Journal of Coastal Research | SI 39 | 39 - 42 | ICS 2004 (Proceedings) | Brazil | ISSN 0749-0208

Oil Spills: Impacts, Recovery and Remediation

E.R. Gundlach

E-Tech International Inc.
15 River Park Drive
New Paltz, NY 12561
ErichEti@cs.com

ABSTRACT

GUNDLACH, E.R., 2006. Oil spills: impacts, recovery and remediation. Journal of Coastal Research, SI 39 (Proceedings of the 8th International Coastal Symposium), 39 - 42. Itajaí, SC, Brazil, ISSN 0749-0208.

Over the past 25 years, substantial information has been gathered during oil spill response efforts that provides guidance related to the interaction of spilled oil within various coastal environments. Commonly observed oil / shoreline interactions, natural and man-induced recovery rates, and cases where additional remedial efforts are needed, are discussed using Brazil's shoreline ranking based on environmental sensitivity. Case examples are taken from major spills in Spain, France, Chile and the United States. A recent damage assessment of a marsh ecosystem indicates potential scientific flaws in the application of U.S. methodology. Lastly, coastal scientists must take an active role in an oil spill response to ensure that their special expertise is applied appropriately during an oil spill response.

ADDITIONAL INDEX WORDS: *Oil spills, coastal environments, cleanup.*

INTRODUCTION

In spite of the best efforts of national governments, international organizations, and the petroleum and shipping industries, oil spills on land and in aquatic environments remain a continuing threat to the well being of human populations and the environment. This paper briefly discusses principal physical interactions of oil on various shoreline types, and includes review of a recent damage assessment applied to an oil spill in a temperate marsh.

In the mid-1970s, there began an approximate 10-year program of scientific research on oil spills. These studies, sponsored primarily by government, among other aspects included evaluation of the physical / geomorphic processes that affect oil impacts on shorelines and also resulted in the development of the Environmental Sensitivity Index (GUNDLACH and HAYES, 1978). Principal among other sources, the proceedings of the biannual International Oil Spill Conferences and Environment Canada's annual Arctic and Marine Oil Program (AMOP) contain a multi-year history of oil spill related publications.

There are many ways to describe the impact of oil on shorelines; however, with the widespread industry (e.g., IPIELA, 1996) and governmental support of the Environmental Sensitivity Index, it is logical to review these interactions in terms of the shoretypes described in the index. In particular, Brazil has recently developed detailed methodology by which to undertake sensitivity mapping projects (MMA, 2002). While this paper is not focused on a review of sensitivity mapping, the shoreline types described in MMA (2002) serve as a basis to review observed oil interactions within various coastal environments.

Shoreline Types

The ESI concept describes shorelines in terms of increasing sensitivity to oil spills, with 1 being least sensitive and 10 being most sensitive. The value assigned to a particular shoretype may vary somewhat from country to country. For this discussion, we use the Brazilian ISL (Indice de Sensibilidad do Litoral), adapted by ARAÚJO *et al.* (2000) from the United States as standardized by NOAA (2002). The Brazil sensitivity index is presented in Table 1.

The examples described here were obtained primarily while participating in the oil spill response, as part of the scientific assessment or spill management teams. Photographs of the oil spills presented in this paper, and from other spills, are provided in jpg format at www.oil-spill-info.com. Table 2 lists the spills discussed herein.

ANALYSIS

Shorelines of Low Sensitivity

These shorelines include index values 1 and 2 in Table 1.

Table 1. *Environmental Sensitivity Index (Indice de Sensibilidad do Litoral) developed for application to Brazil by ARAÚJO et al. (2000) as published in MMA, 2002.*

Index Value/Shoretype	Examples
1. Exposed, steep impermeable substrates:	Exposed rocky cliffs. Exposed sedimentary scarps. Exposed artificial structures.
2. Exposed, flat-lying impermeable substrates:	Exposed low-lying rocky shores and terraces.
3. Semi-permeable substrates, with low oil penetration / burial:	Medium to fine sand beaches. Sand spits and dune fields. Exposed sand scarps.
4. Medium permeable substrates, with moderate oil penetration / burial:	Beaches of: coarse sand or sheltered medium to fine sand.
5. Medium to high permeable substrates, with high oil penetration / burial:	Mixed sand / shell hash beaches. Irregular or vegetation-covered platforms. Interior of fringing reefs.
6. High permeable substrates:	Shell / calcareous beaches. Detrital beaches. Talus slope beaches. Exposed riprap. Porous terraces / platforms.
7. Flat-lying, exposed permeable substrates:	Low-tide terraces. Exposed sand flats.
8. Sheltered substrates with low to moderate permeability with abundant epifauna:	Sheltered rocky shores. Sheltered riprap.
9. Sheltered semi-permeable substrates or reefs:	Unvegetated tidal flats. Sheltered low-tide terraces. Reefs supporting corals.
10. Wetlands:	Vegetated deltas and bars. Vegetated terraces and bars and river / lakes margens. Marshes. Mangroves.

Table 2. *Oil spills included in this discussion.*

Oil Spill	Cargo (approximate)
Alvenus, 1984. Gulf of Mexico, Texas, USA	9,500 tons heavy Venezuelan Crude Oil
Amoco Cadiz, 1978, Brittany, France	233,000 tons Saudi Arabian Crude Oil
Erika, 2000. Brittany, France	18,900 tons Heavy Fuel Oil
Exxon Valdez, 1989. Alaska, USA	37,000 tons North Slope Crude Oil
Metula, 1974. Patagonia, Chile.	64,000 tons Saudi Arabian Crude
Prestige, 2002. Northwest Spain	25,000 tons Heavy Fuel Oil
Swanson Creek, Maryland, USA	450 tons Fuel Oil

Exposed cliffs and steeply dipping rocky shores have been oiled at numerous oil spills, ranging from Exxon Valdez, to the recent Erika spill in France and Prestige spill in Spain. Flat-lying shorelines have been rarely oiled, and no case examples have been located.

Low sensitivity is based on the high-energy environment usually present. In the best case, waves reflecting off the shoreline keep oil from contacting the shoreline. Figure 1 from the Amoco Cadiz spill in France shows a typical case; the outer coastline is relatively unscathed by the spill, but the more sheltered tidal flat and cobble beaches in the background are heavily oiled.

For the most part, only limited cleanup or remediation is needed on active shorelines and is often access-restricted. In tourist areas, high pressure spraying, sometimes with chemical additives, has been used to remove persistent oil. To overcome the access problem on steep shorelines during the Erika spill in France, professional rope workers were hired to use ropes and cables to travel up and down the cliff faces (KERABRUN, 2003). This effort continued until two years after the spill. In spite of an intensive cleanup, it can be expected for most spills of crude and persistent oils, that some staining and tar blotches will be visible on the shoreline many years after a large event.

Shorelines of Mid-Level Sensitivity

These are sediment-dominated shorelines (values 3 to 6 in Table 1) which show increasing sensitivity as grain-size increases. Sensitivity in this case entails difficulty of cleanup, and is primarily based on the ability of oil to penetrate into coarser substrates.

Fine-grained sand beaches are relatively easy to clean, because the beach is usually able to support heavy equipment such as road graders (Figure 2) and penetration into the beach is limited to about 15 cm or less, influenced both by oil percolating into the beach and by the beach cycle (causing clean sand to be deposited on top of oiled sand, forming a 'layer cake' pattern).

As grain size increases to gravel and cobble-sized material, then oil can penetrate very deeply into the beach (Figure 3), making cleanup extremely difficult.

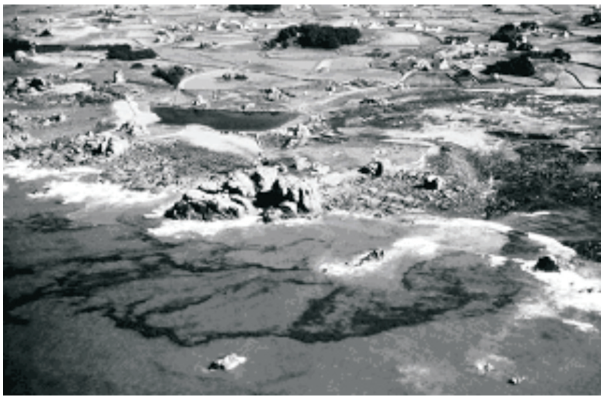

Figure 1. Example of Amoco Cadiz oil being held off rocky shore exposed to high wave activity, while tidal flat and gravel beach in background shows heavy oiling.

Figure 2. Use of road graders on hard-surface, fine-grained sand beach at the Alvenus spill, Texas.

Clean up of oil on coarse sands and gravels usually needs very intrusive physical processes, such as high-volume flushing (Figure 4). After the heavy concentrations of oil are removed, berm relocation (physically pushing the oiled berm into the intertidal zone) to be naturally flushed is a common practice, minimally dating back to 1976 (Figure 5). Oil flushed out then must be collected, as with sorbents.

Final remediation commonly includes the tilling / mixing of oil into the beach, thereby reducing concentrations and exposing the oil to natural bio-degradation. With highly questionable effectiveness, fertilizers have also been added, as at Exxon Valdez, to increase the rate of bio-degradation.

Shorelines of Moderately High Sensitivity

These shorelines consist of exposed tidal flats and rocky shorelines (values 7 and 8 in Table 1) and are ranked fairly high because of potential biological activity susceptible to oil spill damage. Exposed tidal flats commonly show little to no persistent oil because of little penetration and then movement by wave and tidal activity. On the other hand, oil on sheltered rocky shorelines tends to coat the rocks and algae, causing long-term persistence if not removed. Although highly criticized at Exxon Valdez for causing loss of intertidal organisms, high-pressure flushing is commonly used worldwide for heavy concentrations. All response activities at Exxon Valdez, by the way, were approved by state and federal regulators working together with the spiller's representatives.

Figure 3. Illustration of very deep penetration of oil into gravels at the Exxon Valdez spill site.

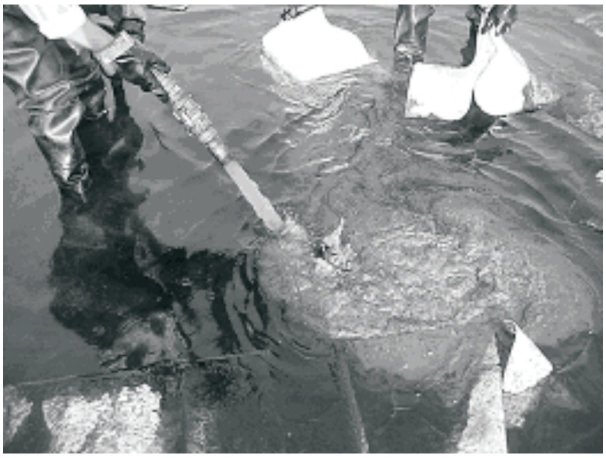

Figure 4. High-pressure flushing and oil recovery from subtidal sands at the Swanson Creek oil spill.

Highly Sensitive Shorelines

The most sensitive shorelines are tidal flats, marshes and mangrove environments. Here we concentrate on marshes. Tidal flats of soft sediments can show oil concentrations for years after the spill, as at Amoco Cadiz. However, the longest case is offered by the Metula oil spill in Patagonia, Chile, where thick oil still remains in the marsh and on hard tidal flat surfaces since originally spilled there in 1974. Figure 6 shows oil remaining on the marsh surface over 21 years later.

In cases where oil is relatively thin (<2.5 cm), the best case is commonly to let it recover naturally. However, even in the worst of cases, marshes can be restored via replanting. Recently, in spite of a series of questionable remedial decisions that included trenching of the marsh and active intervention (Figure 7), as well as preventing natural flushing, marsh replanting significantly improved the condition of the marsh, such that plant coverage is at the level of adjacent unoiled marshes (Figure 8) (GUNDLACH *et al.*, 2003).

The United States has a Damage Assessment and Response Program which has defined the injury to the marsh in Figures 7 and 8 as being long-term (10 years) with only 29 percent of vegetative recovery found after two years (NOAA *et al.*, 2002). As indicated by any observer to the site (Figure 8), this low value for recovery is clearly not supported by science, and leads to the conclusion that the legally based damage assessment process is misusing science to financially punish the spiller. This is not surprising to many in industry of course, but because these results are published as an official government document (fully web available) the reader is likely to be totally unaware as to the bias involved in the report.

ROLE OF SCIENTISTS IN RESPONSE

In many cases, scientists have a communications problem with cleanup operators. This commonly results in an 'us' versus 'them' situation. Outreach from both sides is in order. Cleanup operators are likely to be equally concerned about the environment and attempting to do their best, at many times with little or no scientific guidance. On the other hand, scientists commonly feel independent from the spill response effort, and criticize rather than actively participate in solutions.

Figure 5. Early use of berm relocation in 1976 to naturally cleanse oiled sediments at the Urquiola oil spill.

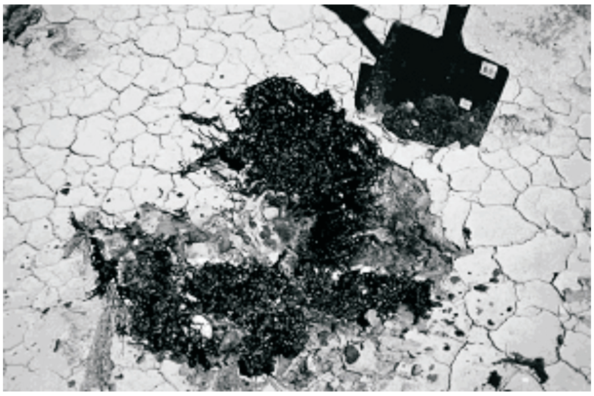

Figure 6. Close-up of Metula oil below light-colored sediment on the marsh surface, 21 years after the spill in 1995.

The active integration of environmental scientists into the response organization is critical to overcome these difficulties and ensure a successful operation. Spill response drills where all can meet and establish their appropriate role is one method to do this before the stress of a real event. During an event, all must work together at the same command post, participate in planning meetings and jointly undertake field surveys. This won't happen by chance. Active leadership is required.

Figure 7. Active intervention on oiled marsh at the Swanson Creek oil spill in 2000.

Figure 8. Nearly full recovery after extensive replanting two years later at the sume marsh site as shown in Figure 7.

LITERATURE CITED

ARAÚJO, S.I.; SILVA, G.H; and MUEHE, D., 2000. Minuta do Manual Básico para Elaboração de Cartas de Sensibilidade no Sistema. PETROBRAS. 170 p.

GUNDLACH, E.R. and HAYES, M.O., 1978. Classification of coastal environments in terms of potential vulnerability to oil spill damage. Marine Technology Society Journal, vol. 12(4), 18-27.

GUNDLACH, E.R.; BACA, B.; and BARRY, D.C., 2003. Emergency marsh restoration as part of response to the Swanson Creek (Maryland) oil spill. 2003 International Oil Spill Conference, 10 p.

IPIECA. 1996. Sensitivity Mapping for Oil Spill Response. IMO / IPIECA Report Series: Volume One. 24 p.

KERABRUN, L., 2003. Erika oil spill: responding to difficult-to-access coves and on cliffs. 2003 International Oil Spill Conference. 6 p.

MMA, 2002. Especificações E Normas Técnicas Para A Elaboração de Cartas de Sensibilidade Ambiental Para Derramamentos De Óleo (Cartas SAO). Ministerio do Meio Ambiente, 94 p.

NOAA. 1997. Environmental Sensitivity Index Guidelines, Version 2.0. NOAA Technical Memorandum NOS ORCA 115. Seattle: Hazardous Materials Response and Assessment Division, National Oceanic and Atmospheric Administration. 100 p.

NOAA et al., 2002. Final restoration plan and environmental assessment for the April 7, 2000 oil spill at Chalk Point on the Patuxent River, Maryland, November 2002. National Oceanic and Atmospheric Administration, Maryland Department of Natural Resources, Maryland Department of the Environment, and U.S. Fish and Wildlife Service. NOAA Damage Assessment Center, Silver Spring, MD, 138 p.