Chapter 4

ASSESSMENT OF THE IMPACT OF DISPERSANT USE ON RESPONSE CAPABILITY

In this chapter:

- ***What efficiency and environmental concerns influence dispersant use?***
- ***Has dispersant use been accepted as a viable response option?***
- ***What is the current state of dispersant technology?***
- ***What dispersant options are available currently?***
- ***Is including a requirement and/or offset for a dispersant capability practicable in light of the current technology, market availability, overall distribution of dispersant resources, and current (and projected) Regional Response Team (RRT) dispersant use policies?***

Dispersant use as an oil spill response option is inherently more controversial and, in passing always seems less desirable than on-water mechanical recovery options. On-water mechanical recovery is attractive because it is the only response option that results in recovering at least some of the spilled oil. Experience, however, shows that mechanical recovery generally results in recovering no more than 20–30% of spilled oil because of the nature of floating oil. As a consequence, mechanical recovery does not provide the desired level of protection for sensitive resources threatened by slicks on the water surface.

Dispersant use provides an increased level of shoreline and surface resource protection, but does so by increasing the potential exposure of resources in the water column. Environmental considerations, not engineering efficiency, drive decisions about dispersant use. It is possible to determine when and where dispersants might be an economically and ecologically acceptable response option by combining information on ecological consequences with information on distribution of spills and availability of suitable response resources. This chapter examines when dispersant use is technologically and ecologically feasible, and provides a determination as to whether it is practicable to include dispersant capabilities in the required response planning Caps for the United States. Throughout this chapter, changes that have affected these considerations from 1990 through 1998 are discussed to identify trends that might influence future dispersant use decisions.

4.1 ISSUES INFLUENCING DISPERSANT USE

In a paper presented at the 1989 International Oil Spill Conference, Butler (1989) summarizes the results of the National Research Council's multi-year review (NRC, 1989) of the role of dispersants in the marine environment with two questions:

- Do they do any good?
- Do they do any harm?

Ten years later, there is still a debate over these two questions, with the National Research Council report (NRC, 1989) beginning the re-evaluation of dispersant use. The environment and circumstances of each oil spill are so variable that there is no absolute answer to these questions. The NRC report does conclude, however, that concerns over adverse ecological effects in the water column often had been overstated, and that exposure to dispersed oil was unlikely to be an issue except in shallow-water habitats with restricted circulation. Even then, the benefits of shoreline protection could well outweigh potential impacts. With respect to "effectiveness," however, the NRC report concludes that field evidence was not sufficient to confirm high efficiencies in actual spill response operations.

4.1.1 Efficiency Concerns

A critical aspect of any decision about dispersant use is whether it is likely to be effective. There are several aspects to this question. According to Lewis and Aurand (1997), the main issues for an effective dispersant operation are:

- Confirming that the dispersant will in fact work on the oil of concern under the circumstances that exist at the spill scene.
- Being able to track spilled oil.
- Having adequate and appropriate dispersant supplies and equipment.
- Being able to find and treat the thickest patches of oil.
- Being able to complete the operation in a timely fashion before oil weathers and becomes difficult or impossible to disperse.
- Finally, monitoring the effectiveness of dispersant application.

There have been only a few instances of dispersant use where all of these issues have been documented systematically. The various elements concerning efficiency will be discussed throughout portions of this Caps review, and their status in the United States will be discussed in detail.

4.1.2 Environmental Concerns

A second critical aspect of dispersant use concerns the effects upon the environment as a result of their use on spilled oil. Early dispersant products were derived from engine room degreasers and were very toxic to aquatic life. Efforts to develop less toxic and more effective formulations began in the early 1970s, with modern dispersants significantly improved in both areas. Concerns about the toxicity of dispersants, however, have been slow to dissipate and often are expressed by opponents to their use. As a consequence, any planning decisions about dispersant use must examine toxicity of dispersants and dispersed oil in the aquatic environment. In many instances, this analysis has been approached as an absolute evaluation of the safety of dispersant use, and planners have attempted to define an acceptable threshold for toxicity. This approach has limited value when discussing dispersant use in open waters since dilution is very rapid. Even there, opponents often argue that there is no acceptable exposure threshold.

A more recent approach is to compare the fate and effects of spilled oil with and without the use of dispersants. While more difficult, this approach allows the "relative" benefits of dispersant use to be determined, and avoids the use of arbitrary thresholds for use. This general concept has been discussed for a number of years (Fraser, 1989; NRC, 1989; Trudel and Ross, 1987; Trudel *et al.*, 1989). More recently, Baker (1995) discusses this type of analysis as Net Environmental Benefit Analysis (NEBA), and Aurand (1995) calls it a modified ecological risk assessment (ERA) approach.

Historically, planning jurisdictions in the coastal United States have been reluctant to incorporate dispersant use into contingency and response plans, primarily because of uncertainty over environmental consequences. In inland (freshwater) situations, these same environmental concerns, coupled with reduced effectiveness and limited opportunities for application, essentially have eliminated the possibility of dispersant use. In coastal areas, environmental concerns have diminished over the past 5 to 10 years because of several factors, including improved dispersant technology, better laboratory and field data for both dispersant effectiveness and effects, and improved communication about environmental costs and benefits.

4.1.3 The Fate of Oil in the Environment and Implications for Dispersant Application

In order to evaluate these issues, it is important to understand how oil behaves once discharged into the environment and how that behavior is changed by treatment using dispersants. Chemical dispersant use increases oil dispersion in the water column at the expense of other natural processes (weathering). The processes also may be influenced by the timing of dispersant application, which will change the sequence of weathering events.

In evaluating the consequences of dispersant use, some processes are more important than others, with the most important being the following:

- Spreading
- Evaporation
- Dissolution
- Dispersion to the water column
- Formation of emulsion

As soon as oil is spilled on water, it begins to spread. Crude oils and heavy distillates form two phases during spreading: (1) a thick phase (1–20 mm thick) consisting of viscous, partly emulsified oil, and (2) a thin sheen (0.01–0.001 mm thick) (Neff, 1990). Slicks rarely remain intact for long, and include areas of sheen and thicker patches of oil that tend to break apart because of horizontal water currents and eddies. Emulsified or weathered oil may align as windrows (scattered patches) or accumulate in convergence zones on the sea surface (McAuliffe, 1989). The leading (downwind) edge of a slick tends to be thicker than the interior, and usually moves faster than the interior (Elliott *et al.*, 1986). Measurements taken at experimental spills (Lewis *et al.*, 1998) and actual spills (Lunel *et al.*, 1996) show that the thickest areas of a slick can be 3–10 mm of mousse, equivalent to an oil thickness of 1–3 mm. Slick thickness is very uneven, and distribution is patchy. Studies where this has been measured rely primarily on samples physically collected from the water surface. Currently, there is no proven technology to determine slick thickness accurately.

Spreading is a very important consideration in dispersant response planning, as well as in interpreting the ecological effects of dispersed oil. In most cases, planners use a simplified spreading model that assumes a uniform thickness (0.1 mm, accepted as an average thickness) over an approximate area occupied by the entire slick; the dispersant application rate is based on this calculation. Ross (1998) reviews these assumptions with respect to dispersant response planning and cites that these assumptions underestimate the consequences of the patchy distribution of thick oil. As a general rule, only 10% of potential surface area contains 90% of oil. Calculations of water column concentrations of hydrocarbons for evaluation of effects often are based on the same assumptions, which means that the average water column concentration would be too high for much of the slick area and too low for the areas immediately beneath patches of thick oil. In the open ocean, rapid dilution smoothes out these variations, which would not necessarily be true in restricted or shallow waters.

Evaporation is the most important process in the first few hours or days after an oil spill because it affects both the chemical and physical properties of the slick, and rapidly removes many compounds of most concern with respect to toxicity. Lighter components (C_1–C_8) can be expected to evaporate within the first 5 hours (Betton, 1994). As the lighter, volatile compounds evaporate, the density and viscosity of the slick increases, and emulsion formation is enhanced (Neff, 1990). The process is quite rapid, and 50–70% of the amount that will ultimately be lost to evaporation occurs within the first 12 hours (McAuliffe, 1989). Depending on oil composition, evaporation may remove a considerable part of the original volume, in some cases up to 70–80% (for light refined products). If dispersants are applied early enough, then compounds that might otherwise evaporate may be transferred into the water column with dispersed oil droplets. Moving these highly volatile oil components into the water column may influence toxicity concerns for water-column resources.

As a process to remove compounds from an oil slick, dissolution is in direct competition with evaporation, but proceeds much more slowly so dissolved oil components rarely accumulate in the water column (McAuliffe, 1989). Harrison *et al.* (1975) predict evaporative rates that were 100 to 10,000 times faster than the rates of solution for several classes of compounds. Laboratory studies that utilize "water-accommodated" fractions (WAFs)[1] of crude oil often overestimate this process in comparison with what occurs in the environment, where exposure to dissolved compounds is very low. Dissolution could be of greater importance in restricted water bodies, but compared with dispersion—natural or chemically enhanced—it is not considered significant.

Natural dispersion is caused by turbulent mixing and wave action, and, in contrast to the dissolution process, results in the formation of oil droplets of various sizes that are driven into the water column. Once a slick has been reduced by evaporation, natural dispersion becomes the most important process (Neff, 1990). Small droplets rise so slowly that they effectively are dispersed permanently, and are then transported with the water mass. There is some question as to the exact size of droplet where this may occur. Payne and McNabb (1985) suggest a limit of 0.1 mm (100 μ), while Lunel (1995) defines dispersed droplets as less than 50 μ, and suspended droplets as greater than 70 μ. Chemical dispersants are designed to enhance this natural process by decreasing the surface tension at the oil-water interface, thereby decreasing the energy necessary for the formation of droplets. When dispersant use is successful, dispersion is greatly enhanced in comparison with other weathering processes. Sometimes, natural dispersion also can be very significant. For example, the wrecks of the BRAER in the Shetland Islands and the barge NORTH CAPE off the coast of Rhode Island in 1996 resulted in very high levels of naturally dispersed oil in the water column because of very severe weather conditions.

Some oils, especially after weathering, accumulate and retain water droplets in the oil phase as a result of turbulent mixing, thereby producing mousse. These emulsions can contain as much as 75% water and are thicker than the original oil (Neff, 1990). Emulsification is most likely to occur with heavier crude oils with high viscosities, which also form the most stable emulsions. Emulsion formation is due to stabilization of water droplets in the oil mass by the natural surfactant action of the resins and asphaltenes in oil. Weathered crude oil tends to emulsify quicker than fresh crude oil because the resin/asphaltene concentration is higher than 3% (Fingas *et al.*, 1993). If treated oil is dispersed successfully, then emulsion will not form, less oil will impact the shoreline, and environmental damages may be reduced, depending on the circumstances. If oil emulsifies prior to dispersant treatment, the increased viscosity may severely limit dispersant effectiveness, which is a major factor in determining the "window of opportunity" for dispersant use.

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[1] Laboratory-prepared solutions derived from the low-energy mixing of oil with water that is essentially free of particulates of bulk material (greater than 1 μ in diameter) (Coelho and Aurand, 1997).

4.1.4 The Ecological Consequences of Potential Exposure to Oil or Dispersed Oil

Since dispersant use changes the fate of oil in the environment, any evaluation of ecological effects requires determining the relative vulnerability (including toxicological sensitivity and recovery potential) and value of a variety of resources that might be affected differently by dispersed or untreated oil. While toxicity of dispersants is an insignificant ecological risk, the toxicity of dispersed oil is of significant concern, particularly to resource trustees[2]. Recent scientific work has focused on meaningfully addressing the ecological risks presented by chemically dispersed oil (e.g., Lessard *et al.*, 1999; Neff, 1990; Neff and Sauer, 1995; NRC, 1985, 1989).

The way in which oil components are reported is important to the understanding of ecological consequences. Since it is neither meaningful nor practical to report the concentration of individual compounds when dealing with a spill, oil pollution studies often report measures of bulk oil present (which says nothing about composition), or refer to the concentration of total petroleum hydrocarbons (TPHs) or total hydrocarbon content (THC). This terminology potentially is misleading since there is no single definition of, or method for, TPH determination. As a result, reported values in the literature may not be directly comparable, even though the same reporting units may be used.

Not all components present in crude or refined oils are toxic. Some components are of concern because of their acute toxicity, while others pose long-term, chronic risk. The two classes of oil compounds of most concern are the alkanes (branched or unbranched chains of carbon atoms with attached hydrogen atoms and only single carbon-carbon bonds) and aromatic hydrocarbons (characterized by single or multiple rings of six carbon atoms each). The aromatic hydrocarbons are of the most concern (Neff, 1990), and of those, the benzene, toluene, ethylbenzene, and xylene (BTEX) compounds that contain one ring and the lighter polynuclear aromatic hydrocarbons (PAHs) that contain two or more rings are the primary sources of aquatic toxicity. The lighter alkanes, as well as the BTEX compounds, are very volatile and rapidly removed from spilled oil. The heavier PAHs are more persistent, and chronic effects of petroleum are usually related to four- and five-ring PAHs (Neff, 1990; Neff and Sauer, 1995).

The key elements in interpreting laboratory data related to dispersant and dispersed oil impacts on the environment are the definition and interpretation of the exposure regime. These elements are driven by assumptions that are made concerning concentrations that are likely to occur in actual spills. Field studies have compared the concentrations of hydrocarbons in the water column under both treated and untreated slicks, and collected data on the fate of oil slicks. These experiments involved the release of oil in replicate slicks, followed by aerial dispersant application. The volumes spilled varied considerably, but many of the early releases were 20 bbls or less per slick, and the more recent North Sea experiments on the order of 200–250 bbls per slick. Under undispersed oil slicks, measured hydrocarbon concentrations are recorded in the ppb range, while under chemically dispersed oil slicks, concentrations vary but range up to 20–50 ppm in the top 1–5 meters. Dilution of the dispersed oil plume is rapid, and oil concentrations measured below 10 meters water depth

[2] Those agencies entrusted with the protection of natural, historical, and cultural resources.

are typically 1 ppm or less (Brandvik *et al.*, 1997; Canevari *et al.*, 1986; Lichtenhalter and Daling, 1985; Lunel and Davies, 1996). The composition of the oil droplets depends on oil type and weathering state, but effective and early application of chemical dispersant can result in higher levels of volatile components in the water column. Data support a rapid decline to oil concentration values of less than 1% or 2% of the initial level within 2 or 3 hours when chemical dispersants are applied to test slicks at sea. Similar experiments have not been done in restricted areas. Treatment of thicker slicks would lead to higher initial concentrations in the water column directly beneath the surface slick.

In the grounding and subsequent destruction of the BRAER, the severe weather plus the chemical and physical properties of the spilled oil (Gullfaks crude) resulted in the near total physical dispersion of approximately 595,000 bbls of cargo, along with a small volume of fuel oil. Concentrations of total hydrocarbons in the water column near the tanker were in the range of several hundred ppm soon after the grounding. In the following days, concentrations were generally in the 50 ppm range. Ten days after the grounding, concentrations in Quendale Bay (approximately 2–3 km from the wreck) were less than 10 ppm. The ecological consequences were characterized as “relatively slight, and mostly short lived” (Ritchie and O’Sullivan, 1994).

The wreck of the NORTH CAPE led to the loss of nearly 20,000 bbls of home heating oil, a product similar to No. 2 fuel oil in physical and chemical properties. This refined oil has a relatively high toxicity to aquatic organisms in comparison with most crude oils because of the high percentage of lighter compounds. The oil was highly dispersible, and weather conditions were extreme. As much as 80% of the oil may have naturally dispersed within the first 8 hours (OSIR, 1996b). After 2 days, 0 TPH concentrations in the vicinity of the wreck were about 6 ppm, and oil was evenly distributed within the area of the plume to a depth of 20 meters. Three days later, TPH values were below the detection limit of 0.1 ppm (Research Planning, Inc., 1996). In contrast to the BRAER incident, there were considerable biological consequences for this spill, which have become contentious (OSIR, 1998f). The observed mortalities, especially in lobsters, may have been caused by narcosis because of exposure to oil in the water column, followed by physical damage related to the severe turbulence. Because of the inherent toxicity of this type of oil, it would require unusual circumstances for large volumes of oil in spills of this type to ever be considered for dispersant use.

During the SEA EMPRESS spill, dispersants were used extensively on 19 million gals of oil, and a robust data collection effort was conducted. Once again, weather conditions were conducive to good mixing with the water column. Concentrations of physically dispersed oil were as high as 30 ppm near the water surface in localized areas early in the spill. After dispersant application, depth penetration was much greater, typically 3–5 ppm from 0–5 meters under treated slicks. Decline was relatively rapid with time (days) and distance. The dispersant application was credited with dramatically reducing shoreline impacts.

The differences in the ecological effects noted for these three spills appear to be largely due to the nature of the oil, biological communities present, and physical conditions during the spills. The observed results are consistent with those expected based on field and laboratory studies, but highlight the need for seriously considering the potential consequences of dispersant use.

Data from all these spills suggest that, while peak concentrations are variable and dependent on the initial concentration of oil on the surface, oil concentrations throughout the water column for moderate-sized spills decline very rapidly as long as dilution occurs. The rate of this oil concentration decline is volume and energy dependent. For small slicks in open water, it takes only hours to return to background levels. For large slicks with rapid dispersion, it may take several days before the oil concentration in the water column returns to background levels. Even for large slicks, if the area being treated is large, the rate of decline locally may be very rapid; however, this is situation-dependent and would be slower in restricted areas.

Despite these data, the research community has been slow to adopt laboratory experimental designs that reflect a declining exposure regime, and the regulatory community often makes very conservative assumptions about exposure during spill response planning. If the rapid dilution observed in field experiments is accurate for small- to moderate-sized spills, static 96-hour laboratory tests would overestimate oceanic exposures by more than 100-fold. Concurrently, the spiked exposure regime being used by the laboratories working on dispersed oil toxicity would overestimate oceanic exposure by a factor of five (based on a laboratory half-life of 2.5 hours, compared to field data suggesting a half-life near 30 minutes), but would be much more appropriate for nearshore situations where dilution is less rapid (Aurand, 1998). In 1995, a expert panel convened to evaluate issues related to the use of chemical countermeasures for oil spill response, and concluded that water column concentrations of dispersed oil at or below 10 ppm for 2–4 hours of exposure were unlikely to cause adverse ecological effects (SEA, 1995).

4.1.5 Summary of Issues Influencing Dispersant Use

- Dispersants remove spilled oil from the water surface into the water column in the form of small droplets that remain suspended in the water column. These droplets spread vertically and horizontally in the water column. They are diluted quickly to concentrations in the ppb range.
- Field experiments and actual spill responses indicate that existing dispersant formulations can be effective in removing large quantities of oil from the water surface, thereby significantly reducing the emulsification of oil and the quantities of oil that ultimately are deposited on shore.
- These experiments and incident-specific applications also indicate that the effects of dispersed oil are typically not observed and that adverse impacts on sensitive shoreline resources are likely to be reduced because of reduction in quantity of oiled shoreline.
- Considering environmental tradeoffs with dispersant use is important and can be accomplished largely during the planning process.

4.2 DISPERSANT PROCESS

Like mechanical recovery, dispersant use is a multi-step process (Figure 4-1). The oil must be located, tracked, identified as dispersible; thick areas identified; dispersant applied; effectiveness of the process monitored; and finally, a decision must be made as to when to cease operations.

First, as with all response options and as described for mechanical recovery, oil must be located and mapped so that resources can be effectively deployed. In general, all of the considerations already discussed in Chapter 3 regarding oil tracking apply here as well. Identification of thick areas of oil is especially critical for efficient dispersant use.

The next critical step is to determine if the oil is dispersible. This requires knowledge of the oil type and its weathering state. Databases on dispersability exist for most major oils, but weather and environmental conditions play a role in determining the length of time available for an effective response. All of these factors need to be considered quickly to minimize expense associated with deploying response equipment.

Before dispersant operations with aircraft can begin, the proper equipment and a stockpile of dispersant must be available at a staging area located within a reasonable distance of the spill scene. For operations from vessels, the critical factors are getting the response vessel loaded with dispersant and the spray system installed (if not permanently mounted) and ready to operate. Resupply at sea may be an issue for vessels. Restocking the supply facility (for aircraft) with dispersant can become a critical factor if the spill is large.

Once the capability is in place, dispersant applications can begin. Dispersant operations from either surface vessels or aircraft require daylight, good visibility, and reasonable environmental conditions. While some wind is desirable for turbulence, excessive wind will result in poor application efficiency. For planning purposes, it is assumed that a dispersant-to-oil ratio (DOR) of 1:20 will effectively disperse the oil. In reality, effectiveness must be determined empirically through monitoring, since it is impossible to verify the actual dispersant to oil ratio; plus, effectiveness is sensitive to a host of environmental factors. Monitoring is much more critical for dispersant operations than for other options. It is also important that the information be rapidly available to both planners and dispersant application crews so that necessary adjustments can be made. On a qualitative level, visual observations from spotter aircraft work well, and can be coupled with measurements of water column concentrations of oil using fluoremetry if needed. When monitoring suggests that either the majority of the oil has been dispersed or that the operation is no longer effective, then application should be terminated.

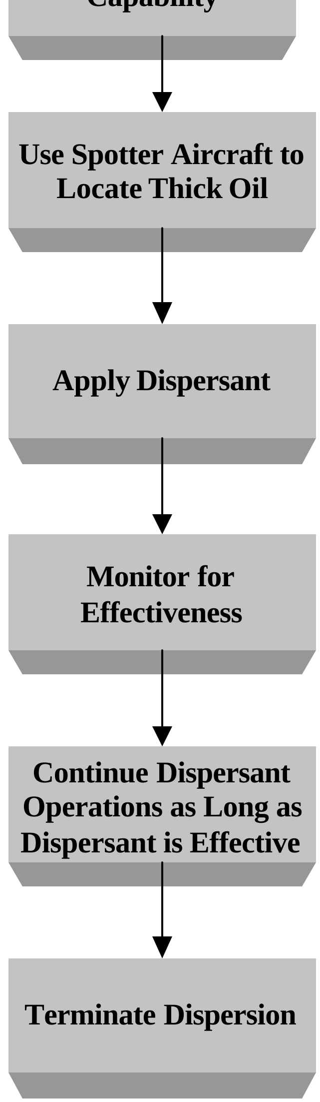

FIGURE 4-1. Schematic of the Dispersant Process.

4.3 HISTORY OF DISPERSANT USE

4.3.1 History of Dispersant Use in the United States

Although dispersant use is not currently widespread in the United States, it is increasing in some jurisdictions. Lewis and Aurand (1997) summarize dispersant use in major spill responses worldwide between 1969 and mid-1996. Their summary includes only well-documented spills, usually of relatively large volumes, that were reported in various technical and professional articles. In many areas of the world, dispersants have been used but not reported in the literature. In the United States, however, Lewis and Aurand's list is relatively complete because of the extensive approval process required. According to these data, there were 11 instances of dispersant use in the United States between 1969 and mid-1996. As part of this Caps review, this search was extended from mid-1996 through December 1998, and four additional instances were identified. All of these spills from Lewis and Aurand (1997) and this Caps review are summarized in Table 4-1.

With 1969 being the first year data are available, 1998 shows more dispersant use than any other year—there were four successful dispersant responses reported, all in the Gulf of Mexico. Prior to 1998, there were only 2 years with more than one application (1969 and 1970), 6 years with one application, and 19 years with no dispersant use. Many applications prior to 1998 did not represent full-scale responses, but rather limited test applications. To date, there have been no reported incidents of dispersant use in either the Great Lakes or rivers and canals in the United States; all incidents have occurred in ocean environments.

4.3.2 History of Dispersant Use Elsewhere in the World

Lewis and Aurand (1997) identify 41 instances in 16 different countries of dispersant use in oil spill literature from 1990 through mid-1996. Dispersants were used most frequently in the United Kingdom, Greece, Japan, Australia, Korea, South Africa, and India. As part of this evaluation, 12 spills in addition to those listed in Table 4-1 were identified in 11 different countries through 1998 (Table 4-2).

Etkin (1998a) summarizes information on dispersant planning internationally. Based on data available through the Oil Spill Intelligence Report database, 73% (110 of the 150) nations tracked worldwide allow dispersant use. In 35 countries, dispersants are listed as the primary response option, while eight nations prohibit dispersant use under any circumstances, and nine countries list them as an option of "last resort." Of the 35 countries that list dispersant use as the primary response option, the United Kingdom is the most frequent user. Other nations where dispersant use is the primary option include Brazil, China, India, Pakistan, Saudi Arabia, Singapore, South Africa, Taiwan, Thailand, and the United Arab Emirates. In many countries, dispersant use is a secondary response option (Etkin, 1998a), including many of the countries identified by Lewis and Aurand (1997) or those listed in Table 4-2 as having been involved in a response effort using dispersants.

There is a wide range of views on dispersant acceptability in Europe. It is not uncommon for countries in proximity to each other to regulate dispersant use very differently. Even in countries with similar shared natural resources, there can be dramatically different approaches. These differences appear to reflect differences in opinion concerning the effects and effectiveness of dispersant use.

The country with the most experience with dispersants is the United Kingdom, where dispersant use is the main response option for large spills. More documentation, including both experimental field trials and actual spills, is available on dispersant use and its consequences from the United Kingdom than anywhere else. Norwegian research groups also are active in field research on dispersants, and historically, field trials have been conducted in the United States as well.

As a result of the wreck of the tanker BRAER near the Shetland Islands off the coast of Great Britain in January 1993, the Ministry of Agriculture, Fisheries, and Food (MAFF), Directorate of Fisheries Research in the United Kingdom was asked to review the U.K. Oil Spill Dispersant Testing and Approval Scheme (MAFF, 1996). While the wreck involved limited chemical dispersant use, the extremely severe weather and type of oil released (approximately 23 million gals of Gullfaks crude oil) resulted in natural dispersion of most of the spilled oil.

TABLE 4-1. Oil Spills in the United States Where Dispersants Were Used, 1969–1998.

DATE	GENERAL LOCATION	NAME	VOLUME OF OIL	TYPE OF OIL	DISPERSANT USED	REPORTED EFFECTS	REFERENCES
1969	Nearshore	BARGE FLORIDA	175,000 gals	No. 2 fuel oil	?	Dispersant had little to no effect on oil. Several shoreline impacts in marshes.	EPA, 1979
1969	Nearshore	Well A-21, Platform A (Santa Barbara)	77,000 bbls	Santa Barbara crude	ARA Gold Crew Bilge Cleaner	Dispersants used to reduce fire hazards near the platform and prevent oil from reaching the beach. About 37,500 gals applied by boat and aircraft. No estimate of effectiveness. No impacts attributed to dispersant.	ATA and CSA, 1990; Exxon, 1994
1970	Inland (Estuarine)	DELIAN APOLLON	?	No. 6 fuel oil	COREXIT 8666 and 7664	Used to restore tidal zone. Studies revealed no additional impacts from dispersants.	Exxon, 1994
1970	Offshore	Chevron Main Pass Block 41	35,000–65,000 bbls	GOM crude	Primarily COREXIT 7664	2,000 drums sprayed around platform. Maximum level of dispersed oil at 1 nmile was 1 ppm. No evidence of effects on shrimp, blue crabs, or commercial fish based on travel samples.	Exxon, 1994; NOAA, 1992
1978	Nearshore	BARGE PENNSYLVANIA	881 bbls / 143 bbls	No. 6 fuel oil/ No. 2 fuel oil	COREXIT 9527	Extremely effective. No adverse effects on fauna.	Exxon, 1994
1984	Offshore	PUERTO RICAN	100,000 bbls	Lube oil/Lube oil additives	COREXIT 9527	Aircraft used 2,000 gals to disperse slick moving toward shore. Further spraying prevented by weather, but initial application judged to be effective.	Exxon, 1994; NOAA, 1992

Continued

TABLE 4-1. Oil Spills in the United States Where Dispersants Were Used, 1969–1998 (*Continued*).

1987	Offshore	PACBARONESS	30 bpd	Possibly diesel	COREXIT 9527	200 gals applied by aircraft to leading edge of slick, appeared successful. 50 gals applied by helicopter in test near site of sinking, also effective. Rest of slick dispersed naturally.	Exxon, 1994; NOAA, 1992
1989	Nearshore	EXXON VALDEZ	11 million gals (258,000 bbls)	Alaska North Slope crude	COREXIT 9527	Dispersability test run, but no large application made because of logistics, weather, and planning delays.	Morris and Loughlin, 1994
1990	Nearshore	KONDOR	significant amounts	Diesel and lube oil	?	14 bbls applied by boat and 28 bbls by aircraft to protect fish farms. Slick broke up, and damage was less than feared.	Exxon, 1994
1990	Offshore	MEGA BORG	12,000–40,000 gals but did not burn	Light crude	COREXIT 9527	Dispersant applied by aircraft to a 15-mile long slick offshore. Effective; produced concentrations of 20 ppm in 1- to 3-meter depths. Minimal environmental impacts.	Exxon, 1994
1995	Offshore	WEST CAMERON 198	500–700 bbls	Light natural gas condensate	?	?	*Personal communication* [letter], R. Fiocco, Exxon Research and Engineering, Florham Park, NJ, July 1996
January 1998	Offshore	Pipeline	33,600–10,500 gals	Medium sweet crude	3,000 gals COREXIT 9527	Aerial spraying of COREXIT 9527 by DC-3.	OSIR, 1998a
January 1998	Offshore	ULCC Red Seagull	19,000 gals	Arabian light crude	80 gals COREXIT 9527	Aerial spraying of COREXIT 9527 from the fire monitor on a tanker tender.	OSIR, 1998a

TABLE 4-1. Oil Spills in the United States Where Dispersants Were Used, 1969–1998 (*Continued*).

DATE	GENERAL LOCATION	NAME	VOLUME OF OIL	TYPE OF OIL	DISPERSANT USED	REPORTED EFFECTS	REFERENCES
January 1998	Offshore	Production platform	4,800 gals	Natural gas condensate	COREXIT 9527?	Aerial spraying of dispersant.	OSIR, 1998a
October 1998	Offshore	Pipeline	155,400 gals	GOM crude oil	2,000 gals COREXIT 9527 at 5 gpa	Aerial spraying of COREXIT 9527 by DC-3. Minimal environmental impact reported, based on search for oiled birds (near sanctuary). Oil gone in 24 hours	OSIR, 1998b

Note: gals, gallons; *?*, unknown/not found; EPA, U.S. Environmental Protection Agency; bbls, barrels; ATA, Advanced Technology Associates; CSA, Continental Shelf Associates, Inc.; ppm, parts per million; NOAA, U.S. National Oceanic and Atmospheric Administration; OSIR, Oil Spill Intelligence Report; gpa, gallons per acre.

TABLE 4-2. Major Oil Spills Worldwide (Excluding the United States) Where Dispersants Were Used, August 1996–December 1998.

COUNTRY	DATE	GENERAL LOCATION	NAME	VOLUME OF OIL	TYPE OF OIL	DISPERSANT USED	REPORTED EFFECTS	REFERENCES
Japan	January 1997	Nearshore	NADHODKA	1,823,000 gals	Heavy fuel oil	?	Dispersant use delayed because of weather. Nearshore skimming and manual shoreline cleanup conducted.	Etkin, 1998b
Fiji Islands	January 1997	?	DONG HUAI	N/A	Unspecified	?	Dispersants sprayed on slick.	Etkin, 1998b
Argentina	February 1997	Nearshore	SAN JORGE	1,320,000 gals	Candon sec (light) crude	COREXIT 9580, Dasic Slickgone, Enviroclean	Applied dispersants from planes. Manual shoreline cleanup. Cleaning agents used on rocks.	Etkin, 1998b
South Korea	April 1997	Nearshore	OSUNG NO. 3	606,000 gals	No. 6 fuel oil	?	Response vessels used dispersants and absorbents.	Etkin, 1998b
United Kingdom	August 1997	Offshore	CAPTAIN FIELD	200,000 gals	Crude	COREXIT 9500	Oil field standby vessel applied dispersant immediately.	Etkin, 1998b
United Kingdom	September 1997	Offshore	N/A	38,000 gals	Crude, No. 5 fuel oil	COREXIT 9500, Dasic Slickgone NS	Dispersant effectiveness monitored by *in situ* monitoring and remote sensing (test spill).	Etkin, 1998b
Singapore	October 1997	Nearshore	EVIOKOS	8,400,000 gals	Heavy fuel oil	?	Dispersants applied from helicopters. Planes grounded because of haze.	Etkin, 1998b
South Africa	November 1997	Nearshore	ASTER	103,000 gals	Gasoil, Intermediate fuel oil	?	Vessels applied dispersants.	Etkin, 1998b

Continued

Australia	September 1996	Nearshore	IRON BARON	88,200 gals	Heavy fuel oil	?	Vessels applied dispersants.	OSIR, 1996a
Nigeria	January 1998	Offshore	Pipeline	1.7 million gals	?	COREXIT 9527	Vessels applied dispersants. Monitored by helicopter.	OSIR, 1998c
Philippines	October 1998	Nearshore	PRINCESS OF THE ORIENT	159,000 gals bunker fuel and 3,100 gals lube oil; 13,210 gals observed inshore	Bunker fuel and lube oil	1,640 gals, type unknown	Ferry sunk on 18 September. Oil washed into Manila Bay on 6 October. Dispersant application ineffective. Heavy shoreline oiling.	OSIR, 1998d
New Zealand	October 1998	Nearshore	S.K. DONG WON 529	100,000 gals	Marine diesel	Unknown dispersant used over 3 days	Dispersants used to protect bird sanctuary and many rare species. Extensive surveys found no fatalities because of oiling. Initiated studies to determine effects on commercial species (lobster, cod, salmon, scallops, and oysters).	OSIR, 1998e

Note: gals, gallons; *?*, unknown/not found; OSIR, Oil Spill Intelligence Report.

An extensive environmental evaluation of spill consequences was undertaken, considered to represent an “extreme case” analysis of dispersed oil in the environment. The results of the MAFF review support continued dispersant use as the primary response option for most large spills. The U.K. strategy is to reduce the amount of oil coming ashore to a minimum to provide maximum protection of shoreline resources. This strategy is based on (1) the extent of the shoreline (more than 9,000 miles), (2) the poor beach access in many areas, (3) the average weather conditions in the area that favor dispersant use and make mechanical response impractical, and (4) the feasibility of centrally locating dispersant stockpiles and aircraft, given the relatively small size of the United Kingdom.

In February 1996, the tanker SEA EMPRESS grounded at the mouth of Milford Haven, Wales. In contrast to the BRAER, this spill presented an excellent opportunity for dispersant use. Nearly 19 million gals of Forties Blend crude oil (a light North Sea oil) and 100,000 gals of heavy fuel oil were released over a 6-day period (mostly during the last 3 days). Forties Blend crude oil had been used in experimental spills in the United Kingdom and was known to be dispersible. In addition, the threatened coastal area contained many high-value ecological resources, so shoreline protection was considered critical. Lunel *et al.* (1996) summarize the dispersant response. Approximately 120,000 gals dispersant were applied from DC-3 aircraft over a period of 3 days.

The response was judged to be highly successful in reducing shoreline impact, and at the same time, no adverse consequences offshore were noted (although not all research data are available yet). Lunel *et al.* (1996) estimate that approximately 50% of the oil released was dispersed, instead of the 10–20% that would have been expected to be naturally dispersed under the prevailing weather conditions. Based on the formation of a 70% water-in oil emulsion, dispersing 130,000 to 180,000 bbls removed a potential 430,000 to 600,000 bbls of a thick, gummy residue known as “mousse” that could have impacted the shoreline.

Researchers also were monitoring hydrocarbon levels in the water column near the tanker and in the area of the oil slick and dispersed oil plume. Although dispersants substantially increased the concentration of dispersed oil in the water column, concentrations were generally less than 10 parts per million (ppm) because of natural turbulence, except in localized areas. These values were considerably less than the values observed at the BRAER spill, and appear to reflect the difference in rate at which the oil was actually dispersed into the water column at the two spills. During the BRAER spill, the oil was essentially driven into the water column upon release, whereas during the SEA EMPRESS spill, increased dispersion only occurred as areas of the slick were actually treated. The SEA EMPRESS incident is the best-documented, large-scale use of dispersants currently available, and is viewed in the United Kingdom as clear justification of general reliance on dispersants as their primary response option.

4.4 TECHNOLOGY ASSESSMENT

4.4.1 Dispersant Application Systems

This section examines the available information on resources necessary for an effective dispersant response operation in the United States. It also summarizes relevant information about the resources that can be used to assess and compare alternative systems. Characteristics of aircraft and surface vessels, as well as their application capabilities, are presented in Table 4-3 and will be relevant to later discussions of capacity and deployability.

4.4.1.1. Assumptions regarding Oil Slick Behavior (Treatment Areas)

In order to make any reasonable conclusions about the efficiency of various dispersant application systems, it is necessary to develop estimates of the rates at which they can effectively treat oil in the environment. It is still common to base these calculations on an oil slick that evenly distributed on the sea surface. Based on literature values developed in the 1970s, calculations suggested using an average slick thickness of approximately 0.1 mm. This value has been used routinely in planning for dispersant use, as well as for mechanical recovery and in-situ burning.

The use of average values and assumptions of uniformity are attractive to planners, since they allow relatively simple calculations for estimates of recovery rates and equipment requirements. Use of an average uniform thickness also implies that a dispersant application platform will be continually spraying a slick the entire time it is onscene. Unfortunately, the reality in nature is much more complex. Oil slicks do not spread evenly over the sea surface. Instead, they consist of patches of thick oil surrounded by areas of much thinner oil, often only sheen. Based on field studies in the North Sea and elsewhere, and on observations at accidental spills, a rule of thumb has been developed which says that 90% of the oil volume occurs in thick patches which occupy 10% of the total slick area. These patches are often 1 to 3 mm thick, or even thicker, i.e., much thicker than the average for the entire slick. The general tendency of oil to differentiate into thick and thin patches has been recognized for some time (cf. McAuliffe, 1989). This is often in the form of windrows of oil (or emulsified oil) that may spread over a considerable area toward the downwind end of the slick, depending on the environmental conditions. The implication here is that in an actual spill event, more time is spent by application platforms transiting between these patches of oil than actually spraying the dispersant. Even so, most response planning continues to rely on the assumption of uniform distribution, because the actual distribution during a spill is so variable and situationally dependent.

Since the purpose of this review is to determine if it is practicable to require a dispersant response capacity, it is important not to overstate the efficiency of such operations. Calculations based on an average slick thickness of 0.1 mm tend to minimize the amount of time necessary to locate and move from one thick patch to the next as well as the number of passes necessary for a platform to effectively treat a patch of oil. On that basis, the “average” response situation needs to be more accurately defined than was the case when using the assumption of a 0.1 mm thickness over a large area. Since a particular size and spill configuration cannot be assumed, estimates of repositioning time (the ratio of time spent repositioning to time spent spraying) are needed to determine the rate at which dispersant can actually be delivered. Materials presented by Ross (1998) and Exxon (1992) were used to develop "repositioning factors" for the various application platforms, including fixed wing aircraft, helicopters, and vessels. These repositioning factors are key elements for determining the application rates (or treatment capabilities) assigned to these platforms, as outlined in Table 4-3.

4.4.1.2. Assumptions for Aircraft Capability

This has serious implications for dispersant application planning, especially with respect to aircraft operations. Most aircraft application systems can efficiently treat a slick that is 0.1 to 0.3 mm thick at the desired dispersant to oil ratio of approximately 1:20 in one pass. If an aircraft were treating an average minimum slick of .1 mm thickness, it could be assumed to be spraying all of the time it is on station. This type of calculation makes large aircraft appear very effective relative to other platforms (Exxon, 1994).

Realistically, most aircraft cannot deliver more than approximately 10–20 gals dispersant per acre (gpa) (depending on the aircraft being used). However, it has been noted that oil tends to form thick patches, and 50 gpa would be needed to treat an acre slick that is 1-mm thick. An aircraft could need three to five passes over a given patch to achieve the desired dosage. (Alternatively, multiple aircraft can fly over the same spot in sequence.) Even more applications would be needed if the slick were thicker, which could be the case especially early in the spill. This means that an aircraft will spend much of its time repositioning over the slick for short spray runs and then moving to a new location.

In fact, dispersant aircraft spend much of their time repositioning and require a number of passes by a single aircraft to achieve an appropriate dosage. Ross (1998) considers the implications of this situation relative to specific scenarios in Alaska in detail and provides an excellent overview of the issues which planners need to consider. For aircraft, the determining factors are 1) the distance (time) the aircraft can travel during a spray run and 2) the time the aircraft requires to turn 180° and repeat the run. Conceptually, the actual value for repositioning on any sortie in a particular spill could range from 1 (the situation in earlier planning approaches when the aircraft is always spraying) up to a situation where the majority of on-station time is spent trying to locate an appropriate area to spray.

For the purposes of this study, it is useful to look at a series of situations where the distance traveled during each spray run is 0.25, 0.5, 1.0, 2.0 or 4.0 nm. At the end of each run, the aircraft is then required to turn around and repeat the run. Assuming a spraying speed of 150 kts, these runs require 6, 12, 24, 48 and 96 seconds, respectively. Estimates of time in the literature for a large aircraft to complete a 180° turn range from one to two minutes. By adding the time to complete a turn to the time spent spraying, an elapsed time for one complete spray cycle is obtained. Dividing that number by the time actually spent spraying yields an estimate of the "repositioning factor". For example, with a turning time of 60 seconds and a spray distance of 0.25 nm, the total time would be 66 seconds and the repositioning factor would be 11. The results for the various distances and two 180° turn times range from a high of 21 (0.25 nm spray length, two minute turn time) to a low of 1.6

(4.0 nm spray length, one minute turn time). The intermediate value selected for use in this report for aircraft, 4.0, represents a spray distance of between one and two nm with two minute turns and slightly less than 1 nm if the aircraft can turn in one minute.

For example, a DC-3 aircraft would require 5.41 minutes to spray its total dispersant load, but with the repositioning factor, a DC-3 would actually be on-scene for 21.62 minutes. The repositioning factor could be much less if the spill does not spread or if very large patches of thick oil are available for treatment. These assumptions are deliberately conservative to ensure that response capabilities are not over stated.

In addition, Table 4-3 assumes that reloading and refueling do not occur simultaneously, and conservative times are used for refueling. The output of the table is the number of flights each type of unit can complete in a 10-hour work day. Additionally, since this review must examine a wide range of possible events, Table 4-3 is based on the assumption that the spill will occur at a distance of either 50 or 150 nmiles from a support base.

The calculations for helicopter application must be modified to reflect the different flight characteristics of the platform. First and foremost, the helicopter can hover, or fly very slowly, in order to increase the dosage rate in any given location, a luxury the fixed-wing aircraft does not have. Since the helicopter bucket also has a limited capacity, it would be possible to defend a repositioning factor of 1.0 for many situations. Using the data in Table 4-3, the helicopter basically sprays its entire load in a period of three minutes. Assuming a spray speed of 30 kts this is equivalent to a spraying distance of 1.5 nm, and the repositioning factor would be1.0 since the aircraft would not need to maneuver for a second run. If a minimal spray distance, 0.25 nm is used, along with a turning time of 60 seconds, then the repositioning factor is 3.0. For the purpose of this study, the intermediate value of 2.0 was selected.

TABLE 4-3. Platform Capability for Oil Dispersant Delivery Over a 10-Hour Period.

PLATFORM	DISTANCE OUT (NMILES)	MAX. AVG. TRANSIT SPEED (NMPH)	TIME OUT/ BACK (MIN)*	VOLUME OF DISPERSANT (GALS)	PUMP RATE (GPM)	MIN. TIME ON STATION (MIN)†	REPOSITIONING FACTOR	ACTUAL TIME ON STATION (MIN)‡	TIME TO RELOAD (MIN)	TIME TO FLY 1 MISSION (MIN)§	NO. OF FLIGHTS BEFORE REFUEL	TIME TO REFUEL (MIN)	TIME SPENT ON MISSION BEFORE REFUEL (MIN)#	NO. OF FLIGHTS POSSIBLE IN 10 HOURS**	ACTUAL NO. OF FLIGHTS IN 10 HOURS	ACTUAL QUANTITY OF DISPERSANT DELIVERED IN 10 HOURS††
Helicopter	50	90.91	33.00	250.00	79.00	3.16	2	6.33	10	82.33	1	10	92.33	6.50	6	1,500.00
	150	90.91	99.00	250.00	79.00	3.16	2	6.33	10	214.33	1	10	224.33	2.67	2	500.00
Air tractor	50	189.84	15.80	792.60	150.59	5.26	4	21.05	10	62.66	3	30	217.98	8.26	8	6,340.80
AT-802	150	189.84	47.41	792.60	150.59	5.26	4	21.05	10	125.87	3	30	407.61	4.42	4	3,170.40
DC-3	50	151.36	19.82	1,000.00	185.00	5.41	4	21.62	30	91.26	2	35	217.52	5.52	5	5,000.00
	150	151.36	59.46	1,000.00	185.00	5.41	4	21.62	30	170.54	2	35	376.09	3.19	3	3,000.00
DC-4	50	214.33	14.00	2,499.34	499.34	5.01	4	20.02	20	68.02	2	30	166.03	7.23	7	17,495.38
	150	214.33	41.99	2,499.34	499.34	5.01	4	20.02	20	124.00	2	30	278.01	4.32	4	9,997.36
DC-6	50	227.27	13.20	3,000.00	300.00	10.00	4	40.00	15	81.40	2	30	192.80	6.22	6	18,000.00
	150	227.27	39.60	3,000.00	300.00	10.00	4	40.00	15	134.20	2	30	298.40	4.02	4	12,000.00
C-130	50	214.33	14.00	5,495.38	634.08	8.67	4	34.67	20	82.66	2	30	195.32	6.14	6	32,972.28
	150	214.33	41.99	5,495.38	634.08	8.67	4	34.67	20	138.65	2	30	307.30	3.90	3	16,486.14
P-3	50	284.09	10.56	4,000.00	500.00	8.00	4	32.00	30	83.12	2	60	226.24	5.30	5	20,000.00
	150	284.09	31.68	4,000.00	500.00	8.00	4	32.00	30	125.36	2	60	310.72	3.86	3	12,000.00
Fire Monitor- (Vessels)	50	5.63	600.00‡‡	84,000.00	40.00§§	N/A	4	600.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6,000.00

Note: nmiles, nautical miles; nmph, nautical miles per hour; gals, gallons; gpm, gallons per minute.

* Aircraft: time out/time back = (Distance out/maximum average transit speed) × 60. Vessel: at distance of 50 nmiles, a vessel cannot provide any support for the first 10 hours (600 minutes) after mobilization. Once on-scene, however, it can operate for as long as conditions are appropriate for dispersion.

† Minimum time on station = volume of dispersant/pump rate.

‡ Actual time on station = minimum time on station × repositioning factor.

§ Time to fly 1 mission (minutes) = (time out/back) × 2 + actual time on station + time to reload.

\# Time spent on mission before refuel = number of flights before refuel × time to fly one mission + time to refuel.

** Number of flights possible in 600 minutes (10 hours) = (600/time spent on mission before refuel) × number of flights before refuel.

†† Actual quantity of dispersant delivered in 10 hours by aircraft = volume of dispersant × actual number of flights. Actual quantity dispersant delivered in 10 hours by vessels = (actual time on station/reposition factor) × pump rate.

‡‡ Time out only.

§§ Maximum estimated pump rate is 200 gpm. At a speed of 5 knots (kts) and a swath width of 65 ft, however, a fire-monitor equipped vessel is limited to a pump rate of 40 gpm to deliver dispersant at a dispersant-to-oil ratio (DOR) of 1:20 to a 1-mm thick oil slick.

Source: Adapted from Exxon (1992) and Ross (1998).

4.4.1.3 Assessment of Aircraft Application Systems

Experience in the United States demonstrates that aircraft systems are reliable and effective for large-scale operations. The main limitations to aircraft use are weather and visibility. It would be beneficial if the operational window could be extended through the use of remote-sensing systems, but safety considerations will always limit operations. Payload capacity and time on-scene must be considered during operations planning, but are not critical limitations.

Fixed Wing Aircraft. The most familiar method of dispersant application is by spray boom carried by fixed-wing aircraft. In the United States, this approach almost always is used as the basis of any dispersant planning scenario. The most common aircraft are DC-3 or DC-4 aircraft equipped with spray boom, or C-130 aircraft equipped with an Airborne Dispersant Delivery System (ADDS) pack. In addition, small, cropduster-type spray planes sometimes are considered. Good visibility is essential for aircraft operations, and spotter aircraft must be available to direct dispersant aircraft because the pilot cannot visually steer to the areas of thick oil and observe the results while flying at low altitudes.

Fixed-wing aircraft are faster than helicopters, and the larger the aircraft, the greater the payload. The general performance characteristics and dispersant capabilities for typical dispersant aircraft are presented in Table 4-3. The data in Table 4-3 were derived from a variety of sources, including aircraft operators, but much of the information was from Exxon (1992) and Ross (1998). The values presented in the table are not absolute, but represent reasonable estimates for well-maintained units operating at high efficiency. All fixed-wing aircraft have a limited endurance at a spill scene compared to vessels, and require more extensive infrastructure for their operation.

Dispersant spraying from multi-engine, fixed-wing aircraft has evolved from experience with modified crop-spraying aircraft (Lewis and Aurand, 1997), and is preferred in open-ocean areas because of safety issues involved with using single-engine aircraft over the sea. Robust, relatively slow aircraft, which can be used with limited support, are required, so the DC-3 and DC-4 are the most widely used aircraft for dispersant spraying. Both of these airframes, however, are very old and becoming difficult to maintain, and there are very few still operational in the United States. Because of this, a generic, next-generation spray plane, based on the P-3 airframe, has been included for comparative purposes in Table 4-3. Commercial versions of aircraft sharing the characteristics of a P-3 airframe are readily available for purchase from the private sector of the aviation industry.

It is expensive to maintain aircraft on standby, and the desire to use readily available aircraft, rather than specially equipped spray planes, led to the development of the ADDS pack. This unit can hold 147 bbls of dispersant and can be fitted rapidly inside a C-130 (Hercules) aircraft. Currently, three ADDS packs are commercially available for use in the United States—two in Alaska and one in Florida. The only commercially available C-130s, however, are based in Alaska.

Helicopter Systems. Helicopter systems, while not yet used in the United States, appear to be a mature technology and can be an effective application platform when equipped with a dispersant bucket and spray boom. They could be especially valuable in the Gulf of Mexico and other areas currently serviced by helicopters. Helicopter systems have many of the same limitations as fixed-wing aircraft, plus a lower payload and a shorter range. Recent work to develop larger dispersant buckets and the ability for reloading dispersants at sea demonstrates that the technology continues to improve.

Helicopters can be useful for smaller spills, provided an aircraft and a suitable support base are close to the site of the spill (Lewis and Aurand, 1997). As with fixed-wing aircraft, it is expensive to maintain dedicated dispersant-spraying helicopters. Helicopters equipped with rapidly mountable spray buckets could be effective in areas such as the Gulf of Mexico, where oil exploration and production activities pose a risk of oil pollution (Lewis and Aurand, 1997). Helicopters have a much higher transit speed than surface vessels, although the cruise speed of a helicopter has to be reduced to about 80 kts when carrying an externally slung load such as a full or empty spray bucket (Lewis and Aurand, 1997). The amount of dispersant that can be carried depends on helicopter type, but ranges from 7–21 bbls (Lewis and Aurand, 1997). The actual operational load depends on distance to a spill and prevailing conditions. This Caps review assumes an operational range of 50 nmiles offshore for these aircraft.

Brandvik *et al.* (1996) examine the possibility of refilling the bucket from tanks onboard a ship while a helicopter hovers above to decrease transit flights. This proved to be successful. Like all aircraft, helicopters can only conduct spraying operations in daylight hours with relatively good visibility and flying conditions.

In comparison to fixed-wing aircraft, helicopters can effectively deliver high quantities per acre relative to other aircraft because they can fly very slowly. This means that they have to reposition less frequently and therefore have a smaller repositioning factor (2). With a capacity of only 250 gals (Table 4-3), one helicopter can only treat 5 acres of 1-mm thick oil before returning to refill.

4.4.1.4 Assumptions for Vessels

Intuitively, vessel-based application systems will also be less than 100% effective, although the considerations are different than those for aircraft. In the case of surface vessels equipped with fire monitors (the basic case in this analysis), a vessel traveling at 5 kts can treat even thick slicks in one pass. In addition, its turning radius need not take it outside of the thick area of the slick, depending upon the width of the heavy oil. Therefore, the time to complete a turn is not important, but the travel time to move from one area of thick oil to another is important, because of the low transit speed (5 kts).

The reposition factor for vessels then, is the ratio of the distance traveled between spray locations versus the distance traveled within the thick oil. This is defined by the distribution of the oil within the slick, and the area over which the slick has spread. There is little information available in the literature on this subject, although it is possible to estimate the total surface area of slicks of various sizes, based on basic spreading calculations. For example, a 1,000 cubic meter slick (264,200 gallons) would occupy an area of approximately 3 square miles (Ross, 1998). Allowing for elongation of the slick in the direction of the wind, this becomes an area of two by 1.5 miles (1.73 by 1.30 nm). If, within this area, a spray vessel can travel 0.25 nm in thick oil and then must travel 1.0 nm to another patch, the repositioning factor would be 5.0. Alternatively, if the vessel could spray for 1.0 nm and then travel for 1.0 nm to the next patch, the factor would be 2.0.

Deciding on an accurate planning factor for vessels is more difficult than for aircraft. For vessels, turning time (i.e., maintaining position in the thick oil) is minimal compared to the time spent spraying, but the time spent moving from one patch to the next may be relatively large, depending on the size and distribution of thick oil. For this analysis, a factor of 4.0 was selected as a conservative intermediate value, which reflects the difficulty a vessel may have in traveling directly from one thick patch of oil to the next. The repositioning factor of 4 effectively means that in a vessel's 10-hour day, only 2.5 hours would actually be spent spraying. This factor is reasonable, but may be rather conservative, especially during the early phases of a response to a large spill where large patches of thick oil may be present in close proximity.

As was the case for helicopters, it is possible to make a strong case for a very low repositioning factor for vessels, especially for large slicks early in the spill when it may be possible for the vessel to maintain itself in thick oil for extended periods. For smaller spills, however, and for all spills later in the event, the patches will be more widely distributed and the repositioning time would likely be even higher.

4.4.1.5 Assessment for Vessel Application Systems

In many parts of the world, vessel-based application systems are a familiar means of dispersant application. Although rarely considered in the United States, vessel-based spray boom systems are a mature technology, and a wide range of vessels can be equipped for dispersant spraying, using either permanent or portable equipment. The major potential advantages of ship-based systems—their high payload capacity and long on-scene time—are counterbalanced by their slow transit and application speeds. Under the proper circumstances, these systems can be very effective.

Traditionally, ship systems consist of spray boom extended from the vessel's sides. More recently, the use of fire monitors (spray units originally designed to spray water or firefighting foam) has been used, both experimentally (Major and Chen, 1995) and operationally at the RED SEAGULL spill in the Gulf of Mexico (*Personal communication*, B. Stong, O'Briens Oil Pollution Service, Houston, TX, August 1998), to show that their deployment might be particularly beneficial since they have a much higher treatment capacity than conventional boom systems.

Some ships, such as standby vessels or tugs, can be permanently fitted with dispersant-spraying gear if they are used routinely near oil installations. The weight of these systems is low, and surface application systems can be stowed away so that they do not interfere with normal day-to-day operations. Other systems can be taken out of storage and rapidly deployed on vessels-of-opportunity (Lewis and Aurand, 1997). Some ships also have the load-carrying capacity to store large quantities of dispersant onboard for prolonged periods without excessive transportation costs

(Lewis and Aurand, 1997). It is even possible to use slightly modified fire monitors to apply dispersants effectively from ships (Major *et al.*, 1993; Ross, 1998).

Ship-based operations are limited because of the low transit speed (5–12 kts), as well as the low spraying speed (3–4 kts for boom-equipped vessels [Lewis and Aurand, 1997], 5–10 kts for vessels with fire monitors). Spraying speed is limited for boom-equipped vessels because the bow wave created by the ship pushes an oil slick out of the way. This is less of a consideration with fire monitors, which have a greater swath width.

Fire monitor-equipped surface vessels would be capable of delivering high concentrations of dispersant per acre, but move slowly relative to either helicopters or fixed-wing aircraft (see Table 4-3). At a speed of 5 kts and a swath width of 65 ft, a surface vessel with an appropriately configured fire monitor could treat approximately 45 acres in 1 hour at 40 gpm, much less than the potential pumping rate of 200 gpm per monitor. In contrast to aircraft systems, fire monitor-equipped vessels are more limited by the area that they can cover in a given period than by their application rate. If a surface vessel equipped with a boom system were used instead, its maximum pumping rate of 12 gpm would mean that the vessel would need to decrease its speed. The effective treatment rate would be reduced by a factor of 3, so that approximately 15 acres of 1-mm thick slick could be treated in 1 hour.

Storage capacity is another critical factor for vessels. Based on the dispersant delivery rate calculation in Table 4-3, that storage capacity must be at least 18,000 gals to allow a minimum of 3 days continuous operation without resupply.

In summary, ships make good spraying platforms because they have the capacity to carry a large amount of dispersant and can operate for prolonged periods. Ships also can operate in weather conditions that may preclude the use of spray aircraft and remain on-scene at night (although not spraying dispersant). They are slow compared with aircraft, and the time taken to reach a spill could mean that they would not reach a spill site until after the window of opportunity to use dispersants has closed. Spill incidents that happen close to major ports and harbors or where standby vessels are present for other reasons can be handled effectively by ship-based dispersant spray systems.

4.4.2 Assessment of Dispersants

Concern about ecological effects has been a driving force in the development of currently available dispersants that are specifically formulated to be low in toxicity. The dispersants likely to be used now on an oil spill in the United States are more effective and less toxic than those used 10 years ago. Several sources provide summary information on chemical composition (EPA, 1999 [National Contingency Plan Product Schedule]; Exxon, 1994; NRC, 1989). Early dispersant products were derived from petroleum-based engine room degreasers and were often very toxic. Efforts to develop less toxic, more effective formulations began in the early 1970s and resulted in modern dispersants that are significantly improved in both areas. Modern dispersants contain one or more nonionic surfactants (15–75% of the total formulation), sometimes an anionic surfactant (5–25% of the formulation), and one or more solvents. The purpose of the solvent is to dissolve any solid surfactant and reduce viscosity so that dispersant can be sprayed effectively. In most modern dispersants, solvents are glycols (similar to those used in anti-freeze), and surfactants are similar to those used in laundry detergents (Gilfillan, 1993).

Historically, the window of opportunity for dispersant use has been considered to be several hours or perhaps a day, depending on the oil. This window of opportunity was based on observations that older dispersants tended to be effective only if the viscosity of the oil (or emulsion) did not exceed 2,000–5,000 centistokes (cSt) (NRC, 1989). Recent experiments in the North Sea (Brandvik *et al.*, 1996; Lewis *et al.*, 1998; Lunel and Davies, 1996) show that modern dispersants can be effective on weathered and heavy oils, as well as fresh, light crude oils at much higher viscosities (perhaps several times higher), thereby extending the opportunities (oil type and time after the spill) for use. Any estimate of dispersability, however, is dependent on oil type and environmental conditions. Under the proper circumstances, dispersion efficiencies for individually treated patches of dispersible oil may approach 90–100%. Often, only sheen will remain after treatment. The overall efficiency for a particular spill depends on a variety of factors, including weather, oil type, time since spill occurred, and encounter rate. While it may be feasible to continue to improve dispersant performance, many of the existing formulations are quite effective.

The size of dispersant stockpiles depends on assumptions that are made concerning dispersant effectiveness. Early recommendations were for a DOR of one part concentrated dispersant to ten parts oil. Recent field experiments demonstrate that much lower ratios may be effective (Lewis *et al.*, 1998). If the oil is of low viscosity, such as a lightly weathered crude oil, or if the sea is rough, then an even lower DOR (1:50 or 1:100 or even less) may be effective. High viscosity oils such as Bunker C/No. 6 fuel oil (especially at low temperature), or crude oils that are waxy or have weathered into highly stable, high viscosity water-in-oil emulsions, will not disperse even when much higher treatment rates of dispersant (such as DOR of 1:10) are applied (Lewis and Aurand, 1997).

Given the increased effectiveness of dispersant formulations, the infrequency of large spills, and the continued cautious approach to dispersant use in the United States, establishing a DOR of 1:20 for the purposes of planning for a large spill is appropriate. This will ensure availability of sufficient dispersant stockpiles to treat smaller spills at higher DORs if effectiveness monitoring during an incident indicates additional treatment applications are appropriate. A higher DOR of 1:10 would set an expectation that dispersants would be applied at that rate initially, possibly resulting in frequent overdosing and inefficient use. Operationally, applying at the lower DOR (1:20) accommodates reapplication to portions of the slick not fully dispersed on the first pass.

Dispersant stockpiles need to be stored as close as possible to where it may be used, but only general locations (based on probabilities) can be determined. The best option is to distribute dispersants regionally near transport facilities so that they can be moved rapidly to where needed. Dispersant manufacturers offer rapid resupply of significant quantities of dispersant in the event of an oil spill. This can reduce the size of the stockpile needed, but it makes resupply a more important issue. The nature of the oil likely to be spilled also must be considered to ensure that resupply is rapid enough to meet the window of opportunity.

4.4.3 Assessment of Command, Control, Coordination, and Intelligence (C3I)

U.S. policy (40 CFR 300) supports the use of an Incident Command System (ICS) to manage oil spill response operations. Hanzalik and Hereth (1997) discuss adapting ICS to accommodate dispersant operations. They suggest modifying the operations and planning sections of contingency and response plans to specify the functions necessary to plan and execute dispersant operations. EPA Region III currently is working with the National Response Team to develop a dispersant use protocol as a template for use around the country. The protocol will provide summary information on the dispersant-use decision process and identify types, locations, and availability of dispersant stockpiles and dispersant application equipment in the region.

Once a dispersant operation is implemented, operational management systems must be adequate to control, monitor, and evaluate the operation effectively. If multiple aircraft or other application platforms are involved, the operation can be complex. Many of the general planning requirements for dispersant operations are similar to those for mechanical recovery, but must be adapted to deal with the issues of effective application and monitoring dispersant effectiveness.

There are two reasons to try to monitor dispersant operations: (1) to determine the efficiency of the operation and (2) to determine if there are adverse ecological consequences occurring in areas exposed to dispersed oil. Pond *et al.* (1997) review the issues related to dispersant use monitoring (efficiency) and data gathering to estimate effects during response operations. For monitoring to be of any value during an actual spill response, information must be available to decision makers in a near real-time basis, and there must be criteria against which the results can be compared to guide decisions concerning continued operations. To confirm dispersant has contacted and is dispersing oil, monitoring is an important part of any dispersant spraying operation, but can be difficult. It is important to know if it is worth starting to spray dispersant, if spraying should continue, and if it is time to stop (either because the dispersant has stopped working or because oil is already dispersing at a rapid rate) (Lewis and Aurand, 1997).

The best method currently available to provide the least ambiguous indication of dispersant effectiveness on-scene is visually through airborne surveillance and empirically through UV fluorescence detectors positioned in the water column and operated from a boat (Lewis and Aurand, 1997). Procedures for this have been developed and are detailed in the Scientific Monitoring of Advanced Response Technologies (SMART) protocol (USCG *et al.*, 1998). If a boat is positioned in a slick before a test dispersant spray, it will be able to record the background oil concentration (caused by natural dispersion) and record the increase after dispersant has been sprayed. The fluorescence readings must be calibrated against laboratory analyses to be quantitative. These readings do not provide any information on classes of compounds, but they are very valuable as an indicator of effectiveness. Typically, values will rise from background levels of 0.1 ppm or less before dispersant spraying to more than 5 ppm, and possibly up to 30–50 ppm near the surface, immediately after spraying (Lewis and Aurand, 1997; Lunel *et al.*, 1996). The actual peak concentration depends on the amount of oil dispersed and the dilution rate. These results cannot be used to calculate an overall mass balance accurately because they are made at only one point in the slick. They can be used, however, to indicate unambiguously that the dispersant has or has not produced the required effect and when a dispersant becomes less effective because of oil weathering. Currently, either the Special Response Operations Monitoring Program (SROMP) or SMART would be implemented during any major dispersant operation.

Effectiveness monitoring in accordance with the SMART protocol (USCG *et al.*, 1998), is practicable and has been successfully implemented during several dispersant response operations. Because visual and fluoremetry monitoring can be performed in “real-time,” these monitoring results can be used by responders in determining whether to continue dispersant operations. Effects data collection during an incident—including water sampling for chemical characterization and toxicity testing—can be used to analyze effects retroactively. Because effects monitoring technology does not provide immediate, usable data, effects monitoring cannot be used by responders in determining whether to continue dispersant operations. These data may be useful, however, in adjusting contingency and response plans in anticipation of future incidents.

The existing command and control structure in the United States is adequate and appropriate to support the current level of dispersant operations. If the frequency and intensity of operations were to increase, however, there would be some areas in need of improvement or expansion: the availability of remote-sensing systems, air traffic control systems, and monitoring equipment, and the ability to integrate extended real-time data flow into the management structure.

4.4.4 Relationship of Dispersant Use to Other Oil Removal Options

In the United States, dispersant use usually has been an alternative or supplement, and usually secondary to mechanical recovery because of environmental concerns. While this may be true under certain circumstances, it is more appropriate to view mechanical recovery and dispersant application as complementary because each technique offers opportunities to achieve response objectives. Each also has different requirements for success. The optimal approach is to develop a flexible planning strategy that integrates all available response options within the constraints and opportunities of a particular spill scenario.

4.5 AVAILABILITY ASSESSMENT

4.5.1. Application Systems

Many different manufacturers produce dispersant-spraying equipment (Tables/Figures B-11 and B-12, Appendix B). Dispersant application equipment is available from a number of suppliers, and commercial availability has increased since 1993. Many types and numbers of fixed-wing aircraft are potentially available for dispersant operations, but only a few are currently being used. At this time, dispersant application aircraft is provided by Airborne Support, Inc. (ASI), which has one DC-4 and two DC-3s available (Table 4-4). ASI has a contract with Marine Industry Resources Gulf (MIRG), which has contracts with MSRC, National Response Corporation (NRC), and various cooperatives around the country. ASI aircraft operate out of Houma, Louisiana and are obligated to be loaded with dispersant and ready to deploy on 3-hours notice. On-station time depends on spill location.

TABLE 4-4. Contracted Dispersant Application Platforms and Equipment.

	LOCATION	**QUANTITY**
SHORT-RANGE AIRCRAFT*	Valdez, AK	2
	Fairbanks, AK	1
	Oxnard, CA	5
	Perkasic, PA	1
	Coolidge, AZ	1 (AT-802)
	Palmer, AK	1 (Thrush-cropduster)
VESSELS	Valdez, AK	2 (OSRVs)
	Long Beach, CA	1 (OSRV)
	Slaughter Beach, DE	1 (OSRV)
LONG-RANGE AIRCRAFT	Anchorage, AK	1 (C-130)
	Houma, LA	1 (DC-4)
	Houma, LA	2 (DC-3)
EQUIPMENT	Nikiski, AK	3 (Helio-buckets)
	Valdez, AK	2 (Helio-buckets)
	Slaughter Beach, DE	1 (Helio-bucket)
	Long Beach, CA	1 (Helio-bucket)
	Carpinteria, CA	2 (Helio-bucket)
	Kapolei, Oahu, HI	2 (Helo Spray bucket)
	Alice, TX	2 (Helio-bucket)
	New Iberia, LA	1 (Helo Spray bucket)
	Anchorage, AK	2 ADDS Pack
	Alice, TX	1 ADDS Pack

Note: OSRV, oil spill recovery vessel; ADDS pack, Airborne Dispersant Delivery System pack.

* Helicopters unless otherwise noted.

Source: Table was compiled from personal communication with service providers.

In Alaska, aircraft support to SERVS is provided by Lynden Air Cargo, which maintains one C-130 on charter in Anchorage. SERVS owns two ADDS packs (*Personal communication*, G. Merrell, SERVS, Valdez, AK, March 1999). Cook Inlet Spill Prevention & Response, Inc. (CISPRI) contracts with Glen Air in Palmer for a Thrush-cropduster with a 500-gal dispersant capacity. CISPRI also receives short-range aircraft support from Kenai Air in Kenai and Air Logistics of Alaska in Valdez and Fairbanks, which can provide helicopters (*Personal communication*, D. Letsch, CISPRI, Cook Inlet, AK, February 1999).

Table 4-5 lists additional aircraft that might be suitable for dispersant application work. It includes both short-range (helicopters and air tractors) and long-range (DC-4, DC-6, and C-130) aircraft. A total of 4 long-range aircraft and 243 short-range aircraft could be available relatively quickly for response operations. The locations of all contracted or identified aircraft are shown in Figures C-1 and C-2 (Appendix C).

Based on this information, the potential for available delivery platforms is adequate for the level of activity (i.e., relatively small spills occurring infrequently) likely to occur, particularly in the Gulf of Mexico, California, and Alaska. However, while many suitable platforms are available, most are not maintained in a state of readiness or contracted to perform this function at this time.

Helicopters that are potentially suitable for dispersant application are widely distributed in the United States but have not been used. At the present time, there are few contracts for helicopter support in the continental United States and in Alaska (Table 4-4). In the Gulf of Mexico, the total helicopter population exceeds 600 units, but no attempt has been made to identify how many of these models could be used for dispersant application, or what would be necessary to make them available (*Personal communication*, C. Thayer, Petroleum Helicopters Inc, Lafayette, LA, January 1999). The general distribution of these units is shown in Table 4-5. There are several dispersant buckets available in the lower 48 states (Table 4-4); in Alaska, CISPRI owns one 250-gal and two 350-gal buckets, and SERVS owns two 200-gal buckets (*Personal communication*, G. Merrell, SERVS, Valdez, AK, January 1999).

Surface vessels that are suitable for dispersant application are widely distributed in the United States. According to the USCG, many offshore supply vessels and OSRVs, particularly in the Gulf of Mexico, have fire monitors, and most others could be equipped with them relatively easily (Table 4-6). In addition, many other vessels are capable of being retrofitted with monitors, and a wide range of tugs and fireboats also are available in major port areas that already have or could be equipped with fire monitors. Vessels equipped with spray boom arms are much less common, although fitting commercially available systems onto support vessels is relatively inexpensive. A few such vessels were identified in the United States (Table 4-4); in Alaska, SERVS operates two vessels equipped with spray systems, and CISPRI owns a marine vessel boom spray system but no longer has a suitable vessel (*Personal communication*, D. Letsch, CISPRI, Cook Inlet, AK, February 1999). The distribution of contracted and identified dispersant-capable vessels is shown in Figure C-3 (Appendix C).

TABLE 4-5. Identified Dispersant Application Platforms.

	LOCATION	QUANTITY
SHORT-RANGE AIRCRAFT*	Santa Barbara, CA	3
	Lompoc, CA	2
	Santa Maria, CA	1
	Camarillo, CA	1
	Fairbanks, AK	1
	Kenai, AK	1
	Venice, LA	22
	Houma, LA	20
	Morgan City, LA	60
	Intracoastal City, LA	100
	Sabine, TX	15
	Fort Lauderdale, FL	6
	Olympia, WA	3
	Whitefield, ME	2
	Rigby, ID	2 (AT-802)
	Fort Pierce, FL	1 (AT-802)
	Mer Rouge, LA	2 (AT-802)
	Rosenburg, TX	1 (AT-802)
LONG-RANGE AIRCRAFT	Mesa, AZ	1 (DC-4)
	Anchorage, AK	3 (C-130)

* Helicopters unless otherwise noted.

Source: Table was compiled from personal communication with service providers.

TABLE 4-6. Identified Dispersant Application Vessel Platforms.

	PORT LOCATION	QUANTITY
OFFSHORE SUPPLY VESSEL	Anchorage, AK	2
	Corpus Christi, TX	6
	Galveston, TX	31
	Hampton Roads, VA	1
	Houston, TX	12
	Jacksonville, FL	1
	Los Angeles, CA	6
	Memphis, TN	1
	Miami, FL	1
	Mobile, AL	18
	Morgan City, LA	556
	New Orleans, LA	73
	New York City, NY	1
	Port Arthur, TX	41
	Valdez, AK	3
OIL RECOVERY VESSEL	Astoria, OR	1
	Cape May, NJ	1
	Corpus Christi, TX	1
	Edison, NJ	1
	Everett, WA	1
	Fort Jackson, LA	1
	Galveston, TX	2
	Hampton Roads, VA	1
	Honolulu, HI	1
	Houston, TX	1
	Ingleside, TX	1
	Lake Charles, LA	1
	Los Angeles, CA	8
	Miami, FL	2
	Morgan City, LA	1
	New Orleans, LA	1
	New York City, NY	2
	Philadelphia, PA	4
	Port Arthur, TX	1
	Port Hueneme, CA	1
	Portland, ME	1

Continued

TABLE 4-6. Identified Dispersant Application Vessel Platforms (*Continued*).

	PORT LOCATION	QUANTITY
OIL RECOVERY VESSEL (*Continued*)	Portland, OR	2
	Richmond, CA	1
	Salem, NJ	1
	San Francisco, CA	6
	San Juan, PR	1
	Savannah, GA	1
	Seattle, WA	6
	St. Croix, VI	1
	Tampa, FL	1
	Valdez, AK	5
	Virginia Beach, VA	1

Source: Table was compiled from personal communication with service providers.

4.5.2 Dispersant Stockpiles and Supporting Equipment

At present, only four dispersant products are listed on the National Contingency Plan Product Schedule, which is maintained by the U.S. Environmental Protection Agency (EPA, 1999) (Table 4-7). Being listed is a requirement for use in the United States. Only the two COREXIT products are widely available. Both have been studied extensively with respect to performance and toxicity.

TABLE 4-7. National Contingency Plan Product Schedule.

PRODUCT NAME	SUBMITTER	DATE LISTED	DATE RELISTED	PRODUCT TYPE
COREXIT 9527	Nalco/Exxon Energy Chemicals, LP	03/10/78	12/18/95	Dispersant
NEOS AB 3000	NEOS Company Limited	04/22/85	01/26/96	Dispersant
MARE CLEAN 200	Taiho Industries Co., Ltd.	02/23/88	01/26/96	Dispersant
COREXIT 9500	Nalo/Exxon Energy Chemicals, LP	04/13/94	12/18/95	Dispersant

Source: EPA (1999).

To maintain an effective dispersant response, there must be adequate supplies and equipment to sustain the operation. Given the length of the U.S. coastline, this becomes a critical issue, as do the logistics and maintenance issues associated with resupply and application. Table 4-8 presents currently available dispersant stockpiles throughout the United States, including Alaska. The general location of these stockpiles and the volumes available are shown in Figures C-4 and C-5 (Appendix C). Dispersant stockpiles are widely distributed, with the largest volume available in the Gulf of Mexico. Material is stored in drums, tank trucks, bulk storage, or tanks onboard response vessels. The method of storage is a critical factor in issues of resupply. The manufacturer of COREXIT can produce either COREXIT 9527 or 9500 in volume with 4–5 days lead time. Rates could be as high as 50,000 gals per day.

Based on the information available dispersant stockpiles are adequate for the level of activity (i.e., relatively small spills occurring infrequently) likely to occur, particularly in the Gulf of Mexico, California, and Alaska. Most areas can obtain sufficient dispersant to treat spills of at least 10,000 bbls (in some cases higher) with existing supplies in the general geographic vicinity (e.g., California, Gulf of Mexico, Alaska, etc.). Available equipment and supplies, however, would be heavily taxed if a very large spill in excess of 20,000 bbls that was suitable for dispersant application were to occur. Supporting a dispersant operation on the East Coast or in Washington/Oregon would be possible only if equipment and some supplies could be moved in from other parts of the country within the window of opportunity. An increased reliance on dispersants would mean that existing stockpiles would need to be expanded, and possibly additional sites established, depending on the nature of the requirement. There is no indication that obtaining additional equipment and supplies necessary to support an expanded dispersant capability would be difficult.

TABLE 4-8. Dispersant Stockpile List*.

ORGANIZATION	LOCATION OF DISPERSANT	TYPE OF DISPERSANT	AMOUNT (GALS)	EPA LISTED†	USCG DISTRICT
MSRC	Edison, NJ	COREXIT 9527	24,750	Yes	1st
A Clean America	Yorktown Heights, NY	COREXIT 7664	330	Yes	1st
Delaware Bay & River Cooperative	Slaughter Beach, DE	COREXIT 9527	1,650	Yes	5th
Clean Harbors	Stored at Clean Venture, NJ	COREXIT 9527	13,750	Yes	5th
NRC	Ft. Lauderdale, FL (at San Juan, PR)	COREXIT 9527	3,780	Yes	7th
CCC	Ft. Lauderdale, FL Ft. Lauderdale, FL Ft. Lauderdale, FL	COREXIT 9527 COREXIT 9527 COREXIT 9500	6,985 5,000 18,425	Yes Yes Yes	7th
Clean Gulf Associates‡	Houston, TX Houma, LA	COREXIT 9527 COREXIT 9527	28,985 5,665	Yes Yes	8th
LOOP, Inc.‡	Houma, LA Galiano/Fourchon, LA	COREXIT 9527 COREXIT 9527	24,000 5,665	Yes Yes	8th
Nalco/Exxon Energy Chemicals, L.P.§	Sugar Land, TX	COREXIT 9500	27,500	Yes	8th
Nalco/Exxon Energy Chemicals, L.P.§	Sugar Land, TX	COREXIT 9500	27,500	Yes	8th
Abasco Environmental Services§	Sugar Land, TX	COREXIT 9500 COREXIT 9527	21,614 2,750	Yes	8th
MIRG	Houma, LA (ASI)	COREXIT 9527	16,445	Yes	8th

Continued

TABLE 4-8. Dispersant Stockpile List* (*Continued*).

ORGANIZATION	LOCATION OF DISPERSANT	TYPE OF DISPERSANT	AMOUNT (GALS)	EPA LISTED†	USCG DISTRICT
Clean Seas	Carpinteria, CA	COREXIT 9527	20,405	Yes	11th
		COREXIT 7664	1,335	Yes	
Clean Seas Cooperative	Carpinteria, CA	COREXIT 9527	9,000	Yes	11th
	Carpinteria, CA (Cooperative use only)	COREXIT 9527	11,000	Yes	
Clean Bay Cooperative	Richmond, CA	COREXIT 9527	14,740	Yes	11th
Clean Coastal Waters, Inc.	Long Beach, CA	COREXIT 9527	5,775	Yes	11th
Clean Sound Cooperative, Inc.	Ferndale, WA	COREXIT 9527	6,250	Yes	13th
Clean Islands Council	Honolulu, HI	COREXIT 9500	4,400	Yes	14th
	Oahu, HI	COREXIT 9527	3,080	Yes	
Cook Inlet	Nikiski, AK	COREXIT 9550	2,255	Yes	17th
	Nikiski, AK	COREXIT 9527	9,295	Yes	
	Anchorage, AK	COREXIT 9527	11,275	Yes	
Alyeska/SERVS	Anchorage, AK	COREXIT 9527	9,240	Yes	17th
	Anchorage, AK	COREXIT 9527	60,000	Yes	
	Valdez, AK	COREXIT 9527	6,000	Yes	
CISPRI	Nikiski, AK	COREXIT 9527	9,405	Yes	17th
	Nikiski, AK	COREXIT 9550	2,255	Yes	
	Anchorage, AK	COREXIT 9527	11,275	Yes	

Note: gals, gallons; EPA, U.S. Environmental Protection Agency; USCG, U.S. Coast Guard; MSRC, Marine Spill Response Corporation; NRC, National Response Corporation; CCC, Clean Caribbean Cooperative; MIRG, Marine Industry Resources Gulf; CISPRI, Cook Inlet Spill Prevention & Response, Inc.

* USCG National Strike Force Coordination Center oil spill removal organization (NSFCC OSRO) Database.

† "Yes" denotes that the dispersant is listed on the National Contingency Plan Product Schedule.

‡ Clean Gulf and LOOP dispersant is with Airborne Support, Inc. (ASI).

§ TS Abasco is Exxon's exclusive distributor, only half available for emergencies.

Source: Based on *Personal communication*, D. O'Donovan (MSRC, Washington, DC, September 1998) and National Contingency Plan Product Schedule (EPA, 1999).

4.6 DEPLOYABILITY ASSESSMENT

Table 4-9 summarizes information on dispersant pre-authorization status in the coastal United States as it changed from 1990 to 1998 (Walker *et al.*, 1999; also see Figure D-1 in Appendix D). As can be seen, there has been a dramatic increase in the number of areas with some type of pre-authorization over the past 8 years. Dispersant use may be a viable option in almost any area of the United States, provided geographic and depth criteria are met. With the exception of California, relatively conservative criteria have been established for pre-authorization zones. These criteria are based on ensuring adequate mixing and water depth to minimize any threat to benthic or water column biological resources from exposure to dispersed oil, and that the undiluted dispersed oil plume is unlikely to contact the shoreline. As a result, dispersant use planning effectively is limited to offshore waters, usually 3 nmiles from shore, in water depths of at least 30 ft. In one instance—the Big Stone Beach lightering area at the mouth of Delaware Bay—dispersants are pre-authorized in an “estuarine situation” because of the high risk associated with surface oil impacts in the Delaware Bay. Most states/regions have dispersant use protocols in non-preauthorization areas, but these options usually are viewed as too time-consuming to be effective, given the need for rapid response.

4.6.1 Policy Considerations

In California, relatively deep water very close to shore, often turbulent environmental conditions offshore, and concern over consequences of oiling the coastline have led to the development of an expedited approval process for spills occurring greater than ½ nmile from shore (minus several exclusion zones). This is designed to result in a decision within 2 hours for the entire region. In theory, this approach significantly broadens the options available in that region, but the decision mechanism has yet to be fully demonstrated. The result is that the entire coastline of the United States, except for Connecticut, Oregon, and Washington, is covered by an expedited approval or pre-authorization agreement signed by government responders.

In regions where pre-authorization exists, the Federal On-Scene Coordinator (FOSC) is given authority to direct the use of dispersants without further consultation under certain circumstances. In practice, FOSCs, state OSCs, and resource trustees in regions where these agreements have been signed agree that:

- The FOSC is expected to provide advance notice of any intended dispersant operations.
- Dispersant operations will not commence or continue if any objection is raised by the state OSC or resource trustees.

TABLE 4-9. Dispersant Pre-Authorization Status in Coastal Areas of the United States in 1990, 1994, and 1998.

REGION*	**1990**	**1994**	**1998**
I – New England	Case-by-case only in entire region. No formal plan.	Case-by-case only in entire region. No formal plan.	Portland, ME Area Pre-Approval Policy (for Maine and New Hampshire) and Boston, MA Area Pre-Approval Policy (for Massachusetts and Rhode Island) give FOSC and state OSC discretion > 2 nmiles from shore. Consultation required from ½ to 2 nmiles. Case-by-case < ½ nmile. Case-by-case only in Connecticut.
II – Northeast	Case-by-case only in entire region. No formal plan.	Pre-authorization	Region II MOU (including addendum of May 1996) gives FOSC discretion > 3 nmiles from shore. Trial application can be made > ½ nmile. Applies only to south shore of Long Island, not to Long Island Sound.
III – Mid-Atlantic	Case-by-case only in entire region. No formal plan.	Expedited approval.	Region III MOU and Philadelphia, PA COTP MOU give FOSC discretion > 3 nmiles from shore. Test applications > ½ nmile from shore. Case-by-case elsewhere. Dispersant use also authorized at Big Stone Beach Lightering Area in Delaware Bay.
IV – Southeast	Case-by-case only in entire region. No formal plan.	Pre-authorization in Florida.	Region IV MOU gives FOSC discretion >3 nmiles from shore and > 33 ft depth, with exclusions for special federal management areas and designated exclusion areas. Case-by-case elsewhere. In Florida, water depth must be 65 ft.
IV – U.S.	Case-by-case only in entire region. No	Pre-authorization.	Pre-authorization.

Caribbean	formal plan.		
VI – Gulf Coast	Case-by-case only in entire region. No formal plan.	Pre-authorization plan for entire region > 3 nmiles from shore and > 33 ft depth, with minor exclusions	Pre-authorization plan for entire region > 3 nmiles from shore and > 33 ft depth, with minor exclusions. Case-by-case elsewhere
IX – California Coast	Case-by-case only in entire region. No formal plan.	Expedited approval.	Expedited approval process beyond ½ nmile from shore. Approval within 2 hours via one conference call.
X – Pacific Northwest	Case-by-case only in entire region. No formal plan.	Case-by-case. Pre-authorization plan cannot be implemented without state-approved monitoring protocol.	Case-by-case. Pre-authorization plan cannot be implemented without state-approved monitoring protocol.
Oceania	Case-by-case only in entire region. No formal plan.	Pre-authorization.	Pre-authorization.

Note: FOSC, Federal On-Scene Coordinator; nmile, nautical mile; MOU, Memorandum of Understanding; COTP, Captain of the Port.

* Federal (EPA) regions are defined as follows: I – New England (Connecticut, Rhode Island, Massachusetts, New Hampshire, Vermont, Maine), II – Northeast (New York, New Jersey), III – Middle Atlantic (Delaware, Maryland, Virginia), IV – Southeast (North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi), IV – U.S. Caribbean (Puerto Rico, U.S. Virgin Islands), VI – Gulf Coast (Louisiana, Texas), IX – California (California), X – Pacific Northwest (Oregon, Washington), Alaska, and Oceania (Hawaii, Guam).

Source: Adapted from Walker *et al.* (1999).

In California, the expedited approval process indicates a commitment on the part of the state OSC and resource trustees to respond quickly if dispersant use potential exists:

- The FOSC *must* provide advance notice of any dispersant operation.
- Dispersant operations will not commence or continue if any objection is raised by the state OSC or resource trustees.

If a contacted agency does not issue an objection within 2 hours, then concurrence is presumed. In recent years, the Region IX response community has been nearly as aggressive as Region VI in developing a dispersant use policy. Region IX is pushing the expedited approval boundary to within ½ nmile from shore, as well as assessing environmental tradeoffs between dispersant use and other response methods even closer to shore.

4.6.2 Potential For Use

Chapter 2 reviews the history of spills 1,000 gals or greater in the United States from 1993 to 1998. Criteria roughly approximating existing pre-authorization (see Section 4.6) indicate that 21% (49 of 231) of all spills in the data set that occur in nearshore and offshore waters may be candidates for dispersant use. If pre-authorizations were extended to within ¼ nmile from shore and 10 feet or more water depth, 45% (103 of 231) of all spills in the data set would be candidates for dispersant use.

Kucklick and Aurand (1995) report similar findings. They review oil spills 1,000 bbls or more in the coastal and offshore waters of the United States (excluding Alaska) from January 1973 through June 1994. They identify 321 reported spills, but could obtain adequate data on only 207 of those (69 crude oil spills and 138 refined oil spills). Using the existing criteria described in Chapter 2 of this report (roughly equivalent to existing pre-authorization zones of greater than 3 nmiles from shore), only 6% (13 of 207) of all spills in Kucklick and Aurand's data set were candidates for dispersant use. Using the expanded criteria (spills greater than ¼ nmile from shore and 10 ft or more water depth), 28% (60 of 207) of all spills in that data set would be potential dispersant use candidates. The authors conclude that restricting dispersant use to offshore areas significantly limits the potential for use throughout the United States, except for the Gulf of Mexico, which has the greatest number of spills.

Based on the data from Chapter 2 and Kucklick and Aurand (1995), if dispersant use consideration is limited to pre-authorization areas (greater than 3 nmiles from shore), then:

- Candidate spills 1,000 bbls or greater may occur approximately once per year.
- Candidate spills 1,000 gals or greater may occur approximately 5 times per year.
- The greatest percentage of candidate spills will occur in the Gulf of Mexico (8th USCG District).
- Candidate spills 1,000 gals or greater may occur in any region of the country in a given year.

If dispersant use consideration is expanded to ¼ nmile from shore and 10 ft of water, then:

- Candidate spills 1,000 bbls or greater may occur approximately 3 times per year.
- Candidate spills 1,000 gals or more may occur approximately 20 times per year.
- The greatest percentage of candidate spills will occur in the Gulf of Mexico (8th USCG District).
- Candidate spills may occur in any region of the country in a given year.

4.6.3 Geographic Considerations

In this section, information developed in the preceding sections is examined in the context of the likelihood of dispersant use in various geographic regions. This information, in turn, is used to make a recommendation concerning the feasibility and nature of a mandatory dispersant capability in such locations. For each geographic area, the following topics are discussed:

- Policy and planning issues
- Environmental issues
- Equipment and logistics issues

Finally, the section concludes with a discussion of the dispersant capability necessary to respond to various spill scenarios.

4.6.3.1 Offshore (> 3 nmiles from shore)

Policy and Planning Issues. Based on the information in Table 4-9, dispersant use is pre-authorized (i.e., at the discretion of the FOSC) in offshore zones throughout the United States except in Washington and Oregon (where case-by-case consultation is required) and California (where expedited approval through a single conference call is needed). There are localized variations based on water depth requirements or location of sensitive resources, but these are relatively minor. Data on spill location and frequency identified by Kucklick and Aurand (1995) indicate that spills in this area are infrequent. These data do not include all spills, but they indicate that only one or two spills (or less) greater than 1,000 bbls are likely to occur annually in this region. Some regions of the country (e.g., the Washington/Oregon coast) did not have a spill of this size offshore in the 25 years for which data was examined; two occurred from Maine to North Carolina and three from South Carolina to Florida. Most of the spills identified offshore occurred in the Gulf of Mexico, California, or Hawaii. The spill size is very variable. Of the 13 identified by Kucklick and Aurand (1995), eight were less than 10,000 bbls. The largest spill was nearly 240,000 bbls. The fact that these spills were identified as candidates for dispersant use does not mean that such a response would be likely. In several cases, the spills posed no threat to land or resources. Based on the 1993–1998 data in Chapter 2 (spills over 1,000 gals), the number of candidate spills annually increases to approximately five per year. The most probable location is still the Gulf of Mexico, but they occur nationwide.

While the likelihood of an offshore spill in any part of the United States is low, spills do occur and vary widely in size and type of oil. The regulatory structure is in place to permit timely use of dispersants offshore throughout most of the United States, including California, where an expedited approval process should be effective.

Environmental Issues. Environmental issues in the pre-approval areas of this geographic zone have been resolved by restricting the extent of the offshore zone to areas where mixing should be adequate to ensure rapid dilution of the dispersed oil to concentration levels that are not considered to represent an environmental risk. This determination is independent of oil type and anticipated spill size, and based on a conservative consensus by decision makers in various planning areas that they are irrelevant given the potential for dilution within the pre-authorization zone. Exclusion zones or "setbacks" around sensitive resources are used to provide additional protection for high-value natural resources in some areas. In planning areas with pre-authorization, an informal, very conservative risk assessment has been conducted, concluding that the rate of dilution makes the risk of water column effects so low that they can be discounted in the decision process. Based on the field and laboratory data discussed in Section 4.1.4, this conclusion appears reasonable. It is not, however, one that is accepted nationwide, probably because the assumptions concerning risk have not been explicitly examined, and the consequences of using or not using dispersants not directly compared.

Equipment and Logistics Issues. Historically, mechanical recovery efficiency in offshore spills has been consistently low. Given the limitations of mechanical recovery technology, it is unlikely that mechanical recovery by itself will be able to provide the level of protection necessary to successfully prevent the oiling of our coast during a large spill. If a threat to the shoreline or other sensitive resources from an open-ocean spill is perceived, then dispersants become an attractive option. This is particularly true as spill size increases. Action must be taken promptly before oil spreads, leaves the pre-authorization zone, or weathers to an extent that will inhibit dispersion.

The equipment for dispersant application currently available in the United States is largely based on the assumption that any likely scenario will involve application to a (relatively large) spill offshore using fixed-wing aircraft. There is some other equipment stockpiled in the United States (see Table 4-4), but it is not extensive (4 dispersant-spraying, boom-capable OSRVs and 13 helicopter buckets). The primary response capacity (two DC-3s and one DC-4 in the Gulf of Mexico) would be heavily stressed by any significant spill. Based on the information presented in Table 4-3, it would only be reasonable to rely on helicopters for small spills near support facilities (based on number of sorties required, application rate, and/or transit time). Vessels could be used effectively if they (1) have sufficient payload or can be resupplied effectively and (2) are close enough to the spill scene to respond within the required time. This would be most practical in the Gulf of Mexico and portions of California where the presence of offshore oil facilities and large numbers of support vessels offer a widely distributed support base. In other planning areas, aircraft are more likely to be the only effective option.

The most compelling issue is determining the size of the resource stockpile and the level of response capacity that might be needed. Based on historical analysis, large spills are rare but do occur.

Spills are not evenly distributed, however, and there are parts of the country that rarely, if ever, have spills more than 3 nmiles offshore. Throughout the United States, refined oil spills are more likely than crude oil spills. Crude oil spills are a significant portion of the total only in the Gulf of Mexico. The relative frequency of both types of spills must be considered when estimating needed stockpiles. Some refined products are more difficult to disperse, and this should be considered in estimating needed stockpiles. Also, environmental concerns may be higher for some types of refined products. Any response capability needs to reflect these limitations.

4.6.3.2 Nearshore (¼ to 3 nmiles from shore)

Policy and Planning Issues. Dispersant use is generally restricted nearshore, but there are exceptions (Table 4-9). In California, the expedited procedures zone covers this entire area with noted exclusion zones. In Region I, pre-authorization exists beyond 2 nmiles from shore, and consultation is required between ½ and 2 nmiles. In Regions II and III, "trial" applications can be made at greater than ½ nmile from shore.

Data on spill location and frequency indicate that there are more spills closer to shore. The data from Kucklick and Aurand (1995) suggest that most spills were between ¼ and ½ nmile from shore and/or in 10–30 ft of water. In total, this accounted for 51% of crude oil and 18% of refined oil spills analyzed, with the remaining spills being less than ¼ nmile offshore and/or in less than 10 ft of water, or in estuaries.

The Caps review data show a much higher proportion of refined oil spills than Kucklick and Aurand's data (1995) (93% versus 67%), which can be attributed to the inclusion of many more small spills in the Caps review (down to 24 bbls instead of 1,000 bbls) that tend to be more refined product. As can be seen in Figure 2-5, in the 5-year period analyzed, crude oil spills were identified only in the following USCG Districts: 5th (New Jersey to North Carolina), 8th (Texas and Louisiana), 14th (Hawaii), and 17th (Alaska). The other four districts recorded only refined product spills, and even in the districts where crude oil spills occurred, there were many more refined product spills. In Kucklick and Aurand (1995), this same trend was observed but less pronounced. In that study's 20-year period, however, all districts reported at least one crude oil spill.

As detailed in Chapter 2, moving within ¼ nmile of shore and decreasing the depth requirement to 10 ft would increase the opportunities for dispersant use. The spills identified vary widely in size. Most are small, and the majority are refined oil spills. In some areas of the country, the prevalence of refined product spills is overwhelming. California is the only area of the United States where a clear regulatory structure for dispersant use nearshore exists. On the East Coast, a 2-nmile limit exists in New England, but doesn't significantly increase the number of spills available to disperse. It is reasonable to assume, however, that if a spill occurred nearshore adjacent to an existing pre-authorization area, then there would be pressure to consider dispersant use. This is particularly true if the depth requirements of the pre-authorization zone were met, and significant shoreline or surface resources were threatened. It is not clear that the environmental issues discussed below could always be resolved in a timely fashion.

Environmental Issues. For many geographic regions, the environmental considerations for the area from ¼ to 3 nmiles from shore are the same as for waters further offshore. In that case, the same conservative assumptions about dilution apply, and dispersant use could proceed with essentially no risk of water column effects. In other areas, this is not the case because of shallow water, and environmental considerations would be more difficult to resolve. In such cases, the type and volume of oil spilled becomes a more important consideration when determining environmental tradeoffs than was the case in deeper, offshore waters. Light refined products tend to be more toxic; however, crude oils or heavy refined products may be more persistent. In relatively shallow water, concentrations sufficient to exceed conservative thresholds may be possible for lighter oils (either refined or crude). This does not mean, however, that ecological analyses would conclude that dispersants should not be used. The decision should be based on an assessment of the environmental tradeoffs involved. In some cases (e.g., 2 nmiles from shore in 30 ft of water with a projected landfall in a marsh), it may be relatively easy for decision makers to quickly conclude that the benefits from dispersants are significant, and rapidly approve dispersant use. In other cases, analysis must be more detailed and cannot be completed as part of the decision process.

The existing pre-authorization zones are based on very general and conservative assumptions, and a number of planning areas are now examining whether or not these criteria can be modified to include a larger number of anticipated spills. In some areas, it is quite likely that the existing pre-authorization zones will be extended, but the details cannot be predicted.

Equipment and Logistics Issues. The issues related to equipment and logistics are essentially the same as those discussed for offshore areas. Except in areas close to support facilities (50 nmiles or less), fixed-wing aircraft probably would be the application system of choice. The expansion of existing pre-authorization zones to within ½ nmile of shore would increase the probability of being able to use dispersants, but not by enough that a change in equipment or supply stockpiles would be appropriate. The majority of dispersible spills continue to occur in the Gulf of Mexico, which would need the most capability.

4.6.3.3 Estuaries and Very Nearshore Coastal Areas (inland)

Policy and Planning Issues. The only area in an estuary where dispersant use is pre-authorized is the Big Stone Beach Lightering Area near the mouth of Delaware Bay. In all other areas in this geographic zone, approval would be on a case-by-case basis. The 1993 through 1998 data examined for this Caps review, as well as the data in Kucklick and Aurand (1995), suggest that this is where most coastal spills, large or small, have occurred in the past and are likely to occur in the future. It is also a region of high-value ecological resources, restricted waters, and high visibility, and pre-authorization for dispersant use will be more difficult to achieve and be more restrictive if it does occur. The decision regarding dispersant acceptability almost certainly will be decided on the basis of relatively detailed environmental risk determinations and be sensitive to oil type and volume.

The likelihood of spills in this geographic zone is high throughout the country. Most will be small spills of refined product very close to shore, but also will include a wide variety of sizes, including large crude oil spills. As before, the majority of spills occur in the Gulf of Mexico, but there are also a large number that occur in estuaries associated with high volume ports. Except for one location in Delaware Bay, all decisions concerning dispersant use in this geographic zone would need to be made on a case-by-case basis and are likely to be controversial and potentially not made fast enough to protect nearby shoreline resources. Defining pre-authorization criteria in such areas would be difficult, but potentially very beneficial.

Environmental Issues. This geographic zone offers the opportunity for the most benefits from dispersant use, but also includes the regions with the most difficult ecological issues to resolve. Spill size and oil type are critical considerations because for most areas in this geographic zone, it cannot be argued that dilution will prevent any important water column effects. Depending on spill size and rapidity of dispersant application, water column effects may be likely. The effects observed during the NORTH CAPE spill clearly indicate the potential for adverse effects of naturally dispersed oil in shallow water. The possible impacts to shoreline resources from floating oil may be much worse in terms of the structure and recovery of the estuarine or coastal system involved than the damage to the benthic or water column resources. In some cases, limited dispersant application (to prevent excessive water column concentrations) might be used to protect shoreline areas where mechanical recovery or protection is not effective.

There is never going to be a simple answer to the question of dispersant acceptability in these areas. In most areas, the issues are best resolved through a structured, analytical approach that can identify circumstances in which tradeoffs indicate greater ecological benefit from dispersants. These must be scenario driven, covering a range of sizes and oil types, so that criteria for approval can be developed. It may be possible to identify pre-authorization zones based on spill volume and type, general location, and season, or to prepare a short list of criteria for discussion as part of an expedited approval process. These must be identified, coordinated with concerned groups, and established and tested well in advance of any spill.

Equipment and Logistics Issues. Relying solely on fixed-wing aircraft would be inappropriate in estuaries and many coastal areas less than ½ nmile offshore, based on both economic and logistics considerations. Many of these spills would be very close to or in high volume ports that could support surface vessels and helicopters, as well as fixed-wing aircraft. Scenarios that benefit from the presence of all of these application platforms occur throughout the country. It is unlikely that there will be enough time to deploy resources into the area from remote locations. To be effective, the response capability will have to be locally available to enable a rapid response on spills of small to medium volumes.

4.6.4 Rivers And Canals

Policy and Planning Issues. Consideration of dispersant use in freshwater systems is much less common than that for marine or coastal areas. There is often a general perception that dispersant use is inappropriate in freshwater because of the limited volume of the receiving body of water and the lower effectiveness of the dispersants currently stockpiled in the United States, which are primarily designed for marine systems. Both of these concerns are relevant but not necessarily true in all circumstances. There are no pre-authorized areas for dispersant use in rivers and canals of the

United States, and five states (Walker *et al.*, 1999) have rejected the use of dispersants in such areas.

Environmental Issues. Almost no serious attention has been given to the environmental consequences of dispersant use in true freshwater systems. When they are considered, it is generally assumed that dilution would be too slow to be acceptable and/or that low efficiency would yield poor protection of shoreline or surface resources. Because waterfowl and valuable shoreline habitat certainly exist in these areas, in theory, benefits could accrue from dispersant use as an alternative method to protect these resources. In flowing systems, this has never received much consideration because oil moves so rapidly, and spills in lakes are not that frequent. The most likely locations for any such use are in large rivers entering estuarine systems (e.g., a spill at a refinery on the Delaware River near Philadelphia that threatens the Delaware Bay, or a spill in the lower Mississippi River). The issues could be resolved using the same approach suggested for coastal and estuarine waters. Dispersant use in lakes could protect shoreline resources, but unless the lake volume was large relative to the volume of oil and the flushing rate was rapid such as in the Great Lakes, water column concentrations might be unacceptably high.

Equipment and Logistics Issues. Fixed-wing aircraft would be largely ineffective in such areas, but both surface vessels and helicopters could be used effectively in some situations. No existing systems would be very effective in small- or moderate-sized rivers, but those are unlikely to be seriously considered for dispersant use. Current dispersant formulas are designed to be effective in brackish and marine situations; their effectiveness in freshwater is unlikely. In most lakes, the lack of sufficient turbulent mixing energy to ensure dispersion is also an issue.

4.7 DEPLOYABILITY – OPERATIONAL/REGIONAL CONSIDERATIONS

This section will evaluate the operational feasibility of using various dispersants application systems in light of spill size and history. It is important to develop general information regarding equipment capacities that would be required to respond to spills of various sizes and locations. Four different spill volumes are examined for each Coast Guard district: average spill in the past 5 years, maximum spill in the last 5 years, maximum spill in the last 25 years, and a 40,000-bbl spill. The evaluation draws from the data in Table 4-3 for application systems and also uses the following assumptions with regard to spill data:

- A spill occurs at a distance of either 50 nmiles or 150 nmiles from the appropriate support facility.
- Oil remains dispersible for 72 hours.
- Dispersant effectiveness is 100%, and DOR is 1:20.
- Over 72 hours, 40% of the oil will evaporate.
- Weather conditions are appropriate for dispersant operations.
- The repositioning factor (designed to be conservative) used to calculate mission times and/or daily delivery rates is sufficient to account for time needed to relocate to new areas of the slick and to make multiple passes to obtain appropriate application rates for the various application platforms (see discussion in Section 4.4 for the assumptions used to estimate this factor).

It is important to remember that the following analysis is based on a whole series of assumptions, some of which relate to the characteristics of the different platforms (see Table 4-3). Changing any of these assumptions will affect the results presented below. The operational feasibility of each type of delivery system is examined separately.

Surface Vessels. Surface vessels are only an efficient platform if they are located close to a spill scene. Since most spills occur close to shore and near major ports, they have considerable local potential, especially for small spills. Vessels that have, or could be equipped, with fire monitors would be available in most of these ports, and could be potentially effective as an early response option out to the limit of the 50-nmile circle. The disadvantage of using a vessel—its slow transit speed (5–10 kts)—may be compensated by its endurance and by its large dispersant-carrying capacity once on-scene. Spotter aircraft would still be necessary, and repositioning will be restricted to 5 or 10 kts.

Assuming that a vessel is available with the characteristics listed in Table 4-3, then it would require 10 hours for the vessel to arrive on-scene. Once on-scene, if the vessel's speed is 5 kts and the repositioning factor is 4 (i.e., most of the on-scene time is spent moving between thick patches of oil), then a fire monitor-equipped vessel could deliver 6,000 gals dispersant in a 10-hour day, which is enough to disperse a 120,000-gal slick. If it had the onboard payload assumed in Table 4-3 (84,000 gals), then the vessel would be able to continue on station without reloading for a total of 14 days at this application rate. In 3 days under these assumptions, such a vessel system could treat approximately 360,000 gals of 1-mm thick oil (8,571 bbls). There are considerable uncertainties associated with this analysis, especially with respect to the amount of time necessary to reposition the vessel once on-scene. It does indicate, however, that, for most spills close to shore, vessels should not be discounted. In fact, in all USCG Districts if located in close proximity to the spill, one vessel system as described above could have treated the average 5-year spill (from Table 4-10) in less than 1 day (once on station), and would have been able to treat the maximum 5-year spill in six of

TABLE 4-10. Fire Monitor-Equipped Vessel Requirements for Theoretical Response Levels in All USCG Districts.

SPILL DESCRIPTION	SPILL VOLUME (GALS)	PLATFORM DAYS*	UNITS NEEDED IN 3 DAYS†
Theoretical spill planning size (derived from USCG Issue Paper)	1,680,000/(40,000 bbls)	9.0	3.0
1st District			
Largest spill in 25 years	7,699,860	39.0	13.0
Largest spill in 5 years	828,000	5.0	2.0
Average spill in 5 years	55,974	1.0	N/A
5th District			
Largest spill in 25 years	11,172,000	56.0	19.0
Largest spill in 5 years	40,000	1.0	N/A
Average spill in 5 years	12,903	1.0	N/A
7th District			
Largest spill in 25 years	9,699,984	49.0	17.0
Largest spill in 5 years	750,000	4.0	2.0
Average spill in 5 years	40,704	1.0	N/A
8th District			
Largest spill in 25 years	10,699,962	54.0	18.0
Largest spill in 5 years	176,400	1.0	N/A
Average spill in 5 years	7,286	1.0	N/A
11th District			
Largest spill in 25 years	2,101,176	11.0	4.0
Largest spill in 5 years	40,000	1.0	N/A
Average spill in 5 years	4,293	1.0	N/A
13th District			
Largest Spill In 25 Years	700,014	4.0	2.0
Largest Spill In 5 Years	26,000	1.0	N/A
Average Spill In 5 Years	4,721	1.0	N/A
14th District			
Largest spill in 25 years	9,979,200	50.0	17.0
Largest spill in 5 years	96,000	1.0	N/A
Average spill in 5 years	9,053	1.0	N/A
17th District			
Largest spill in 25 years	10,500,000	53.0	18.0
Largest spill in 5 years	92,610	1.0	N/A
Average spill in 5 years	8,107	1.0	N/A

Note: gals, gallons.

* The number of platform days needed to treat at dispersant-to-oil ration (DOR) of 1:20 (rounded up to the nearest whole day).

[†] The number of units needed to complete response in 3 days (rounded up to the nearest whole number).

the eight USCG Districts in 1 day. It is always advisable to respond as quickly as possible, but given their wider availability, vessels may be a valuable asset close to major ports.

Short-Range Aircraft (helicopters and air tractors). Figures C-6 through C-12 (Appendix C) show the potential coverage for short-range aircraft throughout the United States. The figures show the locations of existing airports that can support either helicopters or air tractors, and Table C-1 gives the runway specifications for these airports. Not all airports are shown; in any given region, an attempt was made to locate sufficient airports to provide continuous coverage of the coast. There are sufficient airports to achieve this goal throughout the United States, except for small areas in Alaska and possibly one area in Hawaii. On this basis, dispersant operations using short-range aircraft would be feasible throughout the United States, at a distance of 50 nmiles or less.

Resource requirements for both long- and short-range aircraft for the four spill sizes identified are shown in Tables 4-11 through 4-18. For each of the spill volumes, the number of platform days necessary to treat the spill is calculated, along with the number of units necessary to complete the response within 3 days (excluding time to deploy to the response location). The distance to the spill scene is given as either 50 nmiles or 150 nmiles. These calculations are based on the assumptions presented in Table 4-3. For both helicopters and air tractors, results are calculated for both 50 and 150 nmiles, but it is assumed that they would not be used beyond 50 nmiles.

For helicopters, the average 5-year spill (from Tables 4-11 to 4-18) could be treated by one unit in 1 day or less except in the 1st District, where 2 platform days would have been required. For the maximum 5-year spill, one helicopter could provide the required response capacity within 3 days or less in every USCG District except the 1st District (New England) and 7th District (South Atlantic), where six and five units would have been required for 3 days, respectively. Helicopters would have been totally inappropriate to deal with the 25-year maximum spills except in the 13th District (Oregon/Washington), and they also would be inappropriate to handle a 40,000-bbl spill. This suggests that helicopters might be a valuable asset for most USCG Districts for all spills except the rare, high-volume spills.

TABLE 4-11. Dispersant Equipment Requirements for Theoretical Response Levels in the 1st USCG District.

				Theoretical spill planning size (derived from USCG Issue Paper)		LARGEST SPILL IN DISTRICT IN 25 YEARS		LARGEST SPILL IN DISTRICT IN 5 YEARS		AVERAGE SPILL IN DISTRICT IN 5 YEARS OVER 1,000 GALS	
				Gals	Bbls	Gals	Bbls	Gals	Bbls	Gals	Bbls
Amount spilled				**1,680,000**	**40,000**	**7,699,680**	**183,330**	**828,000**	**19,715**	**55,974**	**1,328**
Total Oil After Evaporation (assume 40% evaporation)				**1,008,000**	**24,000**	**4,619,916**	**109,998**	**496,800**	**11,829**	**33,584**	**797**
Total Dispersant at 1:20 Ratio‡				**50,400**	**1,200**	**230,996**	**5,500**	**24,840**	**591**	**1,679**	**40**
PLATFORM	**DISTANCE TO SPILL SITE (NMILES)**	**FLIGHTS PER 10-HOUR DAY**	**GALLONS OF DISPERSANT DELIVERED IN 10 HOURS**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**
Helicopter	50	6	1,500.00	34	12	154	52	17	6	2	N/A
	150	2	500.00	101	34	462	154	50	17	4	2
Air Tractor	50	8	6,340.80	8	3	37	13	4	2	1	N/A
	150	4	3,170.40	16	6	73	25	8	3	1	N/A
DC-3	50	5	5,000.00	11	4	47	16	5	2	1	N/A
	150	3	3,000.00	17	6	77	26	9	3	1	N/A
DC-4	50	7	17,495.38	3	1	14	5	2	N/A	1	N/A
	150	4	9,997.36	6	2	24	8	3	1	1	N/A
DC-6	50	6	18,000.00	3	1	13	5	2	N/A	1	N/A
	150	4	12,000.00	5	2	20	7	3	1	1	N/A
C-130	50	6	32,972.28	2	N/A	7	3	1	N/A	1	N/A
	150	3	16,486.14	4	2	14	5	2	N/A	1	N/A
P-3	50	5	20,000.00	3	1	12	4	2	N/A	1	N/A
	150	3	12,000.00	5	2	20	7	3	1	1	N/A

* The number of platform days needed to treat at dispersant-to-oil ratio (DOR) of 1:20 (rounded up to the nearest whole number).

† The number of units needed to complete response in 3 days (rounded up to the nearest whole number).
‡ Volume of dispersant = spill volume × .40 (assume 40% evaporation in 3 days) ÷ 20 (dispersant oil ratio of 1:20)

TABLE 4-12. Dispersant Equipment Requirements for Theoretical Response Levels in the 5th USCG District.

				Theoretical spill planning size (derived from USCG Issue Paper)		**LARGEST SPILL IN DISTRICT IN 25 YEARS**		**LARGEST SPILL IN DISTRICT IN 5 YEARS**		**AVERAGE SPILL IN DISTRICT IN 5 YEARS OVER 1,000 GALS**	
				Gals	**Bbls**	**Gals**	**Bbls**	**Gals**	**Bbls**	**Gals**	**Bbls**
Amount spilled				**1,680,000**	**40,000**	**11,172,000**	**266,000**	**40,000**	**952**	**12,903**	**307**
Total Oil After Evaporation (assume 40% evaporation)				**1,008,000**	**24,000**	**6,703,200**	**159,600**	**24,000**	**571**	**7,742**	**184**
Total Dispersant at 1:20 Ratio‡				**50,400**	**1,200**	**335,160**	**7,980**	**1,200**	**29**	**387**	**9**
PLATFORM	**DISTANCE TO SPILL SITE (NMILES)**	**FLIGHTS PER 10-HOUR DAY**	**GALLONSOF DISPERSANT DELIVERED IN 10 HOURS**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**
Helicopter	50	6	1,500.00	34	12	224	75	1	N/A	1	N/A
	150	2	500.00	101	34	671	224	3	1	1	N/A
Air Tractor	50	8	6,340.80	8	3	53	18	1	N/A	1	N/A
	150	4	3,170.40	16	6	106	36	1	N/A	1	N/A
DC-3	50	5	5,000.00	11	4	68	23	1	N/A	1	N/A
	150	3	3,000.00	17	6	112	38	1	N/A	1	N/A
DC-4	50	7	17,495.38	3	1	20	7	1	N/A	1	N/A
	150	4	9,997.36	6	2	34	12	1	N/A	1	N/A
DC-6	50	6	18,000.00	3	1	19	7	1	N/A	1	N/A
	150	4	12,000.00	5	2	28	10	1	N/A	1	N/A
C-130	50	6	32,972.28	2	N/A	11	4	1	N/A	1	N/A
	150	3	16,486.14	4	2	21	7	1	N/A	1	N/A
P-3	50	5	20,000.00	3	1	17	6	1	N/A	1	N/A
	150	3	12,000.00	5	2	28	10	1	N/A	1	N/A

[*] The number of platform days needed to treat at dispersant-to-oil ratio (DOR) of 1:20 (rounded up to the nearest whole number).
[†] The number of units needed to complete response in 3 days (rounded up to the nearest whole number).
[‡] Volume of dispersant = spill volume × .40 (assume 40% evaporation in 3 days) ÷ 20 (dispersant oil ratio of 1:20)

TABLE 4-13. Dispersant Equipment Requirements for Theoretical Response Levels in the 7th USCG District.

				Theoretical spill planning size (derived from USCG Issue Paper)		LARGEST SPILL IN DISTRICT IN 25 YEARS		LARGEST SPILL IN DISTRICT IN 5 YEARS		AVERAGE SPILL IN DISTRICT IN 5 YEARS OVER 1,000 GALS	
				Gals	Bbls	Gals	Bbls	Gals	Bbls	Gals	Bbls
Amount spilled				**1,680,000**	**40,000**	**9,699,984**	**230,952**	**750,000**	**17,857**	**40,704**	**969**
Total Oil After Evaporation (assume 40% evaporation)				**1,008,000**	**24,000**	**5,819,990**	**138,571**	**450,000**	**10,714**	**24,422**	**581**
Total Dispersant at 1:20 Ratio[‡]				**50,400**	**1,200**	**291,000**	**6,929**	**22,500**	**536**	**1,221**	**29**
PLATFORM	**DISTANCE TO SPILL SITE (NMILES)**	**FLIGHTS PER 10-HOUR DAY**	**GALLONS OF DISPERSANT DELIVERED IN 10 HOURS**	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**[†]	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**[†]	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**
Helicopter	50	6	1,500.00	34	12	194	65	15	5	1	N/A
	150	2	500.00	101	34	582	194	45	15	3	1
Air Tractor	50	8	6,340.80	8	3	46	16	4	2	1	N/A
	150	4	3,170.40	16	6	92	31	8	3	1	N/A
DC-3	50	5	5,000.00	11	4	59	20	5	2	1	N/A
	150	3	3,000.00	17	6	97	33	8	3	1	N/A
DC-4	50	7	17,495.38	3	1	17	6	2	N/A	1	N/A
	150	4	9,997.36	6	2	30	10	3	1	1	N/A
DC-6	50	6	18,000.00	3	1	17	6	2	N/A	1	N/A
	150	4	12,000.00	5	2	25	9	2	N/A	1	N/A
C-130	50	6	32,972.28	2	N/A	9	3	1	N/A	1	N/A
	150	3	16,486.14	4	2	18	6	2	N/A	1	N/A
P-3	50	5	20,000.00	3	1	15	5	2	N/A	1	N/A
	150	3	12,000.00	5	2	25	9	2	N/A	1	N/A

[*] The number of platform days needed to treat at dispersant-to-oil ratio (DOR) of 1:20 (rounded up to the nearest whole number).

[†] The number of units needed to complete response in 3 days (rounded up to the nearest whole number).

‡ Volume of dispersant = spill volume $\times$ .40 (assume 40% evaporation in 3 days) $\div$ 20 (dispersant oil ratio of 1:20)

TABLE 4-14. Dispersant Equipment Requirements for Theoretical Response Levels in the 8th USCG District.

				Theoretical spill planning size (derived from USCG Issue Paper)		**LARGEST SPILL IN DISTRICT IN 25 YEARS**		**LARGEST SPILL IN DISTRICT IN 5 YEARS**		**AVERAGE SPILL IN DISTRICT IN 5 YEARS OVER 1,000 GALS**	
				Gals	**Bbls**	**Gals**	**Bbls**	**Gals**	**Bbls**	**Gals**	**Bbls**
Amount spilled				**1,680,000**	**40,000**	**10,699,962**	**254,761**	**176,400**	**4,200**	**7,286**	**173**
Total Oil After Evaporation (assume 40% evaporation)				**1,008,000**	**24,000**	**6,419,977**	**152,857**	**105,840**	**2,520**	**4,372**	**104**
Total Dispersant at 1:20 Ratio[‡]				**50,400**	**1,200**	**320,999**	**7,643**	**5,292**	**126**	**219**	**5**
PLATFORM	**DISTANCE TO SPILL SITE (NMILES)**	**FLIGHTS PER 10-HOUR DAY**	**GALLONS OF DISPERSANT DELIVERED IN 10 HOURS**	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**[†]	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**[†]	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**[†]	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**[†]
Helicopter	50	6	1,500.00	34	12	214	72	4	2	1	N/A
	150	2	500.00	101	34	642	214	11	4	1	N/A
Air Tractor	50	8	6,340.80	8	3	51	17	1	N/A	1	N/A
	150	4	3,170.40	16	6	102	34	2	N/A	1	N/A
DC-3	50	5	5,000.00	11	4	65	22	2	N/A	1	N/A
	150	3	3,000.00	17	6	108	36	2	N/A	1	N/A
DC-4	50	7	17,495.38	3	1	19	7	1	N/A	1	N/A
	150	4	9,997.36	6	2	33	11	1	N/A	1	N/A
DC-6	50	6	18,000.00	3	1	18	6	1	N/A	1	N/A
	150	4	12,000.00	5	2	27	9	1	N/A	1	N/A
C-130	50	6	32,972.28	2	N/A	10	4	1	N/A	1	N/A
	150	3	16,486.14	4	2	20	7	1	N/A	1	N/A
P-3	50	5	20,000.00	3	1	17	6	1	N/A	1	N/A
	150	3	12,000.00	5	2	27	9	1	N/A	1	N/A

[*] The number of platform days needed to treat at dispersant-to-oil ratio (DOR) of 1:20 (rounded up to the nearest whole number).

[†] The number of units needed to complete response in 3 days (rounded up to the nearest whole number).

‡ Volume of dispersant = spill volume $\times$ .40 (assume 40% evaporation in 3 days) $\div$ 20 (dispersant oil ratio of 1:20)

TABLE 4-15. Dispersant Equipment Requirements for Theoretical Response Levels in the 11th USCG District.

				Theoretical spill planning size (derived from USCG Issue Paper)		LARGEST SPILL IN DISTRICT IN 25 YEARS		LARGEST SPILL IN DISTRICT IN 5 YEARS		AVERAGE SPILL IN DISTRICT IN 5 YEARS OVER 1,000 GALS	
				Gals	**Bbls**	**Gals**	**Bbls**	**Gals**	**Bbls**	**Gals**	**Bbls**
Amount spilled				**1,680,000**	**40,000**	**2,101,176**	**50,028**	**40,000**	**952**	**4,293**	**102**
Total Oil After Evaporation (assume 40% evaporation)				**1,008,000**	**24,000**	**1,260,706**	**30,017**	**24,000**	**571**	**2,576**	**61**
Total Dispersant at 1:20 Ratio[‡]				**50,400**	**1,200**	**63,035**	**1,501**	**1,200**	**29**	**129**	**3**
PLATFORM	**DISTANCE TO SPILL SITE (NMILES)**	**FLIGHTS PER 10-HOUR DAY**	**GALLONS OF DISPERSANT DELIVERED IN 10 HOURS**	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**[†]	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**[†]	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**
Helicopter	50	6	1,500.00	34	12	43	15	1	N/A	1	N/A
	150	2	500.00	101	34	127	43	3	1	1	N/A
Air Tractor	50	8	6,340.80	8	3	10	4	1	N/A	1	N/A
	150	4	3,170.40	16	6	20	7	1	N/A	1	N/A
DC-3	50	5	5,000.00	11	4	13	5	1	N/A	1	N/A
	150	3	3,000.00	17	6	22	8	1	N/A	1	N/A
DC-4	50	7	17,495.38	3	1	4	2	1	N/A	1	N/A
	150	4	9,997.36	6	2	7	3	1	N/A	1	N/A
DC-6	50	6	18,000.00	3	1	4	2	1	N/A	1	N/A
	150	4	12,000.00	5	2	6	2	1	N/A	1	N/A
C-130	50	6	32,972.28	2	N/A	2	N/A	1	N/A	1	N/A
	150	3	16,486.14	4	2	4	2	1	N/A	1	N/A
P-3	50	5	20,000.00	3	1	4	2	1	N/A	1	N/A
	150	3	12,000.00	5	2	6	2	1	N/A	1	N/A

[*] The number of platform days needed to treat at dispersant-to-oil ratio (DOR) of 1:20 (rounded up to the nearest whole number).

[†] The number of units needed to complete response in 3 days (rounded up to the nearest whole number).

‡ Volume of dispersant = spill volume $\times$ .40 (assume 40% evaporation in 3 days) $\div$ 20 (dispersant oil ratio of 1:20)

TABLE 4-16. Dispersant Equipment Requirements for Theoretical Response Levels in the 13th USCG District.

				Theoretical spill planning size (derived from USCG Issue Paper)		LARGEST SPILL IN DISTRICT IN 25 YEARS		LARGEST SPILL IN DISTRICT IN 5 YEARS		AVERAGE SPILL IN DISTRICT IN 5 YEARS OVER 1,000 GALS	
				Gals	**Bbls**	**Gals**	**Bbls**	**Gals**	**Bbls**	**Gals**	**Bbls**
Amount spilled				**1,680,000**	**40,000**	**700,014**	**16,667**	**26,000**	**619**	**4,721**	**112**
Total Oil After Evaporation (assume 40% evaporation)				**1,008,000**	**24,000**	**420,008**	**10,000**	**15,600**	**371**	**2,833**	**67**
Total Dispersant at 1:20 Ratio‡				**50,400**	**1,200**	**21,000**	**500**	**780**	**19**	**142**	**4**
PLATFORM	**DISTANCE TO SPILL SITE (NMILES)**	**FLIGHTS PER 10-HOUR DAY**	**GALLONS OF DISPERSANT DELIVERED IN 10 HOURS**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**
Helicopter	50	6	1,500.00	34	12	14	5	1	N/A	1	N/A
	150	2	500.00	101	34	42	14	2	N/A	1	N/A
Air Tractor	50	8	6,340.80	8	3	4	2	1	N/A	1	N/A
	150	4	3,170.40	16	6	7	3	1	N/A	1	N/A
DC-3	50	5	5,000.00	11	4	5	2	1	N/A	1	N/A
	150	3	3,000.00	17	6	7	3	1	N/A	1	N/A
DC-4	50	7	17,495.38	3	1	2	N/A	1	N/A	1	N/A
	150	4	9,997.36	6	2	3	1	1	N/A	1	N/A
DC-6	50	6	18,000.00	3	1	2	N/A	1	N/A	1	N/A
	150	4	12,000.00	5	2	8	3	1	N/A	1	N/A
C-130	50	6	32,972.28	2	N/A	1	N/A	1	N/A	1	N/A
	150	3	16,486.14	4	2	2	N/A	1	N/A	1	N/A
P-3	50	5	20,000.00	3	1	2	N/A	1	N/A	1	N/A
	150	3	12,000.00	5	2	2	N/A	1	N/A	1	N/A

* The number of platform days needed to treat at dispersant-to-oil ratio (DOR) of 1:20 (rounded up to the nearest whole number).

† The number of units needed to complete response in 3 days (rounded up to the nearest whole number).

‡ Volume of dispersant = spill volume $\times$ .40 (assume 40% evaporation in 3 days) $\div$ 20 (dispersant oil ratio of 1:20)

TABLE 4-17. Dispersant Equipment Requirements for Theoretical Response Levels in the 14th USCG District.

				Theoretical spill planning size (derived from USCG Issue Paper)		LARGEST SPILL IN DISTRICT IN 25 YEARS		LARGEST SPILL IN DISTRICT IN 5 YEARS		AVERAGE SPILL IN DISTRICT IN 5 YEARS OVER 1,000 GALS	
				Gals	Bbls	Gals	Bbls	Gals	Bbls	Gals	Bbls
Amount spilled				**1,680,000**	**40,000**	**9,979,200**	**2,376,000**	**96,000**	**2,286**	**9,053**	**216**
Total Oil After Evaporation (assume 40% evaporation)				**1,008,000**	**24,000**	**5,987,520**	**142,560**	**57,600**	**1,371**	**5,432**	**129**
Total Dispersant at 1:20 Ratio[‡]				**50,400**	**1,200**	**299,376**	**7,128**	**2,880**	**69**	**278**	**7**
PLATFORM	**DISTANCE TO SPILL SITE (NMILES)**	**FLIGHTS PER 10-HOUR DAY**	**GALLONS OF DISPERSANT DELIVERED IN 10 HOURS**	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**[†]	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**[†]	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**[†]	**PLATFORM DAYS REQUIRED**[*]	**UNITS NEEDED IN 3 DAYS**[†]
Helicopter	50	6	1,500.00	34	12	200	67	2	N/A	1	N/A
	150	2	500.00	101	34	599	200	6	2	1	N/A
Air Tractor	50	8	6,340.80	8	3	48	16	1	N/A	1	N/A
	150	4	3,170.40	16	6	95	32	1	N/A	1	N/A
DC-3	50	5	5,000.00	11	4	60	20	1	N/A	1	N/A
	150	3	3,000.00	17	6	100	34	1	N/A	1	N/A
DC-4	50	7	17,495.38	3	1	18	6	1	N/A	1	N/A
	150	4	9,997.36	6	2	30	10	1	N/A	1	N/A
DC-6	50	6	18,000.00	3	1	17	6	1	N/A	1	N/A
	150	4	12,000.00	5	2	25	9	1	N/A	1	N/A
C-130	50	6	32,972.28	2	N/A	10	4	1	N/A	1	N/A
	150	3	16,486.14	4	2	19	7	1	N/A	1	N/A
P-3	50	5	20,000.00	3	1	15	5	1	N/A	1	N/A
	150	3	12,000.00	5	2	25	9	1	N/A	1	N/A

[*] The number of platform days needed to treat at dispersant-to-oil ratio (DOR) of 1:20 (rounded up to the nearest whole number).

[†] The number of units needed to complete response in 3 days (rounded up to the nearest whole number).

‡ Volume of dispersant = spill volume × .40 (assume 40% evaporation in 3 days) ÷ 20 (dispersant oil ratio of 1:20)

TABLE 4-18. Dispersant Equipment Requirements for Theoretical Response Levels in the 17th USCG District.

				Theoretical spill planning size (derived from USCG Issue Paper)		LARGEST SPILL IN DISTRICT IN 25 YEARS		LARGEST SPILL IN DISTRICT IN 5 YEARS		AVERAGE SPILL IN DISTRICT IN 5 YEARS OVER 1,000 GALS	
				Gals	Bbls	Gals	Bbls	Gals	Bbls	Gals	Bbls
Amount spilled				**1,680,000**	**40,000**	**10,500,000**	**250,000**	**92,610**	**2,205**	**8,107**	**193**
Total Oil After Evaporation (assume 40% evaporation)				**1,008,000**	**24,000**	**6,300,000**	**150,000**	**55,566**	**1,323**	**4,864**	**116**
Total Dispersant at 1:20 Ratio‡				**50,400**	**1,200**	**315,000**	**7,500**	**2,778**	**66**	**243**	**6**
PLATFORM	**DISTANCE TO SPILL SITE (NMILES)**	**FLIGHTS PER 10-HOUR DAY**	**GALLONS OF DISPERSANT DELIVERED IN 10 HOURS**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**	**PLATFORM DAYS REQUIRED***	**UNITS NEEDED IN 3 DAYS†**
Helicopter	50	6	1,500.00	34	12	210	70	2	N/A	1	N/A
	150	2	500.00	101	34	630	210	6	2	1	N/A
Air Tractor	50	8	6,340.80	8	3	50	17	1	N/A	1	N/A
	150	4	3,170.40	16	6	100	34	1	N/A	1	N/A
DC-3	50	5	5,000.00	11	4	63	21	1	N/A	1	N/A
	150	3	3,000.00	17	6	105	35	1	N/A	1	N/A
DC-4	50	7	17,495.38	3	1	18	6	1	N/A	1	N/A
	150	4	9,997.36	6	2	32	11	1	N/A	1	N/A
DC-6	50	6	18,000.00	3	1	18	6	1	N/A	1	N/A
	150	4	12,000.00	5	2	27	9	1	N/A	1	N/A
C-130	50	6	32,972.28	2	N/A	10	4	1	N/A	1	N/A
	150	3	16,486.14	4	2	20	7	1	N/A	1	N/A
P-3	50	5	20,000.00	3	1	16	6	1	N/A	1	N/A
	150	3	12,000.00	5	2	27	9	1	N/A	1	N/A

* The number of platform days needed to treat at dispersant-to-oil ratio (DOR) of 1:20 (rounded up to the nearest whole number).

† The number of units needed to complete response in 3 days (rounded up to the nearest whole number).
‡ Volume of dispersant = spill volume × .40 (assume 40% evaporation in 3 days) ÷ 20 (dispersant oil ratio of 1:20)

For air tractors, the situation is even more favorable since their 10-hour dispersant delivery capacity is approximately 10 times as great as that of helicopters. All of the 5-year average and 5-year maximum spills in all districts could have been treated in 1 day or less by one unit except for the 5-year maximum in the 1st District (New England) and 7th District (South Atlantic), where 2 days would have been required. Once again, this would not be an appropriate platform to use against the 25-year maximum spills. For the 40,000-bbl spill, multiple (three or four) units could be effective in 3 days or less, which might be acceptable.

Long-Range Aircraft. All of the remaining units listed in Tables 4-11 through 4-18 are considered long-range aircraft, and as such, they could be used at either 50 or 150 nmiles. In terms of dispersant delivery capacity, the DC-3 is by far the least capable, and delivers only 80% of an air tractor's capacity in 1 platform day. The remaining units are much more capable. The DC-4, DC-6, and generic P3 platforms can all deliver approximately the same volume of dispersant in a 10-hour day at 50 nmiles (18,000–20,000 gpd), but at 150 nmiles, the DC-4 is somewhat less capable (10,000 vs. 12,000 gpd). The C-130 has a significantly higher delivery capacity, especially at 50 nmiles.

Figures C-13 through C-20 (Appendix C) show 150-nmiles circles around airports capable of supporting long-range aircraft throughout the United States, and Table C-2 shows the runway specifications for these airports. The same process was used as in the earlier figures—appropriate airports were identified with the goal of obtaining complete coverage of the coast. The only areas where this could not be achieved are the Aleutian Islands and possibly a very small stretch of coast on the Seward Peninsula in Alaska. It is reasonable to assume that no spill in the coastal United States is likely to occur more than 150 nmiles from a potential staging area for large aircraft.

Because the DC-3 is so different than the other large aircraft (in terms of delivery capacity), it is considered separately. One aircraft would have been capable of treating all 5-year average spills in 1 day or less at either distance (Tables 4-11 to 4-18). For the 5-year maximum, one aircraft could have treated all of the spills in 1 day or less except in the 1st and 7th Districts, where two to three platforms would have been required, depending on the distance. For the 25-year maximum spills, for all except the 13th District, a minimum of four (11th District at 50 nmiles) and a maximum of 28 (5th District at 150 nmiles) units would have been required to completely treat the spill in 3 days. For the 40,000-bbl reference spill, 11 to 17 platform days, or four to six units for 3 days, would have been required, depending on distance to the spill.

The remaining large aircraft (DC-4, DC-6, C-130, generic P3) are considered together. For all of these aircraft, in all districts, both the 5-year average and the 5-year maximum spills could have been treated by one unit in 3 days or less (Table 4-11 to 4-18). Except in the 1st and 7th Districts, the value is 1 day or less. In many cases, it is only one or two flights. For the 25-year maximum spill the necessary platform-days ranges from 1 to 34, depending on the type of platform, district, and assumed distance. On this basis, the number of units needed to complete the response in 3 days could be as high as 12, depending on the platform. For the reference spill (40,000 bbl spill), 2 to 6 platform days would be required, or one to three units for 3 days, depending on the circumstances.

Logistics and Support Implications. The platform requirements developed above assume that there are no constraints to the efficient deployment of resources. This is unlikely to ever be the case. In addition, it is useful to compare the anticipated requirements to those that are already available to obtain an estimate of what changes might need to occur to support a given response capability.

With respect to the application platforms themselves, there are varying degrees of availability. For vessels, there are few that are currently equipped or trained for dispersant operations, but this could be done in most ports. Similarly, helicopters are widely available but rarely considered for use. They could be included in the response arsenal without much difficulty. Fixed-wing aircraft, of a variety of types, currently are available but not in larger numbers and in only a few locations. Figures C-21 through C-24 (Appendix C) display the flight times necessary to deploy long-range aircraft from their existing bases to various points in the continental United States and Alaska. If it is assumed that the aircraft can be airborne in 3 hours, then aircraft can be at mobilization sites anywhere in the United States within 12 hours. The overall distribution of air tractors is less well defined, but a similar response time is anticipated. If a more rapid response was desired, then additional aircraft sites would need to be identified in some regions, especially on the East Coast.

Application systems for both vessels and helicopters are available and relatively inexpensive. An increased reliance on these units would mean that additional equipment would need to be stockpiled around the country. Many port areas do not have local stockpiles, however, and would need to rely on shipments from regional stockpiles, which will not provide a rapid response. If the spill is larger, then regional stockpiles may be overwhelmed. Based on the historical record, this will not happen often. Regional stockpiles are capable of handling up to the reported 5-year maximum in all districts except the 1st District, which has no stockpile. The existing stockpiles in the 8th and 11th Districts are adequate to treat the reference 40,000-bbl spill. All other districts would have to rely on shipments from other areas.

Finally, no district has a stockpile sufficient to treat its largest reported spill in the last 25 years, and the very largest spills would require almost the entire stockpile in the United States. The logistics of redistributing this material is a critical issue. Finally, all of the calculations assume that sufficient trained flight and ground crew support can be available to sustain operations for the entire period. This is probably true for limited operations with only a few platforms, but if a large dispersant response effort were mounted (such as many of the 25-year maximum spills), trained crew availability, ground logistics, and resupply would probably limit the operation more than the requirement for delivery platforms.

4.8 CONCLUSIONS AND RECOMMENDATIONS

What environmental and efficiency concerns influence dispersant use?

- Environmental concerns focus on the potential impacts of dispersed oil droplets on organisms in the water column. Potential impacts should be assessed in conjunction with an assessment of shoreline and water surface impact reductions likely to result from dispersant application.
- Dispersant efficiency concerns center on dispersant effectiveness in removing oil from the water surface. Field tests and incident specific use have shown that current dispersant formulations are effective in increasing removal of oil from the water surface instead of natural dispersion.
- The SMART protocol provides an adequate system for monitoring dispersant effectiveness.

Has dispersant use been accepted as a viable response option?

- Dispersant use is the primary response option for spills occurring in offshore waters in several countries, particularly the United Kingdom.
- Dispersant use has been pre-authorized in most U.S. coastal areas, and RRTs and Area Committees around the country are engaged in detailed operational and risk assessment planning to ensure its availability in appropriate spill situations.

What is the current state of dispersant technology?

- Vessels equipped with high capacity delivery systems (modified fire monitors) and sufficient storage capacity could provide considerable capability, provided they were close to the scene when the spill occurred. The major limitation for vessels is the long transit time required if not near the spill scene.
- Both helicopters and air tractors are widely available in the United States, and could be used effectively against most spills that are likely to occur. There are sufficient airports nationwide to support such operations. While these small aircraft could not be used alone against larger spills, they could be used effectively in conjunction with larger, fixed-wing aircraft if they were available as part of a response plan for smaller spills. They would not be effective if the spill were more than 50 nmiles from the support facility, but given the distribution of suitable airports, this is unlikely to occur.
- Several types of large, long-range aircraft are available in the United States that are suitable for use in dispersant operations. The DC-3 platform is much less capable than the other large aircraft. Although the DC-3 platform would be acceptable for most spills, it would be overwhelmed by the largest, 25-year spills identified in tables 4-11 through 4-18. The other large aircraft would be much more effective overall, but even they would be overwhelmed by the largest spills. To treat the reference spill in 3 days,

four to six DC-3s would be required, but only one to three units of the other airframes would be required, depending on circumstances. For smaller spills, especially those close to shore or near ports, the use of vessels and/or small aircraft may be preferable to the use of large aircraft, unless the large aircraft already are deployed in the area.

What dispersant options are available currently?

- Limited dispersant stockpiles are available around the United States.
- There are a variety of aircraft and vessels available that could serve as adequate dispersant platforms, but only a handful of these are under contract for that purpose in the United States.
- There are suitable airport and vessel facilities available throughout the coastal United States to allow establishment and maintenance of an effective dispersant capability within 50 nmiles of the coast within 12 hours.

Is including a requirement and/or offset for a dispersant capability practicable in light of the current technology, market availability, overall distribution of dispersant resources, and current (and projected) RRT dispersant use policies?

- Dispersant capability is practicable and should be mandated for all plan holders carrying Groups II, III, or IV oils, who operate in waters where government pre-authorization or expedited approval for dispersant use exits. Including Groups II, III, and IV oils in this requirement is appropriate because dispersants have been proven effective on oils in all three of these groups. Facilities and vessels with operations that do not extend into the pre-authorization/expedited approval waters should not have to comply with this requirement.
- Tier 1 dispersant application should commence within the first 6 hours and be completed within the first 12 hours after incident specific authorization is received. Dispersant capability should be sufficient to allow 1:20 treatment of 1,000 bbls of oil in (Tier I); an additional 12,500 bbls within the first 36 hours (Tier II); and 10,500 bbls within the first 60 hours (Tier III). This would require establishing a baseline Tier I capability in almost every port in the country and one or two major national supply points for all Tier II and III areas. It would also provide sufficient capability to disperse 40,000 bbls of spilled oil (reduced for evaporation) in the first 3 days of an incident.
    - Tiers I, II, and III response times are modified from those used for mechanical recovery and *in situ* burning. For dispersant use, Tiers I, II, and III dispersant operations should be *completed* within the timeframes indicated (12, 36, and 60 hours in the offshore area). For mechanical recovery and *in situ* burning, Tiers I, II, and III operations should *commence* within the timeframes indicated (12, 36, and 60 hours in offshore area). The shorter response timeframes are practicable and achievable because dispersants can be delivered by aircraft while mechanical recovery and *in situ* burn operations are dependent on surface vessel delivery.

  - Treating the Tier I quantity of 1,000 bbls of spilled oil requires 2,100 gallons of dispersant. This is achievable and practicable for several reasons. As extrapolated from Table 4-3, a single fixed wing aircraft or 3 helicopters can deliver 2,100 gallons from regionally available stockpiles in the six-hour window of actual dispersant operations during Tier I. A single vessel could also deliver the required quantity by the end of the Tier I window if it began operations at hour six as required. As indicated in Tables 4-11 through 4-18, the recommended Tier I quantity is sufficient to treat the average spill of over 1,000 gallons in every US Coast Guard District. The Tier II quantity of 12,500 bbls can be delivered by two or three aircraft supplied with dispersants shipped from stockpiles around the country or possibly by several vessels arriving from outside the region. The lower Tier III quantity (10,500 bbls) can be supplied by the same resources and recognizes potentially diminishing effectiveness of dispersant on day 3 because of increasing viscosity of the oil. The total treatment requirement of 24,000 bbls is equivalent to treatment of a 40,000-bbl spill reduced for evaporation.
  - The dispersant cap level was set at 40,000 barrels. This quantity was originally proposed by the US Coast Guard during public meetings held to discuss the feasibility of dispersant regulations. It is reasonable because it approximates the loss of all cargo from a barge or from two tanks of a large tank vessel. It is also the quantity that was used to establish the original mechanical recovery equipment caps. A 40,000-barrel spill capability is also practical from a logistics and operational control standpoint because, as noted in Tables 4-11 through 4-18, this capability can be delivered by two large aircraft or three vessels operating anywhere in the US. The addition of two or three additional response units, along with requisite spotter aircraft and monitoring platforms, will tax but not overload the existing Incident Command System structure.

- The required capability should focus on the quantity of oil to be treated within a given time frame. It should not be overly prescriptive and should not specify numbers or types of aircraft or vessels that must be contracted to meet the required capability. However at least 50% of the capability should be required to be delivered by fixed-wing aircraft. Aircraft allow coverage over a larger area in a smaller timeframe. This expediency is essential for spills threatening environmentally sensitive areas remote from surface vessel operations. An aircraft 600 miles from a spill site can easily be on scene and spraying within 6 hours of an incident, while a vessel, even traveling at 10 kts would require 10 hours to arrive on scene and commence operations. Further, once on scene, one large aircraft can treat as much oil as three or four small aircraft or surface vessels in the same time period. For large spills or spills of quickly weathering oil this larger, more rapid treatment capacity is critical. Likewise the availability of smaller aircraft and surface vessels allows flexibility in treating smaller spills, close to shore quickly and efficiently. This will allow plan holders maximum flexibility in determining the appropriate mix of resources in meeting the requirements.

- For planning purposes, dispersant delivery by aircraft can reasonably be expected to commence within 6 hours of call-out for any location within 50 nmiles of the coastline of the United States. Dispersant delivery by vessel can reasonably be achieved within 12 hours of call-out to within 50 nmiles of the vessel's location upon call-out. Calculations for determining Tier I resources to be available by contract should consider these response capabilities.