USE OF *IN SITU* BURNING AS AN OIL SPILL RESPONSE TOOL: FOLLOW-UP OF FOUR CASE STUDIES

Jacqueline Michel, Zach Nixon, and Heidi Hinkeldey
Research Planning, Inc,
1121 Park Street
Columbia, South Carolina 29201

ABSTRACT: *Four* in situ *burning sites that varied widely in the physical setting, oil type, timing of the burn, and post-burn treatment were assessed 0.5-1.5 years post-burn: two condensate spills in intertidal marshes at Mosquito Bay, LA in April 2001 and near Sabine Lake, LA in February 2000; crude oil spill in a ponded wetland in Minnesota in July 2000; and a spill of diesel in a salt flat/wetland north of Great Salt Lake, UT in January 2000. When used quickly after a release, burning is most effective at reducing damage to vegetation and the areal extent of impact. Where crude oil was burned within hours after the release at the Minnesota site, the impact area was restricted to 3 acres. In contrast, the diesel in the Utah spill spread over 38 acres within 3 days. The window of opportunity for* in situ *burning to be an effective means of oil removal can be days to months, depending on the spill conditions. The condensate spill at Mosquito Bay site was effectively burned 6-7 days after the release was reported. For spills with snow and ice cover, burning may still be effective months later. In fact, it may be necessary to consider additional burns during thaw periods and during the final thaw. Burning will not reduce the toxic effects of the oil that occurred prior to the burn. It can, however, be very effective at reducing the extent and degree of impacts by quickly removing the remaining oil. In three of the four case studies, the area burned was significantly larger than the oiled area (up to 10 x). Healthy, green, unoiled vegetation is not always an effective fire break, particularly downwind; fires can quickly jump the kinds of fire breaks placed during spill emergencies in wetlands (e.g., vegetation laid down by the passage of airboats).*

Introduction

As a follow-up to a previous study of use of in situ burning of inland oil spills (Dahlin et al., 1999), the American Petroleum Institute funded follow-up field visits at the four sites to assess the efficacy of *in situ* burning on the medium-term recovery of oiled habitats (Michel et al., 2002). This report summarizes the lessons learned from burning at the following sites:

- Mosquito Bay spill in Louisiana: Condensate spill in a tidal salt marsh near the mouth of the Atchafalaya River burned in April 2001.
- Lakehead Pipe Line spill in Ruffy Brook, Minnesota: Crude oil spill into a ponded wetland burned in July 2000.
- Louisiana Point pipeline spill, in Louisiana near the Texas border: Condensate spill in a high salt marsh burned in February 2000.
- Chevron Pipe Line Milepost 68 near Corinne, Utah: Diesel spill into a wetland and salt flats area adjacent to the Great Salt Lake in January 2000 burned twice, in March and April 2000.

Mosquito Bay pipeline release, Terrebonne Parish, Louisiana

The release occurred from a condensate pipeline located on Point au Fer Island, a salt marsh island in Mosquito Bay. The vegetation consisted of mixed stands of salt cordgrass, giant cordgrass, and salt grass. Fiddler crab burrows reached densities of up to 100/m^2. Much of the oil was trapped in the dense vegetation and pooled in depressions and along small tidal channels. However, some of the oil flowed out of the marsh via a main tidal channel and blew into a small adjacent bay to the west (Figure 1). Oil had penetrated up to 20 cm into the marsh soils via crab burrows and root cavities; free oil was up to 4 cm thick, pooled on the water surface and in burrows, though there were extensive areas where the oil thickness was on the order of 1 mm.

The first burn was conducted in the small bay to the west of the release (Figure 1) during high tide (to maximize the water layer in the marsh) 6 days after the spill was discovered. The water layer over the marsh surface was 0.1-5 cm. Winds were >10 knots from the south. A firebreak was placed around the burn site by repeated passes with an airboat. Once started, the fire burned quickly downwind, jumped the firebreak, and burned to the water's edge or to large patches of black rush or sedges.

A second burn at the release site was conducted early on 13 April, when the wind speed was expected to be lowest, but during mid-tide. Little to no water covered the marsh soils, except as isolated pools in the deeper depressions. Winds were 5-10 knots from the south. Attempts to set a down-wind fire stalled, so many small fires were started in oil pools throughout the site. The fire again burned both oiled and unoiled vegetation, stopping mostly at the water's edge.

Immediately after both burns, survey teams reported little to no free water remaining on the marsh surface, however the surface soils were wet and soft, with no evidence of soil or root burns. The marsh stems were burned down to 1-10 cm above the soil surface, indicating the localized depth of water or the point where the lowermost stems were too wet to burn. There was no oil or burn residue on the marsh surface, but free oil remained in the sediments and burrows. Approximately 90-95 percent of the surface oil was estimated to have burned.

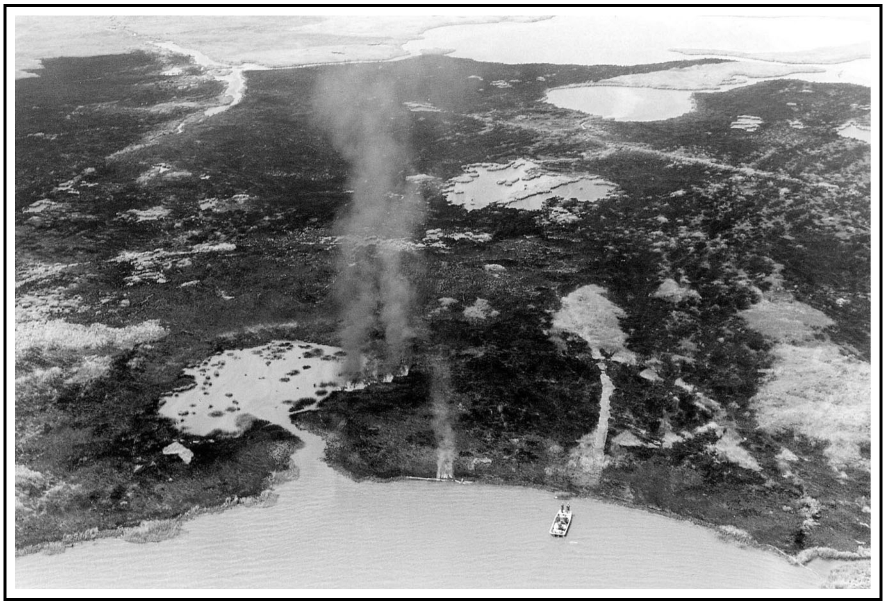

Figure 1. First burn at the Mosquito Bay, Louisiana condensate spill on 12 April 2001, 1 hour after the first burn ended. The firebreak is barely discernable as an arc around the small bay. The marsh burned to the downwind water's edge in most areas.

Ground surveys and post-burn vertical aerial photographs were used to estimate that the oiled area covered 12 acres, whereas the burned area extended over 98 acres. Thus, the burned area was about eight times the oiled area. Based on field observations in 2001 and 2002, the unoiled and burned vegetation was recovering as expected after a burn. However, areas where the condensate pooled on the surface and penetrated the substrate showed a lack of vegetative recovery after 13 months (Figure 2). It is clear that the oil had already affected most of the plants in these heavily oiled areas before the burn was conducted. On 11 April, the vegetation had just started to turn chlorotic, indicating the first stage of toxic effects to the vegetation. The burn was an effective technique to remove the remaining oil, but it could not mitigate the toxic effects that had already occurred. Three factors point toward little residual toxic effects after the burn:

1. *Spartina alterniflora* plugs were planted in the small western bay to stabilize a channel bank against potential erosion. The planted area is in the area delineated as heavily oiled and burned. At least in this area, the soils are no longer acutely toxic to vegetation.
2. In October 2001, large numbers of live fiddler crabs were present and active throughout the areas of completely dead vegetation. Fiddler crabs have been shown to be very sensitive to the effects of light oils (e.g., Krebs and Burns, 1977 who documented long-term impacts to fiddler crabs from a No. 2 fuel oil spill into marshes in Buzzards Bay). The fact that fiddler crabs were abundant throughout the oiled and burned area suggests that residual toxic effects are minimal.
3. The sediment chemistry for four samples collected from the areas considered to be the most heavily oiled in October 2001 showed relatively low levels of PAHs, from 0.47 to 2.4 ppm, with evidence of extensive weathering in three of the samples.

Figure 2. Main creek channel along which the condensate flowed from the release site at Mosquito Bay, LA spill.

A. 26 April 2001, 14 days post-burn; lightly oiled/burned vegetation had started to re-grow.
B. 17 October 2001, six months post-burn; no re-growth of the heavily oiled vegetation

Lakehead pipeline spill milepost 914 (Ruffy Brook, Minnesota)

The spill resulted from a 34-inch crude oil transmission pipeline with a failed weld, releasing a medium Bow River crude oil with a specific gravity of 0.928 that affected about 3 acres of a ponded wetland (Figure 3A). Water depths in the wetland ranged from 0.3-1m. The bottom sediments were very soft and highly organic, consisting of mostly peat and rooted vegetation. Mechanical oil recovery methods in the patchy submersed and floating aquatic vegetation would have been very difficult and detrimental to the marsh, so a controlled burn was conducted the same day as the release. It is clear that burning was an appropriate option for rapid removal of the oil before it spread further.

The initial burn lasted three hours, with the oil pool burning as a whole, rather than progressively. The fire quickly went out when the edge of the oil was reached. Touch-up burning was conducted over three days. Only the oil and oiled vegetation burned. It was estimated that approximately 80 percent of the oil was consumed during the burn (Natural Resources Engineering Co., 2000). There was a significant amount of burn residue (Figure 3B). In some places, the residue was 1 cm thick. The residue was tar-like and could be picked up in sheets or “globs”. None of the burn residue was observed to have sunk.

In summary, the use of in-situ burning at this site appears to have been very successful. Large volumes of oil were removed quickly, preventing further spread to sensitive areas and the potential for significant sediment contamination. Water depths in the ponded wetland were ample to prevent damage to the substrate and plant roots, a particularly important consideration in areas with soils of such high organic content (in many areas the soils were almost pure vegetative matter). The burn residue was removed quickly, preventing its eventual sinking and contamination of bottom sediments. It is important to note that crude oils generally produce a burn residue that will have to be removed post-burn. It appeared that most of the herbaceous vegetation quickly recovered after the burn. Willows, which are known to have low fire tolerance, showed little recovery.

Figure 3. Ruffy Brook spill.

A. Oblique aerial photograph, taken on 17 July 2001, one year post burn, showing the position of the pipeline right-of way (red dashed line), the release location (green star), and the nature of the burn site. Prior to the burn, willows grew close to the release site (indicated by the arrow). The willows died after the burn; an arrow indicates bare stumps and dead trees. The approximate area of the burn is outlined in yellow.

B. Photograph showing the nature of the tarry residue that was manually removed within three days after the burn; it was picked up in sheets.

Louisiana Point pipeline release, Cameron Parish, LA

The release was discovered on 23 February 2000, occurring as a pinhole leak in a buried pipeline crossing a high marsh at about 500 m from the Sabine River. An unknown amount of condensate was released, impacting about 13 acres of high salt marsh dominated by salt cordgrass, sea-oxeye, batis or saltwort, glasswort, and salt grass during the dormant season. The oil was burned on 25 February 2000. It is possible that the oil had been in contact with the marsh for 3-5 days (John Chance Land Surveys, Inc., 2000). There was very little information available about the site conditions before and during the burn, particularly the amount of standing water on the marsh surface. Figure 4 shows a vertical aerial photograph of the burned area taken 2.5 months post-burn, with the area of the oil spread indicated. Note that the eastern extent of the burned area appears to have been contained within the firebreak laid down by airboat. However, the fire spread to the south and burned for several days, re-igniting from hotspots thought to be smoldering woody debris. In some places, the marsh burned to the shoreline along the Sabine River channel. The total area burned is estimated to be 135 acres, thus the burned area was about ten times the oiled area. There was no estimate of percent of the burn efficiency.

Ground surveys and vertical aerial photographs taken 19 months post spill show that the unoiled and burned vegetation recovered completely, with no visual difference when compared with adjacent unburned vegetation. The post-burn monitoring program included percent cover, stem height and stem density in oiled/burned, unoiled/burned, and unoiled/unburned areas. The results for dominant species are shown in Figure 5, which show that, early in the growing season right after the burn, most species in the oiled/burned quadrats had reduced cover and stem density. By October 2000, at the end of the growing season, there had been increases in vegetation cover and stem density for all species, indicating that some of the vegetation in the oiled and burned quadrats had survived and were growing. However, there were still significant differences between sites for total cover, sea-ox-eye, and saltgrass. The single, woody stem of *Borrichia* would make it highly susceptible to damage from both exposure to a toxic oil and burning. As a vegetatively propagating perennial shrub, *Borrichia* is expected to have a slow recovery after oiling and burning. Overall, it is clear that *Batis* has recovered the most, and *Borrichia* has recovered the least.

Sediment samples collected from five oiled and burned quadrats in May 2000 contained 16-236 ppm (with a mean of 76 ppm) diesel range organics. By October 2000, all samples were below the detection limit of 10 ppm. There was no evidence of oil residues in the marsh soils by October 2001. No sheens were observed, and no odors were detected during the site visit. The soils appeared to be oxygenated in all areas, with no strongly reducing soils with depth.

Figure 4. Vertical aerial photograph of the Louisiana Pt. site on 5 May 2000, three months post-burn. The oiled area was 13 acres, and the burned area, as interpreted from the photograph, was 135 acres. The vegetation burned to the edge of the Sabine River.

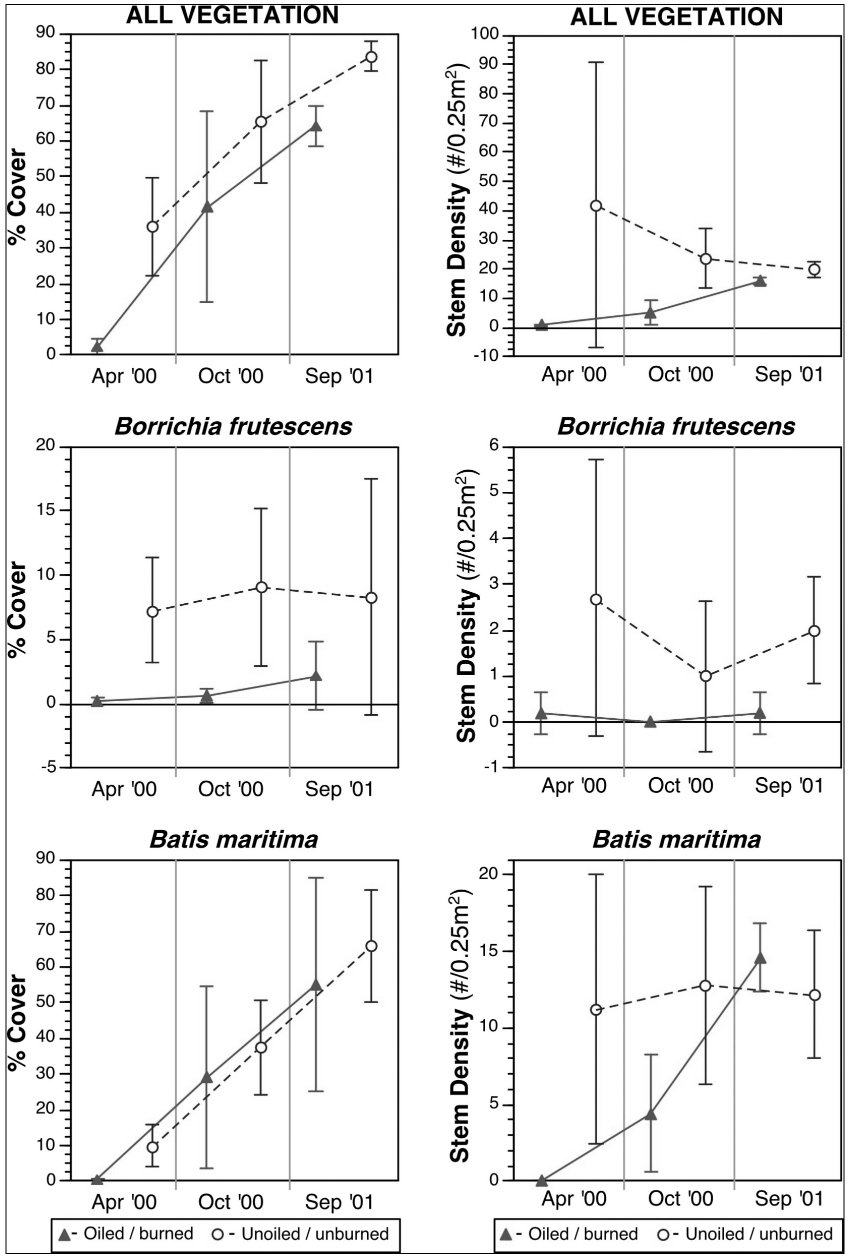

Figure 5. Recovery plots of percent cover and stem density for all vegetation and the individual species for oiled/burned quadrats (n=5) and unoiled/unburned quadrats (n=10).

Chevron pipe line milepost 68 diesel spill

The spill resulted from a pinhole leak in a weld on an 8-inch steel pipeline that followed an oil railroad grade. An adjacent landowner discovered the spill on 20 January 2000. The site was very remote, located north of the Great Salt Lake, on land managed by the Bureau of Land Management. Vegetation in the brackish marsh was dominated by cattail, hardstem and alkali bulrush, and saltgrass. Portions of the alkali flats were sparsely populated with glasswort. The diesel spread in two directions: 1) about 75 m north of the release into a ponded wetland formed by the old railroad grade, and 2) south of the release, flowing across a salt flat area with free oil reaching 650 m downstream and sheens visible for a distance of 1.6 km downstream from the release site. The details of the burn and monitoring results are provided in Williams et al. (2003), thus are not repeated here. In summary, the history of treatment at the spill site is:

- 38.2 acres oiled on 20 January 2000
- 15.3 acres with free-floating oil and 22.9 acres with sheens only
- 12.7 acres burned on 10 March 2000
- 3.4 acres burned on 27 April 2000
- 6.8 acres tilled on 29 September 2000
- 3.4 acres tilled on 2 August 2001

The lessons learned from *in situ* burning at this spill are summarized as follows:

- Snow and ice can both help and hinder the use of *in situ* burning on land. Snow and ice can slow the spread of oil, increasing the oil thickness and the overall efficacy of the burn. However, when the ice does not melt during the burn, it can slow the heat transfer process and prevent the oil from vaporizing and burning. After the first burn, it was clear that there were areas that had been covered by ice and did not efficiently burn, thus a second burn after all the snow and ice had melted was required. For spills in areas of snow and ice, sites should be surveyed during thaw periods or after the final thaw to determine the need for additional burning or other response actions.

- Snow and ice also slow natural oil weathering processes, lengthening the window of opportunity for use of *in situ* burning as a response option.
- One of the primary objectives of the burn was to reduce the threat of oil transport from the spill site to downstream areas utilized by migratory and resident birds. It was the most effective option for removing as much oil as possible from an area where vehicular access was very restricted and foot access was difficult.
- Burning is not effective in removing oil that has penetrated into the soils. It is not clear whether burning had a wicking effect that drew oil to the surface at this site.
- Burning did not prevent the toxic effects of the oil that occurred prior to the burn. In the areas closest to the release site, on both the north and south sides of the release site, some vegetation mortality was noted.
- The burn would have been more effective if it had been conducted soon after the release was discovered. Rapid burning would have reduced the potential for oil penetration into soils and the toxic effects to vegetation. Once it is clear that mechanical and manual removal efforts are not feasible, burning should be evaluated as a response option.

Lessons learned from all case studies

The four *in situ* burning sites followed in this study varied widely in the physical setting, oil type, timing of the burn, and post-burn treatment. Impacts to vegetation and the rates of recovery also varied widely. Yet, there are some key lessons that can be used to support decision-making in the future.

- Burning is most effective at reducing damage to vegetation and the areal extent of impact when it is used quickly. The best example is the Ruffy Brook site, where the crude oil was burned within hours after the release, and the impact area was restricted to about 3 acres. In contrast, the diesel in the Utah spill spread over 38 acres within a few days.
- The window of opportunity for *in situ* burning to be an effective means of oil removal can be days to months, depending on the spill conditions. It was surprising to many that a condensate spill at the Mosquito Bay site could be effectively burned 6-7 days after the release was reported. Yet, up to 1 cm of condensate remained on the marsh surface at the time of the burn. For spills with snow and ice cover, burning may still be effective months later. In fact, under snow and ice conditions, it may be necessary to consider additional burns during thaw periods and during the final thaw.
- Burning will not reduce the toxic effects of the oil that occurred prior to the burn. It can, however, be very effective at reducing the extent and degree of additional impact by quickly and efficiently removing the remaining oil.
- Responders considering the use of *in situ* burning should be very aware of the possibility that the fire will spread to unoiled areas. In three of the four case studies, the area burned was significantly larger than the oiled area. Healthy, green, unoiled vegetation is not always an effective firebreak, particularly downwind and for vegetation that has a low moisture content. Fires can quickly jump the kinds of firebreaks placed during spill emergencies in wetlands (e.g., vegetation laid down by the passage of airboats). Responders should consider the consequences of burning adjacent areas in burn plans. Where the spread of the fire is determined to be unacceptable, then additional efforts are needed to control the spread of the fire.
- It is very important to make and record observations on the site conditions prior to the burn (oiled area, oil thickness, amount of water on the surface, soil and vegetation type) and post-burn (duration of the burn, amount of oil remaining, amount of water remaining, soil conditions, area burned). These observations will allow objective evaluation of the effectiveness and effects of the burn, to support the use of burning at other spill sites.

Biography

Jacqueline Michel is geochemist who provides scientific support for 50-100 spills per year. Her expertise includes evaluation of countermeasures for shoreline cleanup and restoration.

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