COSTS ASSOCIATED WITH THE CLEANUP OF MARINE OIL SPILLS

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ABSTRACT: *The cost of offshore and coastal cleanup of spilled oil varies greatly from spill to spill but is of high interest in risk assessments, because cost is often used as the basis of comparison. We present data on the costs associated with mechanical offshore cleanup, shoreline cleanup, and offshore burning. A review of eight offshore recovery operations in North America indicates a mean offshore, on-water cleanup cost of approximately $2,500/bbl, with a range of $10 to $6,000/bbl. Smaller spills (1,000 to 2,000 bbl) have a higher per-unit recovery cost than large spills (≥10,000 bbl)—at about two to three times the cost. Review of ten shoreline cleanup operations indicates a mean cleanup cost of approximately $8,000 to $9,000/bbl, an average of 2.5 to 4 times higher than the cost of offshore recovery. Variability in shoreline cleanup costs is high, and costs are highly dependent on both the size of the spill and the remoteness of the spill location; small, widely dispersed spills, such as the* Nestucca *(British Columbia and Washington coasts), involve cleanup costs of more than $20,000/bbl. Although there are few spills where offshore* in situ *burning has been used as a response option, preliminary estimates indicate comparable unit "elimination" costs of about $500/bbl, five times less expensive than offshore on-water recovery and more than an order of magnitude less than mean shoreline cleanup costs.*

Knowledge of spill cleanup costs provides an important framework in risk assessments and spill response planning. There is, however, an extremely wide variation in cleanup costs for different incidents, depending on spill conditions, logistical support in the spill area, and various environmental and sociological factors. We were particularly interested in estimating the relative costs of traditional cleanup approaches (mechanical offshore recovery and shoreline cleanup) versus offshore burning. This paper presents a review of selected spills and their estimated oil cleanup costs.

Approach

We limited our analysis to spills that occurred from 1988 to 1991 (*Lee Wang Zin* occurred in 1979 and is the exception), spills in North American marine waters, and spills that involved crude oil, heavy fuel oils, or bunker oil. A database search by the *Oil Spill Intelligence Newsletter* using these criteria listed 32 spills. Eleven were selected for additional analysis because there was both onshore and offshore cleanup or there was a reasonable chance that cost estimates could be developed.

A variety of published and unpublished sources were used to estimate costs associated with both offshore and onshore cleanup of oil spills. The quality of available information varied considerably. For example, a review of the *American Trader* spill had very good information on logistics, manpower, and recovery efficiency, but no information on costs; in this case, standard day rates for vessel and labor support were assumed to arrive at aggregate cleanup costs for the offshore and onshore activities.[12]

Numerous individuals provided unpublished information about various portions of the cleanup, efficiencies, and various cost components. A common problem for several of the spills was the oil content associated with oily debris; we used figures of 1 to 2 percent average oil content in our calculations, which are probably overestimates.

The basic procedure used was the following.

- Estimate the volume of oil recovered offshore
- Estimate the volume of oil recovered from the shoreline
- Estimate the cost associated with offshore cleanup
- Estimate the cost associated with shoreline cleanup

Using this information, cleanup costs per barrel of oil recovered could be calculated. Figures were converted to 1991 U.S. dollars (US$) for comparison. Costs include administrative support costs but not compensation costs.

The cleanup estimates (Table 1) *should be regarded as approxima-*

Table 1. Summary of spill cleanup costs for mechanical offshore and shoreline cleanup[1]

Spill	Location	Volume (bbl)	Offshore costs Estimate ($/bbl)	Offshore costs Range ($/bbl)	Shoreline costs Estimate ($/bbl)	Shoreline costs Range ($/bbl)	Ratio shoreline/offshore costs Estimate	Ratio shoreline/offshore costs Range
American Trader	Long Beach, CA	9,500	2,251		8,480		3.8	
Apex barges	Galveston Bay, TX	16,500	344	172–542	323	198–625	0.9	0.4–3.6
ARCO Anchorage	Port Angeles, WA	5,690	2,400		4,480		1.9	
Lee Wang Zin	BC/Alaska	2,400–7,100			5,900	5,900–8,970		
Mega Borg	Gulf of Mexico	>9,000	1,375	844–1,646				
Nestucca	Washington/BC	5,500			23,230	9,870–53,440		
Nord Pacific	Corpus Christi, TX	15,350	11		124		11.4	
Rio Orinoco	Gulf of St. Lawrence	620			29,600	20,000–78,000		
Tenyo Maru	Juan de Fuca Strait	1,430	5,900	4,000–8,160	10,680	6,700–15,260	1.8	1.1–2.8
Texaco Anacortes	Anacortes, WA	650	4,230	2,270–8,810	22,600	13,560–54,240	5.3	1.5–2.4
World Prodigy	Narragansett, RI	7,000	2,850	1,430–3,140	8,930	6,700–12,280	3.1	2.1–8.6
		Median	2,325		8,705		3.1	
		Mean	2,420		11,433		4.0	

1. All costs converted to 1991 U.S. dollars.

tions only. In general, it was not possible to find independent confirmation of our estimates. We provide a separate table indicating costs associated with our most complete data sets (Table 2).

Comparison of offshore recovery to shoreline cleanup

Overall results of our review are provided in Table 1. The results indicate an average offshore, mechanical recovery cost of approximately $2,000 to $2,500/bbl. Upper limits for offshore, on-water recovery appear to be in the $9,000/bbl range. Estimates from the data sets in which we have the most confidence (Table 2), support the general estimates of average offshore recovery costs in the range of $2,500 to $3,500/bbl.

Shoreline cleanup costs show a much greater range, with a median of $8,700/bbl and a mean of $11,500/bbl (Table 1). Upper limits on the order of $20,000 to $30,000/bbl have occurred in unusual circumstances. Our best estimates of shoreline cleanup costs are in the range of $7,500 to $8,500/bbl (Table 2).

Shoreline cleanup costs are about 2.5 to 4.0 times greater than on-water recovery costs (Tables 1 and 2). The ratio is significantly lower than the "10 times" ratio commonly quoted in the industry. Our estimates do not include compensation costs, however, and it is probable that there are larger compensation costs associated with shoreline oiling conditions because of greater degrees of disturbance associated with cleaning shorelines and greater length of time to recovery.

Moller et al. surveyed a number of spills, primarily from the North Sea, and reported on the relative cleanup costs associated with offshore mechanical and shoreline cleanup (Table 3).[10] Ratios of shoreline cleanup costs per barrel to offshore cleanup costs per barrel ranged from 0.2 to 7 and averaged about 2 in their study, which is consistent with our results. Moller et al. obtained overall values for offshore and shoreline cleanup much lower than ours, probably reflecting more recent increases in cleanup costs and a different regulatory climate in North America.

Short, case-by-case summaries of the spills reviewed are presented in the following sections.

American Trader. The *American Trader* spill was almost an ideal spill from the standpoint of oil recovery; an estimated 44 percent of the 9,500 bbl spilled in the Huntington Beach area of California was recovered.[12] Estimated costs associated with offshore cleanup appear reasonable. The $8,480/bbl for shoreline cleanup appears high given the ease of access and the sandy nature of the beaches. However, it appears that a high cleanup effort was expended on the shoreline because a large portion of the oiled shoreline was a recreational beach.

***Apex* barges**. The large *Apex* barges spill in Galveston Bay represents some of the lowest cleanup costs. About 50 percent of the 16,480 bbl spill was recovered.[5] The very low costs associated with the cleanup were probably largely due to the protected environment in which the spill took place, resulting in a high recovery efficiency; and good infrastructure in terms of cleanup equipment and support vessels close to the spill site. Contractors described backing up vacuum trucks to the shoreline and "just sucking up buckets of oil."

ARCO Anchorage. The *ARCO Anchorage* spill occurred near Christmas 1985 at Port Angeles, Washington, and involved 5,690 bbl of oil, of which an estimated 58 percent was recovered.[9] Offshore cleanup costs were similar to those associated with the *American Trader* and the *World Prodigy*. The shoreline cleanup costs were relatively low, especially if the cost of cleaning the pulp logs is removed from the calculations (shoreline cleanup without logs is estimated at $2,500/bbl). The low cost is possibly a reflection of the ease of access and proximity to

Table 2. Summary of spill cleanup costs for mechanical offshore and shoreline cleanup; most reliable data sets[1]

Spill	Location	Volume (bbl)	Offshore costs Estimate ($/bbl)	Offshore costs Range ($/bbl)	Shoreline costs Estimate ($/bbl)	Shoreline costs Range ($/bbl)	Ratio shoreline/offshore costs Estimate	Ratio shoreline/offshore costs Range
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World Prodigy	Narragansett, RI	7,000	2,850	1,430–3,140	8,930	6,700–12,280	3.1	2.1–8.6
		Median	2,551		8,705			
		Mean	3,350		8,143		2.4	
	Mean less Tenyo Maru		2,500		7,297		2.9	

1. All costs converted to 1991 U.S. dollars.

Table 3. Selected spill cleanup costs from Moller et al.,[10]

Spill no.	Location	On-water cleanup costs ($/bbl)	Shoreline cleanup costs ($/bbl)	Ratio
6	Northern Europe	230	786	3.4
10	Northern Europe	3,579	763	0.21
12	Northern Europe	812	1,100	1.35
14	Northern Europe	4,296	2,530	0.59
19	North America	500	1,003	2.01
21	North America	61	139	2.29
23	Far East	176	215	1.22
24	Far East	68	467	6.8
27	Southern Europe	496	115	0.23
	Median	496	763	1.35
	Mean	1,135	1,071	2.0

1. Selected spills for which both onshore and offshore costs were given; original data converted from 1985 to 1991 U.S. dollars

support infrastructure. The author's observations (JRH) of the shoreline oiling were that the oil was very light, nonemulsified, and tended to be easily dispersed from the beach sediments.

Lee Wang Zin. The 1979 *Lee Wang Zin* spill of an estimated 2,400 to 7,000 bbl occurred in northern British Columbia and was carried into Alaskan waters.[2] Stormy weather and the remoteness of the spill site prevented any offshore cleanup. The shoreline cleanup recovered only about 600 bbl (probably a high estimate), with a total associated cleanup cost of $2 to $3 million dollars. Our best estimate of cleanup costs is in the range of $5,900 to $8,970/bbl, which is consistent with cleanup of small amounts of oil on remote shorelines.

Mega Borg. All of the *Mega Borg* spill was offshore in the Gulf of Mexico and was associated with the burning tanker.[8] Over 5,000 bbl of oil were recovered at a relatively low cost of $1,375/bbl. The low cost appears to be a function of highly efficient skimming operations, since skimmers could be positioned immediately downdrift of the crippled tanker; calm weather; and proximity to oil industry support infrastructure. There was no associated onshore oiling.

Nestucca. The *Nestucca* was a relatively small spill (5,500 bbl) of heavy fuel oil.[3,6,15] Oiling was sporadic along much of the Washington and Vancouver Island outer coasts. Severe weather at the time of the spill prevented any offshore recovery. With shoreline recovery costs estimated at $23,000/bbl, this represents one of the highest recovery costs of any spill. Reasons for the high unit cost of recovery include the small amount of oil that was widely distributed along the coast (including in very low concentrations), and most of the coast being accessible only by helicopter. For these reasons, the shoreline inventory program alone was very costly. In addition, the international nature of the spill, which necessitated separate command centers in the United States and Canada, may have contributed to the high unit recovery costs.

Nord Pacific. The *Nord Pacific* spill of 15,350 bbl in Corpus Christi Harbor has the distinction of having the least expensive oil recovery costs. The reason appears to be the protected nature of the spill location, the confinement of the spill to a small area, and the short duration of the cleanup effort (10 days), all factors that would suggest a highly efficient cleanup operation.

Rio Orinoco. The *Rio Orinoco* spill of asphalt and bunker oil was estimated at 620 bbl and occurred along a remote shore of Anticosti Island, Gulf of St. Lawrence.[7] Cleanup and salvage were hampered by freeze-up of sea ice, which occurred shortly after the mid-October spill. Only a very small amount of oil was recovered (an estimated 40 bbl), which is one of the reasons for the very high cost of recovery ($29,600/bbl). Other factors contributing to the high recovery cost were bad weather at the time of the spill, as well as after, the remote site of the grounding, the remote site of the cleanup, the very small size of the spill, and the delayed recovery effort due to freeze-up. The cost recovery data are very sensitive to the volume of oil recovered, which is based on a percentage of oil in the oily debris. If the estimated oil concentration were set at 4 instead of 2 percent, then the cost of recovery would be halved (about $15,000/bbl).

Tenyo Maru. The *Tenyo Maru* spill of 1,430 bbl of fuel oil at the mouth of Juan de Fuca Strait was small and about 50 km from the coast.[14] A high proportion of the spilled oil was recovered (>80 percent), a surprising amount given the distance from the coast. Shoreline cleanup costs were on the high side of the median, probably due to the small amount of oil reaching the shore and the remoteness of the shore. The exceptional feature of this spill is the high unit cost of offshore recovery ($5,900/bbl). Skimming near the wreck was apparently inefficient, and expensive underwater remotely operated vehicles (ROVs) were used to suction off oil from tanks of the sunken vessel.

Texaco Anacortes Refinery spill. Although the Anacortes crude oil spill (5,000 bbl) originated on land, 650 bbl of the oil reached a bay near the refinery, and an extensive offshore and shoreline cleanup operation ensued.[4,11] A variety of approximations were used to estimate cost, and our unit recovery cost estimate is extremely sensitive to these approximations. Offshore, on-water cleanup costs appear to be high compared to other spills; a contributing factor was the shallowness of the bay, which apparently limited the use of skimmers. Verbal accounts indicate poor efficiency of the skimmers. The high shoreline cleanup cost was apparently related to oiling of rubble and riprap at the high waterline; the rubble served as an efficient trap for the oil and eventually had to be removed and replaced. An independently obtained estimate of cleanup put the combined recovery (offshore and shoreline) at $15,000/bbl, which generally supports our high computed cost.

World Prodigy. The *World Prodigy* spill of No. 2 oil originated from the grounding of the ship in Narragansett Bay, Rhode Island.[13] Offshore cleanup costs ($2,850/bbl) are close to the median. Because much of the on-water recovery took place in close vicinity to the vessel, these costs were difficult to separate from the lightering costs. The shoreline costs also fall near the median ($8,930/bbl). Given the protected nature of the bay and the fair weather conditions (summer), one would expect shoreline cleanup costs to be lower. However, the high recreational use of the bay may have necessitated a high degree of shoreline cleanup.

Factors contributing to cleanup costs

Although our overall number of samples is small, a few generalities can be made with respect to offshore, on-water recovery and shoreline cleanup:

- Spill size may the most important factor controlling unit cost recovery (Figure 1). Offshore recovery costs appear to be relatively linearly related to spill size. Shoreline costs are much more variable, but with smaller spills having higher costs.
- Higher offshore cleanup costs occur when conventional skimming equipment is ineffective (as in the *Tenyo Maru* and Texaco Anacortes responses). Lower offshore cleanup costs are associated with higher concentrations of oil in relatively protected environments.
- Two of the highest shoreline unit cleanup costs (*Nestucca* and *Rio Orinoco*) were associated with bad weather spills that were widely dispersed before any offshore collection could be initiated; high shoreline cleanup costs reflect wide dispersal of oil at low concentrations on remote shorelines.
- Cleanup operations in the Gulf of Mexico appear to be orders of magnitude less costly than those in other areas of North America. This may be due to better infrastructure to support cleanup, significantly lower support vessel and labor costs, and greater flexibility in cleanup standards.

Cost comparison of conventional cleanup vs burning

Although there are few spills where offshore in situ burning has been used as a response option, information from war-related burns in Kuwait, the *Exxon Valdez*, and controlled test burns (such as the Newfoundland burn experiment) is sufficient to estimate burning costs. Allen provides preliminary estimates of costs associated with burning, dispersant, and on-water recovery.[1] Costs estimated are not directly comparable to those reported in this paper (Table 1), because our costs represent all-inclusive costs, including associated overhead

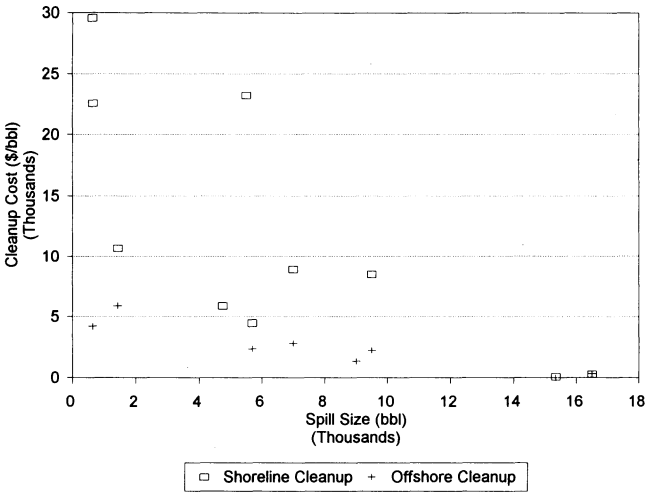

Figure 1. Offshore, on-water cleanup and shoreline cleanup costs plotted as a function of spill size (after Table 1)

and administrative costs, whereas those of Allen are developed for only operational components of the spill. Allen estimates unit recovery costs of $100 to $150/bbl for mechanical, on-water recovery, and of $20 to $50/bbl for in situ burning. Our estimates of all-inclusive, on-water mechanical recovery are in the range of $2,500/bbl, although, under optimal conditions, costs have been lower by an order of magnitude.

The burning costs estimated by Allen of $20 to $50/bbl do not include overhead or administrative costs. Using a ratio based on the offshore, on-water operational costs ($175/bbl; Allen) to calculated mean offshore costs ($2,500/bbl; Table 2), comparable burning costs would be about $500/bbl. The estimates suggest that a factor-of-five cost difference exists between in situ burning and conventional offshore recovery, and one of more than an order of magnitude is found between in situ burning and shoreline cleanup costs, especially if potential compensation costs are considered.

Conclusions

1. A review of cleanup cost data from 11 North American spills provides approximate costs of oil recovery operations. Data for offshore, on-water recovery operations indicate unit recovery costs in the range of $2,500 to $3,500/bbl. Data for shoreline cleanup operations suggest unit recovery costs are higher and more variable, in the range of $8,000 to $11,000/bbl.
2. Data suggest that shoreline cleanup costs are 2.5 to 4 times those of offshore, on-water cleanup, not the 10 times commonly cited in industry; these ratios are consistent with previously reported data of Moller et al.[10]
3. A wide variety of factors affect recovery costs, including dispersal of the spill, size of the spill, and environmental and political factors. The largest spills in our review had the lowest associated cleanup costs (for example *Apex* barges and *Mega Borg*). The smallest spills (<2,000 bbl) had the highest unit recovery costs (*Rio Orinoco* and Texaco Anacortes Refinery).
4. Offshore, on-water recovery costs appear to be only moderately dependent on spill size. Shoreline cleanup costs are more variable and show a much greater dependency on spill size; small, widely dispersed spills, such as the *Nestucca* and *Rio Orinoco*, had the highest unit recovery costs for shoreline cleanup.
5. Comparison of unit costs to in situ burning costs suggests that in situ burning represents a cost lower by approximately a factor of five compared to conventional, on-water recovery, and one more than an order of magnitude lower than shoreline cleanup.

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