HISTORICAL DISPERSANT AND IN-SITU BURNING OPPORTUNITIES IN THE UNITED STATES

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ABSTRACT: *Evaluating the value of using dispersants or in-situ burning in various regions of the United States requires an estimate of how often such technology might reasonably be considered. This study collected information on marine oil spills of 1000 barrels or more occurring in the coastal and offshore waters of the United States (excluding Alaska) from 1973 through June 1994. Each incident was examined using criteria for oil type, weather conditions, water depth, and distance from the shoreline. This allowed the frequency and geographic distribution of dispersible and burnable spills to be estimated. The effect of modifying the criteria on the frequency distribution of dispersible and burnable spills was evaluated.*

Data were obtained on 138 refined product and 69 crude oil spills. The majority of these spills occurred in shallow water, close to the shoreline, and/or close to a sensitive receptor. Depending on the severity of the criteria, between 10% and 51% of the crude oil spills and 4% and 18% of the refined oil spills studied were realistic candidates for dispersant use. Between 35% and 58% of the crude and 22% and 38% of the refined oil spills were realistic candidates for burning.

According to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) of the United States, the federal on-scene coordinator must obtain approval from the regional response team (RRT) for the use of dispersant and in-situ burning techniques. Under the NCP, which was revised after the Oil Pollution Act of 1990 was passed by Congress, RRTs are required to address, as appropriate, the use of these techniques through the implementation of preauthorization plans and agreements between the federal and state agencies. To fulfill this planning initiative, it is useful for the RRTs to have an idea of (1) the frequency and distribution of historical spills in their region, and (2) which of those spills were potentially able to be dispersed or burned. This allows RRTs to more realistically plan for the appropriate use of these techniques in future spills.

The Marine Preservation Association/Marine Spill Response Corporation Dispersant and In-situ Burning Workgroups commissioned this 20-year retrospective study to determine the number of historical marine oil spills where dispersants and/or in-situ burning should have been seriously considered. This study estimates the frequency and geographic distribution of dispersible and burnable spills by considering criteria such as oil type, weather conditions, water depth, and distance from the shoreline or a sensitive receptor (i.e., high-value natural resource or amenity area and/or human population center). In addition, this study evaluates the effect of modifying the criteria to determine which ones influence the frequency distribution of dispersible and burnable spills. Detailed information on the spills included for this study can be found in Kucklick and Aurand (1995). The issue of obtaining preauthorization was not considered as part of the study.

Methodology

Information on historical marine oil spills of 1000 barrels (bbl) or more that occurred in the coastal and offshore waters of the United States (excluding Alaska and Guam, but including Hawaii, Puerto Rico, and the Virgin Islands) from 1973 through June 1994 was obtained from a variety of sources. One thousand barrels was the minimum size incident where a thorough analysis could be conducted.

Information sources. Five information sources were examined for this study:

1. Coast Guard pollution incident reporting system and marine safety information system
2. Minerals management service database
3. "Oil Spill Case Histories: 1967–1991: Summaries of Significant U.S. and International Spills" (National Oceanic and Atmospheric Administration [NOAA], 1992)
4. "Evaluation of Marine Post-spill Sites for Long-term Recovery Studies" (Gundlach *et al.*, 1993)
5. Environmental Protection Agency's environmental response notification system

One major limitation of nearly all the sources is that they do not consistently report the type of crude oil spilled. For the purpose of this analysis, where crude oil was not specified, several assumptions were made to determine if the oil was dispersible. This is explained in more detail under "Assumptions and criteria for analysis" in text following.

The location of the spill, specifically the water depth and distance from shoreline, and weather during the spill incident were critical pieces of information needed to conduct the analysis for this study. NOAA navigational charts were consulted to determine depth and distance. NOAA daily weather maps and monthly averages of air temperature, wind speed, and wind direction (Ruffner and Bair, 1985) were used to obtain estimates of weather conditions.

Table 1. Dispersant and in-situ burning criteria

	Expanded criteria	Base criteria	Restricted criteria
Dispersant			
Oils deemed dispersible	API gravity 17–45[1]	API gravity 17–45 and pour point under 41°F[1]	API gravity 17–45 and pour point under 41°F[1]
Distance from shore	≥1/4 mile	≥1/2 mile	≥3 miles
Water depth	≥10 feet	≥30 feet	≥65 feet
Sea state	≥0	≥2	≥3
In-situ burning			
Oils deemed burnable	API gravity ≤45	API gravity ≤45	API gravity ≤45
Distance from sensitive receptor	≥1/4 mile	≥1 mile	≥3 miles
Sea state	≤4	≤4	≤4

1. John G. Yeager and Associates, 1985.

Assumptions and criteria for analysis

Two conditions were assumed: (1) dispersants, igniting agents, and application equipment for both techniques would have been available within the window of opportunity; and (2) permission to apply dispersants and to burn would have been granted. One criterion not considered in this study was the presence of site-specific ecological resources. Obviously, there were some locations where, because of the presence of a sensitive resource, dispersants or burning would not be considered.

To determine if dispersant application or in-situ burning might have been appropriate, it was necessary to identify specific criteria for what conditions would be suitable for dispersant application or in-situ burning. Table 1 outlines the three sets of criteria: oil type, weather (specifically sea state), and spill location (water depth and distance from shoreline or a sensitive receptor). “Restricted” criteria were developed from information in existing preauthorization dispersant and in-situ burning agreements. The base and expanded criteria were developed to evaluate how the dispersant and in-situ burning opportunities changed under more liberal conditions.

Oil type: Dispersant use. Generally, dispersants are considered to be effective on light- and medium-weight materials where the API gravity is between 17 and 45 and the pour point is less than the water temperature (Exxon Research and Engineering Company, 1994; John G. Yeager and Associates, 1985). The American Petroleum Institute (API) (John G. Yeager and Associates, 1985) assessed the dispersibility of a number of crude and refined products, based on API gravity and pour point (Table 2). For the present study, all oils rated as a 2L or 3L were considered dispersible. Oils rated as a 2H or 3H were considered dispersible when the weather information for that spill day indicated that the water temperature was probably above the oil’s pour point. Oils rated as 2H and 3H were also considered dispersible under the expanded criteria (see Table 1). Oils rated as 1 readily evaporate and therefore chemical dispersion is considered unnecessary. Oils rated 4 are considered nondispersible because of their high viscosity, but this is a conservative estimate. With the newest dispersants many heavy or weathered oils are proving to be dispersible.

This approach to estimating the dispersibility of an oil type does not take into consideration weathering or the chemical makeup of the oil. Both of these factors can affect an oil’s dispersibility, as was the case with two oil spills: the *Puerto Rican*, which involved a mixture of no. 6 fuel oil and lube oil, and the *Pac Baroness*, which involved an intermediate fuel oil. These oils are not considered dispersible based on the API report; however, dispersants were used during both incidents, with varying estimates of success. Both incidents were reclassified as dispersible for this study.

There were several crude and refined oils not listed in the John G. Yeager and Associates (1985) document where API gravity and pour point information could not be obtained. The refined oils included waste oil, clarified oil, coconut oil, carbon black, absorption oil, rosin, resin, and NSX. None of these were assumed to be dispersible. The crude oils included Indian, Santa Maria, and Qatar. Based on the properties of other oils from nearby fields, Indian and Qatar were assumed to be dispersible and Santa Maria was not.

Specific crude oil type was not identified in 41 out of 95 oil spills. However, given the capability of modern dispersants and the physical properties of most crude oils imported and exported throughout the United States, there is a high probability that the unidentified crude oils in this study were dispersible. This assumption is substantiated by the fact that of the 52 spills where crude oil type was known, only 3 oils were not dispersible.

A final assumption relating to oil type involved several spills where two products were spilled, one of which was dispersible and one of which was not, based on the assumptions described in preceding text. In these situations, the incident was assumed dispersible.

Oil type: Use of in-situ burning. All crude and refined oils with API gravities less than or equal to 45 were considered burnable (see Table 1). The 43 unidentified crude oils were also considered burnable, based on the fact that of the 52 oil spills where crude oil type was known, only 1 oil had an API gravity greater than 45. There were several crude and refined oils where the API gravity could not be obtained. The refined oils included waste oil, clarified oil, coconut oil, carbon black, absorption oil, rosin, resin, and NSX. None of these oils were assumed to be burnable. The crude oils included Indian, Santa Maria, and Qatar. All three were considered burnable.

A final assumption relating to oil type involved several spills where two products were spilled, one of which was burnable and one of which was not based on the assumptions in text preceding. In these situations, the spill was assumed to be burnable.

Weather and spill location: Dispersant use. Weather conditions, specifically sea state, have a significant influence on oil dispersibility and dispersant effectiveness. Weather information obtained included wind speed but not sea state. Sea state is based on wave height, which

Table 2. API classification of oil dispersibility[1]

API number	API gravity and pour point conditions	Dispersibility recommendation
1	API gravity over 45	No need to disperse
2L	API gravity 35–45 and pour point under 41°F	Easily dispersed
2H	API gravity 35–45 and pour point over 41°F	Difficult to disperse if water temperature below pour point
3L	API gravity 17–34 and pour point under 41°F	Easily dispersed if treated promptly
3H	API gravity 17–34 and pour point over 41°F	Difficult to disperse if water temperature below pour point
4	API gravity less than 17	Difficult to disperse

1. John G. Yeager and Associates, 1985.

Table 3. The relationship between wind speed and sea state as interpreted from Bhattacharyya (1978)

Wind speed (kts)	Sea state
1–3	0
4–8	1
9–12	2
13–16	3
17–19	4
20–24	5

covers a range of wind speeds. Using Table 5.1 from Bhattacharyya (1978) as a basis, the relationship between wind speed and sea state was inferred as shown in Table 3.

There are no upper limits given for sea state, although there could be extreme environmental conditions where it would be impractical or unnecessary to use dispersants (e.g., during the 1993 *Braer* incident off the Shetland Islands). The upper sea state limit is incident-specific. The majority of U.S. marine spills occurred during a sea state of 1 or 2. Nine spills occurred during a sea state of 5, and three (two riverine and one coastal and offshore spill) occurred during a sea state above 5.

Water temperature is an important consideration for crude oils identified as 2H and 3H. Both are considered difficult to disperse if water temperature is below the oil's pour point. Only two oils fell into this category: Trinidad crude and Angolan Palanca crude. Although water temperature could not be obtained for either spill, it was estimated on the basis of the time of year and the location of the spill.

In addition to weather, water depth and distance from shoreline are important considerations when deciding to recommend dispersant use. Dispersants are typically not recommended in shallow waters close to shore.

Weather and spill location: Use of in-situ burning. As with the use of dispersants, sea state can influence the decision to burn oil. Burning is not typically recommended if the sea state is too high (>4). Information in Table 3 was used to convert wind speed information to sea state for in-situ burning analysis. The distance from a sensitive receptor also influences the use of in-situ burning. For the purposes of this study, the distance from a sensitive receptor was measured as the distance from the shoreline. The only two exceptions were where the spill occurred near an island that is essentially uninhabited, and then the distance from a sensitive receptor was considered to be greater than 3 miles.

Results

Information was obtained on 321 crude and refined oil spills of 1000 bbl or more in the coastal United States (except Alaska) from 1973 through 1994. Of these, 138 (43%) involved refined products and 69 (21%) involved crude oils. In 114 (36%) of the incidents, oil type (crude versus a specific refined) and/or latitude and longitude were not provided by any of the information sources. Table 4 provides specific information on the geographic distribution of the crude, refined, and "unknown" oil spills by U.S. Coast Guard (USCG) district. The largest number of spills occurred in USCG District 8 (Texas to northwest Florida), where crude oil was involved in more spills than refined products.

The 114 "unknown" spills are not considered further in the result analysis, leaving a total of 207 crude and refined oil spills that will be discussed. The fact that these "unknown" spills were not considered in the analysis is assumed to not result in any bias in the analysis because these spills are randomly located throughout the coastal United States.

Because the analysis does not consider the "unknowns," the estimate of potential events where dispersants and in-situ burning could have been considered for use might be an underestimate. If dispersants and in-situ burning could be used with the same relative frequency for unknown as for known spills, then up to half of the 114 unknowns could be considered dispersible or burnable under the expanded criteria.

Tables 5 through 8 display the breakdown of crude and refined oil spills that met the various dispersant and in-situ burning criteria, respectively. Figures 1 and 2 depict the overall geographic distribution of those crude and refined oils that were considered dispersible (Figure 1) or burnable (Figure 2) under the expanded criteria, the most liberal criteria used in this study. Most preauthorization agreements in the country today do not have such criteria for dispersant and burning use.

Conclusions

Dispersant use. For oil spills of 1000 bbl or more, there is an average of 1 to 2 crude oil spills and 1 refined oil spill per year nationwide where dispersants might be considered for use. Using the base criteria,

Table 4. Breakdown by petroleum type and Coast Guard district of petroleum spills of 1000 barrels or more in the coastal United States from 1973 through 1994

Coast Guard district	Petroleum type	Total number of spills	Percent of total spills within district
1	Crude	7	10
(Maine to New York)	Refined	46	70
	Unknown$_1$	13	20
5	Crude	1	2
(New Jersey to North Carolina)	Refined	25	54
	Unknown$_1$	19	43
7	Crude	3	17
(South Carolina to Florida; Puerto Rico and U.S. Virgin Islands)	Refined	15	63
	Unknown$_1$	5	20
8	Crude	50	35
(Northwest Florida to Texas)	Refined	31	22
	Unknown$_1$	61	43
11	Crude	3	15
(California)	Refined	11	55
	Unknown$_1$	6	30
13	Crude	3	18
(Oregon and Washington)	Refined	6	35
	Unknown$_1$	8	47
14	Crude	2	20
(Hawaii only)	Refined	4	40
	Unknown$_1$	2	40

1. Location and/or oil type (crude vs. refined) is unknown.

Table 5. Crude coastal and open ocean oil spills of 1000 barrels or more in the United States (except Alaska) from 1973 through 1994 that met expanded, base, and/or restricted dispersant criteria

USCG District	Expanded criteria[1]	Base criteria[2]	Restricted criteria[3]
1	2 of 7 (29%)	1 of 7 (14%)	1 of 7 (14%)
5	0 of 1 (0%)	0 of 1 (0%)	0 of 1 (0%)
7	3 of 3 (100%)	2 of 3 (67%)	0 of 3 (0%)
8	24 of 50 (48%)	10 of 50 (20%)	3 of 50 (6%)
11	2 of 3 (67%)	1 of 3 (33%)	1 of 3 (33%)
13	2 of 3 (67%)	1 of 3 (33%)	0 of 3 (0%)
14	2 of 2 (100%)	2 of 2 (100%)	2 of 2 (100%)
TOTAL	**35 of 69 (51%)**	**17 of 69 (25%)**	**7 of 69 (10%)**

1. Oils deemed dispersible = 2L, 3L, 2H, 3H (John G. Yeager and Assoc., 1985).
Distance from shoreline ≥1/4 mile
Water depth ≥10 feet
Sea state ≥0
2. Oils deemed dispersible = 2L, 3L (John G. Yeager and Assoc., 1985)
Distance from shoreline ≥1/2 mile
Water depth ≥30 feet
Sea state >2
3. Oils deemed dispersible = 2L, 3L (John G. Yeager and Assoc., 1985)
Distance from shoreline ≥3 miles
Water depth ≥65 feet
Sea state ≥3

25% of crude and 7% of refined oil spills in the past 20 years were candidates for dispersant use. These percentages only consider spills of 1000 bbl or more and do not include the 114 “unknown” spills.

The greatest number of crude and refined oil spills occurred in the Gulf of Mexico (39%). However, only 15% of these spills were dispersible under the base criteria, whereas 22% were dispersible offshore of Washington and Oregon, and 50% dispersible offshore of Hawaii.

Only 7% of the refined product spills are dispersible (according to the base criteria). A dispersant that is effective on refined products, especially no. 6 fuel oil, would be valuable since it was involved in 39% of the refined spills. If no. 6 fuel oil was considered dispersible, an additional 17 refined oil spills would have been considered dispersible.

Table 6. Refined coastal and open ocean oil spills of 1000 barrels or more in the United States (except Alaska) from 1973 through 1994 that met expanded, base, and/or restricted dispersant criteria

USCG District	Expanded criteria[1]	Base criteria[2]	Restricted criteria[3]
1	6 of 46 (13%)	2 of 46 (4%)	0 of 46 (0%)
5	4 of 25 (16%)	1 of 25 (4%)	1 of 25 (4%)
7	1 of 15 (7%)	0 of 15 (0%)	0 of 15 (0%)
8	5 of 31 (16%)	2 of 31 (6%)	1 of 31 (3%)
11	7 of 11 (64%)	3 of 11 (27%)	3 of 11 (27%)
13	1 of 6 (17%)	1 of 6 (17%)	0 of 6 (0%)
14	1 of 4 (25%)	1 of 4 (25%)	1 of 4 (25%)
TOTAL	**25 of 138 (18%)**	**10 of 138 (7%)**	**6 of 138 (4%)**

1. Oils deemed dispersible = 2L, 3L, 2H, 3H (John G. Yeager and Assoc., 1985)
Distance from shoreline ≥1/4 mile
Water depth ≥10 feet
Sea state ≥0
2. Oils deemed dispersible = 2L, 3L (John G. Yeager and Assoc., 1985)
Distance from shoreline ≥1/2 mile
Water depth ≥30 feet
Sea state >2
3. Oils deemed dispersible = 2L, 3L (John G. Yeager and Assoc., 1985)
Distance from shoreline ≥3 miles
Water depth ≥65 feet
Sea state ≥3

Table 7. Crude coastal and open ocean oil spills of 1000 barrels or more in the United States (except Alaska) from 1973 through 1994 that met expanded, base, and/or restricted burning criteria

USCG District	Expanded criteria[1]	Base criteria[2]	Restricted criteria[3]
1	3 of 7 (43%)	2 of 7 (29%)	2 of 7 (29%)
5	0 of 1 (0%)	0 of 1 (0%)	0 of 1 (0%)
7	3 of 3 (100%)	2 of 3 (67%)	1 of 3 (33%)
8	29 of 50 (58%)	24 of 50 (48%)	18 of 50 (36%)
11	2 of 3 (67%)	1 of 3 (33%)	1 of 3 (33%)
13	1 of 3 (33%)	0 of 3 (0%)	0 of 3 (0%)
14	2 of 2 (100%)	2 of 2 (100%)	2 of 2 (100%)
TOTAL	**40 of 69 (58%)**	**31 of 69 (45%)**	**24 of 69 (35%)**

1. Oils deemed dispersible exclude API gravities >45
Distance from sensitive receptor ≥1/4 mile
Sea state ≤4
2. Oils deemed dispersible exclude API gravities >45
Distance from sensitive receptor ≥1 mile
Sea state ≤4
3. Oils deemed dispersible exclude API gravities >45
Distance from sensitive receptor ≥3 miles
Sea state ≤4

The majority of the crude and refined oil spills occurred in very shallow waters and/or very close to the shoreline. When the water depth and distance from shoreline criterion was decreased from 65 feet and 3 nautical miles to 30 feet and 0.5 nautical mile, the number of oil spills (both crude and refined) where dispersants could have been considered nearly doubled (from 7 to 17 spills for crude oil and from 6 to 10 spills for refined oils). If the water depth and distance from shoreline is decreased even more (to 10 feet and 0.25 nautical mile), almost 29% of the spills (both crude and refined) are realistic candidates for dispersants.

Use of in-situ burning. For spills of 1000 bbl or more, there is an average of 2 crude and 2 refined oil spills per year where in-situ burning might be considered for use. Using the base criteria, 45% of crude and 25% of refined oil spills that have occurred in the last 20 years were candidates for burning.

Although the largest number of crude and refined oil spills occurred in the Gulf of Mexico, only 40% of these spills were burnable under the base criteria, while 44% were burnable offshore of Washington and Oregon, 57% were burnable offshore of California, and 67% were burnable offshore of Hawaii.

Table 8. Refined coastal and open ocean oil spills of 1000 barrels or more in the United States (except Alaska) from 1973 through 1994 that met expanded, base, and/or restricted burning criteria

USCG District	Expanded criteria[1]	Base criteria[2]	Restricted criteria[3]
1	13 of 46 (28%)	6 of 46 (13%)	3 of 46 (7%)
5	7 of 25 (28%)	5 of 25 (20%)	5 of 25 (20%)
7	7 of 15 (47%)	3 of 15 (20%)	3 of 15 (20%)
8	11 of 31 (35%)	8 of 31 (26%)	8 of 31 (26%)
11	8 of 11 (73%)	7 of 11 (64%)	7 of 11 (64%)
13	4 of 6 (67%)	4 of 6 (67%)	1 of 6 (27%)
14	2 of 4 (50%)	2 of 4 (50%)	2 of 4 (50%)
TOTAL	**52 of 138 (38%)**	**35 of 138 (25%)**	**30 of 138 (22%)**

1. Oils deemed dispersible exclude API gravities >45
Distance from sensitive receptor ≥1/4 mile
Sea state ≤4
2. Oils deemed dispersible exclude API gravities >45
Distance from sensitive receptor ≥1 mile
Sea state ≤4
3. Oils deemed dispersible exclude API gravities >45
Distance from sensitive receptor ≥3 miles
Sea state ≤4

Figure 1. Crude and refined oil spills in the coastal and offshore areas of the United States of 1000 barrels or more from 1973 through 1994 where dispersants could have been considered for use. Hawaii, Puerto Rico, and the U.S. Virgin Islands are not shown. Spill locations are approximate.

The majority of the crude and refined oil spills occurred close to the shoreline and were therefore considered close to a sensitive receptor. When the criterion was modified and spills closer to a sensitive receptor were considered burnable (i.e., the distance from the receptor was decreased from 3 miles to 0.25 mile), the number of oil spills (both crude and refined) where burning could have been considered nearly doubled, from 24 to 40 spills for crude oil and from 30 to 52 spills for refined oils.

Discussion

The analysis may be conservative in terms of dispersibility of refined products. This was evident with the *Pac Baroness* and *Puerto Rican* spills, both of which involved "nondispersible" oils using the API criteria. However, responses to both incidents used dispersants, with various estimates of success.

More complete data are needed for the smaller spills (those <1000 bbl). It is with these smaller spills that dispersants and in-situ burning could have their greatest utility. According to the USCG database, spills less than 1000 bbl represent the majority of spills in the United States. From 1973 through 1991, 99% of spills were less than 1000 bbl (Brulle, 1994). The original intent of this project was to gather information on spills of 500 bbl or more in size. After preliminary analysis of the data, it became clear that significant information was missing. Data gaps were more pronounced for the smaller (<1000-bbl) spills, so the scope of the project was limited to incidents of more than 1000 bbl. Assuming that dispersants and in-situ burning could be used with the same relative frequency for both sizes, then the opportunity to use these technologies is significantly increased. Reporting and archiving of vital spill information, especially oil type and the latitude and longitude of the spill site, needs to be improved so that a similar analysis could be conducted on smaller spills.

Many dispersant and in-situ burning preauthorization policies currently in place in the United States allow for the use of these responses in areas greater than 3 miles from the shoreline and in water at least 65 feet deep (for dispersant use). These policies were implemented to protect environmental resources from a perceived risk of exposure to either the dis-

Figure 2. Crude and refined oil spills in the coastal and offshore areas of the United States of 1000 barrels or more from 1973 through 1994 where in-situ burning could have been considered for use. Hawaii, Puerto Rico, and the U.S. Virgin Islands are not shown. Spill locations are approximate.

persed oil or the smoke plume. The dispersant policies are also based on very conservative estimates of dilution and mixing in the water column. As this study has shown, the number of spills that have occurred in the past 20 years in waters more than 3 nautical miles from the shoreline is very limited, and probably cannot justify the expense of maintaining response capabilities for offshore areas alone. The majority of the spills identified during this study occurred in shallow waters less than 3 nautical miles from the shoreline. In many of these instances, the environmental conditions and the volume of oil spilled would still have allowed for rapid dissipation of dispersed oil. Smoke production would also have been rapidly dissipated, and sensitive receptors were not always nearby. This suggests that the conservative limits now in place in many areas may eliminate consideration of dispersants or in-situ burning on many spills where the environmental benefits of their use could protect sensitive resources. The inclusion of these incidents as viable opportunities for dispersant or burning use would also improve the economic justification for maintaining the response capability. In fact, more liberal preauthorization policies are under consideration in several areas. California has proposed a policy that allows dispersants in waters 0.5 nautical mile or more from the shoreline, and Hawaii recently approved a burning policy where burning is allowed anywhere as long as human health is not expected to be adversely affected. It would appear that the development of more liberal criteria in general, and for small volumes of oil in particular, would greatly improve the economics of these response options, as well as potentially improve our ability to protect sensitive resources.

Biography

Janet Kucklick is a manager of environmental studies at Scientific and Environmental Associates, Inc. Many of her recent projects have involved the use of alternative oil spill countermeasures, especially dispersants and in-situ burning.

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