ENVIRONMENTAL EFFECTS OF *IN SITU* BURNING IN INLAND AND UPLAND ENVIRONMENTS

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ABSTRACT*:* In situ *burning of inland and upland habitats is an alternative oil spill cleanup technique that, when used appropriately, may be more environmentally acceptable than intrusive manual, mechanical, and chemical treatments. There have been few published reports documenting the environmental effects of* in situ *burning in inland and upland habitats. Thus, this study, sponsored by the American Petroleum Institute, used two approaches to increase the knowledge base and improve the appropriate use of* in situ *burning: (1) detailed review of published and unpublished* in situ *burn case histories for inland and upland spills; and (2) summaries of fire effects and other information from the literature on fire ecology and prescribed burning. Thirty-one case histories were summarized to identify the state of the practice concerning the reasons for burning, favorable conditions for burning, and evaluations of burn effects. The fire ecology and effects summaries included background information from the extensive knowledge base surrounding wildfire and prescribed burning (without oil) as a natural resource management tool, as well as fire tolerance and burning considerations for dominant vegetation types of the United States. Results from these two approaches should improve the application of* in situ *burning for inland and upland spills.*

Introduction

The primary objective of this study was to identify the environmental conditions under which burning should be considered as a response option for oil spilled in inland and upland habitats. Two different approaches were used: (1) documenting the state of the practice from spill case histories where burning was used; and (2) extracting information from the extensive literature on fire ecology and prescribed burning. Combined, these two approaches provide the best available guidance on when burning should and should not be considered for a specific spill in inland and upland areas. Issues relating to human health and air quality were not directly addressed in this study.

Case histories

Previous literature searches (Mendelssohn *et al.*, 1995; S.L. Ross Environmental *et al.*, 1996), recent publications, and personal contacts were used to identify 31 case histories of spills or experiments where oil was burned in inland and upland habitats (see Dahlin *et al.*, 1998, for complete references and contacts). These case histories were reviewed and standard incident summary sheets were generated for each case history. An example incident summary sheet is shown in Table 1.

Generally, burns were conducted mostly in marshes and open fields. Nearly half of the burns of a known volume of spilled oil were for quantities of less than 1,500 liters. The most common type of oil burned was crude oil; there was only one case where a heavy crude oil was burned. Post-burn monitoring was seldom conducted for any period of time. Burning, especially of small spills, is routinely conducted in some states, but there is little documentation available other than the fact that the oil was burned.

The case histories did, however, provide information on the state of the practice in terms of how *in situ* burning is used in inland and upland areas. In the past, spilled oil has been burned for the following reasons:

- To quickly remove oil to prevent its spread to sensitive sites or over large areas
- To reduce the generation of oily wastes, especially where transportation or disposal options were limited
- Where access to the site was limited, by shallow water, soft substrates, or the remoteness of the location

As a final removal technique, when other methods began to lose effectiveness or became too intrusive, the following favorable conditions for burning were also identified from the case histories:

- Remote or sparsely populated sites
- Mostly herbaceous vegetation (fields, crop land, marshes)
- Dormant vegetation (not in active growing season)
- Unvegetated areas (dirt roads, ditches, dry streambeds, etc.)
- In wetlands, presence of a water layer covering the substrate

Table 1. Incident summary sheet for the Kolva river Basin pipeline spill.

Name	Kolva River Basin Pipeline Spill: Site 5
Date	Pipeline leaked from 1986–1994
Location	Kolva River, in the Komi Republic of northern Russia
Quantity spilled/burned	Large volume (exact quantity not reported)/unknown
Oil product/type	Mixture of crude oil and formation water
Environmental setting	Freshwater wetland (muskeg swamp with no outlet)
Spill incident summary	• The spill was the result of multiple leaks in the pipeline over a period of several years. • A large quantity of oil impacted roughly 30 hectares to a thickness of 1 m. • Containment strategies involved the construction of a series of low earthen dikes creating cells of oil. Ditches were dug on the inside toe of the dikes to facilitate oil collection. • The type of igniter used was not reported. • The burn involved six hectares and burned for 20 hours. • There was no standing water on the wetland surface at the time of the burn. The depth of the water table was not reported.
Burn evaluation	• The burn proved to be unsuccessful because it created so much heat that the oil was driven into the organic substrate. • The burn residue remaining on top of the peat mat was extremely viscous and oily. No further cleanup of burned areas was attempted because the oil residues could not be flushed, and the peaty substrate was too soft to support any foot or vehicular traffic.
Reference(s)	Hartley, 1996

- In cold areas, presence of snow and ice which provides natural containment and substrate protection
- Calm winds
- Spills of fresh crudes or light refined products which burn more efficiently

The following operational and post-burn considerations were also developed from the case histories:

- Avoid physical disturbance of the vegetation and substrate.
- When oil does not ignite readily, an accelerant may be needed.
- A crust or residue (which may hinder revegetation) is often left behind after burning, and may need to be broken up or removed.
- Erosion may be a problem in burned areas if plant cover is reduced.
- Vegetation in and adjacent to burn site can be affected by burning, including long-term changes in the plant community.

Burning can severely impact organic soils, such as peat found in certain wetlands.

Fire ecology and prescribed burning

In addition to the case histories, applicable information was gathered from the fields of fire ecology and prescription burning (in the absence of oil). Prescribed fires are often used as a forest and range management tool, and are often conducted for the same reasons as *in situ* burning: fire can be less damaging, more effective, and less costly than chemical and intrusive mechanical methods (Wright and Bailey, 1982). The fire ecology and prescribed burning literature was searched for both general guidelines as well as species-specific profiles on fire ecology and effects, providing valuable summaries on the effects of burning (in the absence of oil) on plant communities. There are many lessons already learned by prescribed fire practitioners and fire ecologists which are directly applicable to the use of *in situ* burning of spilled oil. Major fire ecology and prescribed burning references that were consulted included Wright and Bailey (1982), Cerulean and Engstrom (1995), and Whelan (1995).

In addition to literature sources, the U.S. Department of Agriculture (USDA) Forest Service maintains a Fire Effects Information System (FEIS) which was used as the major source for reviewing and summarizing information on the ecology and effects of fire on specific plant species (Fischer, 1992). This database can be accessed over the World Wide Web at the following address, *http://www.fs.fed.us/database/feis/welcome.htm*. The FEIS contains literature summaries and case histories from a wide body of sources. Pertinent database fields include the following: fire ecology and adaptations; post-fire regeneration strategy; immediate fire effect; plant response to fire; fire management considerations; and fire case studies. For this study, information on fire effects and ecology of the dominant plant species of each U.S. ecoregion were summarized from the FEIS database (over 200 species in total). As an example, a summary for one species is provided in Table 2 (see Dahlin *et al.*, 1998 for other species).

Such summaries should provide spill responders with better information on the potential response of different habitat types and plant species to *in situ* burning. Major points from the literature review and the FEIS ecoregion species summaries on fire effects (in the absence of oil) are discussed below by major vegetation type.

Trees/forests. Even if they are not killed by fire, trees generally take a long time to recover to pre-fire levels of structure and dominance relative to smaller, faster growing shrubs and grasses. Fire may wound or scar trees, providing entry points for pathogens (fungi, insects, etc.) that could lead to delayed impacts or mortality as a result of fire. *In situ* burning in most forested areas should be discouraged; however, for certain types of settings and communities, *in situ* burning of surface vegetation within forested areas may be reasonable. Burning might be reasonable for open or savanna-like forest communities with tree species that are at least moderately fire tolerant, especially if fire threat to trees is minimal or actively minimized. *In situ* burning might also be reasonable for special fire-prone or fire adapted forest species or communities under certain conditions, even if trees will be directly at risk from fire.

Table 2. Fire effects summary for Big bluestem (A*ndropogon gerardii*).

Common name	Growth form	Fire tolerant ? (adaptations)	*In situ* burn potential	Comments and considerations
Big bluestem	Grass	Yes; fire adapted (rhizome 2.5–5 cm below soil surface, fire plays role in maintaining plant community)	High	Grassland fires are low intensity and fast moving; high intensity and/or slow fires may be more damaging; burning in late spring when dormant is best, resulting in vigorous new growth and an increase in flower stalks; summer growing season burns most damaging, regrowth is slower and less vigorous; drought conditions cause reduced growth after burning; similar effects can be seen in areas with naturally low precipitation

Shrubs and associated communities. Woody shrubs may be lumped with trees in certain respects, in that they look similar and may thus be perceived as fire sensitive; however, the shrub species examined showed a wide range of fire sensitivity, with many species being very fire tolerant. Several highly fire-tolerant species examined might be good candidates for *in situ* burning. Shrubs are usually top-killed by fire, but many sprout vigorously from belowground parts and recover quickly from fire. It should be kept in mind that dense shrub thickets can create fire hazards and carry fire to unwanted areas. Also, some very fire "adapted" shrub species and communities are also highly flammable, presenting additional fire hazards.

Grasses/grasslands. Many graminoids (grasses, sedges, etc.) are fire tolerant and appear to be good candidates for *in situ* burning. Most of the species examined respond better during dormant season burns, and when soil conditions are moist or wet, so that roots, rhizomes, and organic soils are less likely to be damaged. For native grasslands, natural and prescribed fires are typically low intensity and fast moving; high intensity, slow burning fires such as those that might be produced by *in situ* burning of oil may be more damaging than typical fires. Native grassland species include many warm season grasses, dormant in cool season months. Many non-native species which occur in prairies, pastures, fallow fields, etc. are cool-season grasses, whose growing season may correspond or overlap with the typical dormant period of warm season species. The types of grass species present (warm season, cool season, or both) could be an important factor when plant dormancy and other seasonal concerns are considered in relation to *in situ* burning. Tallgrass prairie (bluestem) grasslands of the eastern plains appear to be more fire tolerant than mixed and shortgrass prairie (grama-buffalograss) grasslands of the central and western plains, where conditions are more arid. *In situ* burning may have greater potential in areas with tallgrass prairie, where damage to native vegetation is less likely. Finally, although many grasses are fire tolerant, some species or growth forms can be much less so. In general, bunchgrass species or forms are often more fire sensitive than low-growing, rhizomatous grasses. Perennial needlegrasses (*Stipa* spp.) are reported to be the least fire tolerant of the bunchgrasses, and may not be good candidates for *in situ* burning.

Desert habitats/cacti. Many desert or desert-like habitats do not burn very frequently, and plant communities in such areas are generally not fire-adapted, and may be severely damaged or eliminated by fire. Cacti, for example, often experience delayed mortality following fire, and should generally not be burned if they are to be maintained in the plant community. *In situ* burning of desert vegetation might not be advisable in many cases, although areas devoid of vegetation, such as in open spaces between individual plants or in dry channels of intermittent streambeds, may present good opportunities for *in situ* burning. It should be noted, however, that fire can alter or destroy surface crusts which are an important component of desert soils, causing unforeseen impacts, even in unvegetated areas.

Conclusions

In situ burning can be a valuable oil spill cleanup tool in inland and upland environments, particularly under certain conditions. The *in situ* burning case histories examined outline the state of the practice concerning where and when *in situ* burning is feasible and environmentally acceptable. *In situ* burning is clearly suited towards use in certain environmental settings and habitats, but not others. The case histories also highlight important operational and post-burn considerations that should be evaluated for each spill.

Given the available case-history information, the overall knowledge and information base concerning *in situ* burning of inland an upland environments is still limited. To help add to this knowledge base, summary information from the fields of fire ecology and prescribed burning (in the absence of oil) is a valuable tool, increasing the information available to oil spill responders concerning the potential responses of different habitat types and plant species to *in situ* burning. The use of information gathered from the fire ecology and effects literature comes with a strong disclaimer, however. Fire sensitive vegetation types where *in situ* burning should definitely not be used can be clearly identified, however, the appropriateness of burning of oil in plant communities described as fire tolerant or resistant is largely untested. Due to the complexity of fire science and prescribed burning, and fire ecology and environmental effects in particular, we suggest that prescribed-fire practitioners be consulted when *in situ* burning is planned, to provide valuable knowledge and experience not likely possessed by spill responders.

Finally, because relatively few case histories were available, and information borrowed from the fire ecology and prescribed burning literature is largely untested in terms of adding oil, we strongly suggest that all future applications of *in situ* burning be thoroughly documented and the results made available to the response community. Additionally, we recommend that ideas generated by this and other studies be examined both experimentally and during spills of opportunity where *in situ* burns are employed or tested. Efforts in the past have focused on monitoring air quality during burns. Monitoring of vegetation and substrate effects has been inadequate. It is suggested that simple pre- and post-burn ecological monitoring programs be developed as part of the pre-planning for the use of *in situ* burning, in order to generate information that can better support future decisions on when *in situ* burning is a suitable response option.

Biography

Scott Zengel is a senior ecologist with Research Planning, Inc. of Columbia, South Carolina, a consulting firm that specializes in scientific oil spill research, planning, and response.

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