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EDITORIAL

# Response Strategies for Spills on Land ☆

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## Introduction

Many more oil and chemical spills occur on land than on water, a fact that is not really surprising considering the many tens of thousands of kilometers of pipelines that criss-cross both producing and consuming countries and the huge number of transfers between pipelines, storage facilities, rail tankers, and road tankers that take place on a daily basis throughout the world. Most of these spills go unreported in the media as they do not generate dramatic visual images that are associated with vessels in distress. One consequence of the greater focus on coastal or marine spills has been that very often there is a higher level of concern for spills on water when these events take place. This has led to a greater emphasis on research and planning for marine or coastal spills as compared to land spills. For example, the analysis of sensitivity issues, the concept of net environmental benefit, and the evaluation of cleanup endpoints have been the subject of much discussion for marine and coastal spills, yet these topics largely have been ignored for oil spills on land. Similarly, there are few dedicated manuals or guidelines for oil spills on land compared to the plethora of manuals for spills on water. Nor has there been a study for oil spills on land comparable to the comprehensive "Oil in the Sea" review (NRC, 1985), which is currently being updated.

This brief overview of response strategies for spills on land uses comparisons between land and water spills to highlight similarities and differences that are important for the decision process and for the establishment of cleanup endpoints.

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## Oil Fate and Behavior on Land

Response strategies are governed to a large degree by the behavior of the spilled oil. A fundamental difference between the behavior of oil spilled on land and on water is the speed at which oil moves or spreads and the resulting size of the affected area. Oil spilled on water is transported and spread by winds and/or surface currents, which are often variable and only occasionally can be predicted accurately (Murray, 1982). Consequently, the fate, behavior, and effects of spills on water have a much higher level of unpredictability and uncertainty (Galt, 1995; Lehr *et al.*, 1995). If and when oil reaches water, and does not submerge or sink, then transport and weathering rates can increase dramatically (Table 1).

By contrast, oil on land moves much more slowly. Except in rare circumstances, oil, like water, flows downslope and often collects in the same places: creeks, ditches, streams, and rivers. The rate of downslope movement is a function of the oil viscosity, air/ground temperatures, slope steepness, and the surface condition (roughness, vegetation type, soil type, permeability, etc.). The surface of the land is rarely flat so that the thickness of layers of oil varies considerably and the oil collects and forms pools in depressions. As rates of movement are slower and flow directions more simple than on coastal or open waters, the ability to predict transport pathways is greater so that it is then possible to focus response strategies more accurately for land spills. Even if or when the oil reaches a stream or creek, the transport rate may increase dramatically but the flow direction is almost always the same as that of the basically unidirectional river currents.

The rates of the various oil weathering processes are largely dependent on the proportion of the surface area that is exposed. These rates would be expected to be slower on land when compared to oil on water, where oil thins, usually to thicknesses often of only a few millimeters. Also, after a short time period, oil on land reaches a stable condition and the likelihood of further movement and of additional weathering is minimized, which is not necessarily the case on water.

**Table 1** Comparison between spills on land and on water

| Water | Land |
|---|---|
| *Oil behavior* | |
| Oil remains in motion: sometime difficult to locate | Generally slow moving or static |
| Moved by winds and/or currents | Collects in depressions or water courses |
| Degree of unpredictability and uncertainty | Easy to define location and amount of surface oil |
| Generally spreads to form a very thin surface layer | Only light oils will spread to form a thin layer; often considerable pooling of oil |
| Weathering and emulsification are active processes | Weathering slows considerably after approximately 24 h |
| *Resources at risk* | |
| Some are mobile – fish, birds, boats | Some mobile resources – birds |
| Few resources at risk on the actual water surface | Often many static resources – buildings, vegetation, crops, |
| Vulnerability is uncertain | Except in remote areas, usually many more resources at risk |
| | Risks easy to identify |
| *Response operations* | |
| Water based | Land based |
| Weather dependent – fog, winds, waves, currents, etc. | Usually not weather dependent |
| Predominantly mechanical response (booms and skimmers) with potential for burning or dispersant | Predominantly manual response in most cases |
| Often requires considerable support | Usually remove a higher percentage of the oil, as weathering slowly and as cleanup standards are more strict |

The accuracy of forecasting and modeling for the movement and weathering of spilled oil decreases as the oil moves from the land to a stream, then to a large river or coastal environment and finally to open water conditions. This makes planning more complex and difficult as a wider range of possibilities are presented that must be considered. This imprecision often leads to the development of a "Minimum Regret Strategy" in response planning for coastal or open-water spills (Lehr *et al.*, 1995).

## Response Strategies and Tactics

When spills occur on land, the oil generally is static after a short time period, or moves only slowly, so that detection is straightforward and recovery operations generally proceed in an orderly and progressive manner as compared to the more dynamic situations that usually typify coastal or open-water spills. Most response strategies focus on containment and control as near to the source as possible to minimize the spread of the spilled material. An important response strategy for land spills is to prevent the spilled material reaching streams and rivers because of the significant difference in rates of oil transport on land and water. As oil moves from land to rivers to open waters, the sharp increase in the size of the affected area is accompanied by an increase in the numbers and types of resources at risk and by a decrease in the ability of responders both to protect resources at risk and to recover the mobile oil.

After the initial emergency phase of a response to a spill, operations on land do not have the same dynamic character as compared to marine, coastal, or river spills. Response methods for containment and protection on land include barriers, berms, and trenches of different sizes, materials and configurations (see API/NOAA, 1994; CONCAWE, 1983). The selection of appropriate techniques is dependent on the amount and type of material spilled, the slope of the terrain, the surface materials, and the available time to deploy and intercept. One operational objective, if possible, should be to contain the spilled material in such a way as to make recovery easier, for example, by damming to create a pool of sufficient depth to allow the use of skimmers. Recovery techniques are basically the same as are used on coasts: washing; manual, mechanical or suction removal; and *in situ* treatment (burning and land farming).

From an operational viewpoint, for land spills that reach water there is a need to differentiate between large rivers where only one bank is surveyed or cleaned at a time, and small rivers, streams, ditches, or creeks where both banks can be surveyed or cleaned at the same time. Rivers have a variety of valley types that include canyons, bluffs, flood plains, levees, and deltas, and channel types that include straight, meandering, braided, and anabranched (or anastamosed) reaches. By contrast, small streams and creeks tend to be confined to canyons or channels but have a wide range of channel forms that include cascades, rapids, pools, riffles, glides, and jams. As floating oil can move very rapidly on rivers or streams, control and protection strategies may involve the identification of practical interception points and even the pre-staging or pre-deployment of equipment to establish control and prevent spreading downstream (Owens & Douglas, 1999).

## Comparison between Spills on Land and Water

In considering the differences and similarities of response operations between spills in different environments, there are some clear trends between spills on land, small creeks and streams, rivers and coasts, and the open ocean (Fig. 1). The primary driving force behind these trends is the increasing rate of transport, spreading, mixing, and weathering in these different settings. One of the consequences is that planning for land-based spills can be quite site specific and can focus on identifiable potential risks and impacts, more so than for river, coastal, or marine spills as forecasting of spill movements can be more accurate. From a response standpoint, the consequences are that the scale of the response increases with the size of the impacted areas, and the amount of oil that is recovered greatly decreases.

Spills on land have the potential to have a great impact on human-use activities and resources. As a result, in cases where the spill is in a populated area, frequently there is the requirement to clean or treat to a higher level than in a more physically dynamic marine, coastal, or fluvial environment where nature is more active in the degradation and weathering processes. Also, with the presence of a local population, frequently there is a greater involvement of civilian agencies, such as the police or army, to ensure site security, for both the responders and the general public.

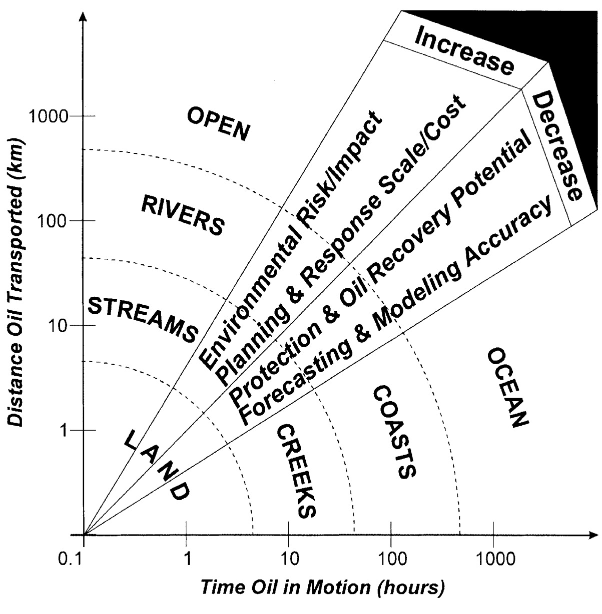


**Fig. 1** Time–space schematic for spills in different environments.

## Discussion

Obviously, there exist many pitfalls associated with generalization when dealing with oil spills, but some of the potential advantages of a response to spills on land over spills on water include the following:

- usually the impacted area is relatively small in size,
- greater potential for predicting the movement and effects of a spill,
- greater operational opportunities and flexibility, and
- greater recovery potential.

Some of the potential disadvantages with a response to a spill on land include:

- slower rates of weathering and natural attenuation,
- greater potential for impacting human-use activities and resources, and the
- potential for more strict cleanup standards and endpoints.

The differences between response operations on a coast, shore, or on land are primarily associated with operational factors on the one hand and levels of cleanup versus natural attenuation on the other. Spills on land have a greater risk of directly impacting human activities or resources associated with social or economic activities. Despite these differences, generally the same objectives, strategies, methods, and equipment are used on land spills as on the coast, so knowledge and operational practices can be transferred from one environment (the land) to another (river banks, lakes shores, and the coastline).

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