a barrier between wildlife and residual oil. Such techniques have been employed in the past in seal haulout areas and as a polishing treatment at a crude oil spill just south of the spill location. The product selected was bagasse – a dried byproduct of local sugarcane production. The application on the thick emulsified oil did little to assist in recovery of bulk oil or provide an effective barrier to wildlife. Dusting with bagasse feed through a leaf blower may have provided a benefit as a final polishing treatment, but was not suitable to enhance recovery of the thick oil concentrations on most of the tidal flats. Far too much bagasse would have had to be applied to fully sorb the oil, and the recovery of the oil-bagged mixture was difficult. When used as a final treatment to dust sticky residues, RRT approval is required, and such applications should only be considered when there are significant wildlife risks and additional cleanup would cause unacceptable habitat injury.

Solidifiers
Solidifiers were evaluated twice during the response. They were evaluated for recovery of oil in small canals and bayous and for possible enhancement of shoreline recovery on the intertidal flats. Solidifiers are generally very effective with light crude and fuel oils that can easily be adsorbed into the polymer matrix. This oil was highly emulsified and appeared to be adsorbed and solidified relatively slowly without heavy agitation to assist. The primary limiting factor appeared to be one of contact with the relatively viscous water-in-oil emission. For on water recovery, boat access would also be required to apply and recover the product. It was determined that if a small boat could access the area, small drum and brush-type skimmers would be the most effective tools. Relative to treating and recovering the thick emulsified oil on the shoreline, the solidifier approach would be further challenged because this was not the type of situation for which the product was designed. This was not an oil on water situation. The oil was highly emulsified, and there was no way to effectively introduce mixing. A decision was made to include a solidifier in the field test to better understand the potential of such solidifying agents and as an additional method to assess the nature of the oil that we were attempting to recover. Similar to the natural sorbents sprayed onto the oil, the solidifying agent only reacted with the surface oil where contact was made. Attempting to mix the solidifying agent into the oil using rakes was not part of the experimental design. The result was a film of solidified oil and unmodified oil just below. The problem encountered was one of contact rather than polymer-oil interaction. With a different oil, the results might have been different, but then a different oil may not have adhered to the mud flat.

In-Situ Burning
Burning was considered but it failed the bench scale test. The highly emulsified oil would not ignite. The demulsified, weathered oil would be ignited, but then create an oily residue. There was some consideration for burning difficult to collect demulsified (red) oil in very shallow canals, but the oil needed to be very thick to burn hot enough to provide an efficient burn. In the bench-scale test, the residual that was left behind was very dark and vicious. When burning, the red oil boiled steam and splattered similar to what you observe if you add small amounts of water to very hot cooking oil in a skillet. There were also concerns over the potential for secondary impacts to unoiled adjacent vegetation by collateral burn. These would prove unimportant as much of the adjacent marsh was burned for marsh management by the landowner anyway. Regardless, the emulsified oil would not burn, and stranded emulsified oil was the problem being investigated.

Vacuum Recovery
The spill management team was able to identify a source for small vacuum systems that could be operated from airboats using 55-gallon drums for recovery. The thought of using these as you would a floor vacuum was considered, but considered unfeasible. It was decided that it was not practical to vacuum the flat. The best technique was to use manual methods such as squeegees to move the oil to the vacuum hose operated in a small sump or even on the flat of a shovel. Using the vacuum system in conjunction with squeegees proved to be highly effective.

Summary of Results
After evaluating all of the results, small vacuum systems operated on airboats were the most effective method to recover the emulsified oil. When deployed operationally, a collection team consisted of three airboats: one was positioned adjacent to the stranded oil on the exposed mud flat for worker access, a second airboat containing the vacuum system was positioned parallel to and on the outside, and a third airboat was used to shuttle drums of recovered oil. Under ideal conditions, the vacuum system would fill a drum with emulsified oil in less then 15 minutes. The time limiting factors became the time it took to move the oil and concentrate it at the vacuum hose and the transfer time between filling each drum. The technique required logistical planning, attention to detail, and a little finesse. Three vacuum system collection teams were used as the primary mud flat recovery teams. Additional teams were used for debris recovery and final cleaning/polishing with conventional sorbents. Teams using conventional small skimmers on water were used for oil that did release and was collected in containment booms adjacent to or near the flats. Overall, the shoreline cleanup required a mixture of conventional as well as non-conventional techniques.

CONCLUSION
The Bayou Perot well blowout and subsequent oil spill response and cleanup provided an excellent case study of why no two oil spills are the same. During the process to develop response tactics for the exposed intertidal mud flats, the Planning and Operations Sections worked closely with the scientific technical specialists to evaluate a series of possible cleanup options using bench-scale and actual field-testing. Ideas developed while sitting around a table
in the command post often sound feasible, but until tested in the field, should only be considered possible solutions. In the end, a combination of shoreline cleanup techniques were used to recover stubborn oil “stuck” to exposed mud flats and floating oil in shallow ponds and canals adjacent to Bayou Perot. The combination of the manual use of squeegees with airboat deployed vacuum recovery systems was the most efficient. The overall cleanup process was labor intensive and complicated by winter weather conditions, but the defined cleanup endpoints were achieved. The last cleanup site was signed off by the Unified Command on 1 May 2007 (99 days after the blowout). More than 3000 bbls of oil and oily fluids were recovered in the shallow canals, ponds, and exposed mud flats after the conventional open-water recovery operations in Bayou Perot had ceased. This value is very near the estimated 3330 bbls calculated from aerial imagery assessments (see Locke et al, 2008), but there is no way to accurately calculate the true variance in either the estimation based on digitally characterizing the aerial photography or the true volume of oil recovered with water from the cleanup. Even the true volume of oil released will remain an unknown given the release conditions. Some oil did migrate into vegetated marshes during a few higher water level events; some of that oil may have stranded in undetected and unrecoverable locations or flushed back out and was recovered. There are always unknowns. Actual oil spills are not controlled, scientific experiments. It was clear from field monitoring that only light residual oiling (that would have caused unacceptable environmental injury to recover) was left in the environment, and this residual was a small fraction of the oil quantified on 7 February. This was one of the largest recent spills in the United States. The site was remote and the response, challenging. The use of airboat deployed small vacuum systems to recover oil adhered to exposed mud flats was an innovative solution to an unusual problem. The cleanup techniques used in and adjacent to sensitive habitats required attention to detail and finesse to reduce collateral environmental damage. The credit for such professionalism is owed to the cleanup crews, the field supervisors, and the airboat drivers.

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REFERENCES


FIGURE 4. MANUAL RECOVERY IN CONJUNCTION WITH AIRBOAT DEPLOYED VACUUM SYSTEM. NOTE, THIS PHOTOGRAPH DEMONSTRATES CLEANUP IN PROGRESS AND NOT THE ENDPOINT OF CLEANUP (PHOTO CREDIT, NOAA).