Non-mechanical Response Gap Estimate:

Literature Review and Recommended Limits

Report to
Prince William Sound Regional Citizens' Advisory Council

Nuka Research and Planning Group, LLC

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Introduction

Prince William Sound Regional Citizens' Advisory Council (PWSRCAC) has contracted Nuka Research and Planning Group, LLC to analyze the response gap that exists for non-mechanical response operations at two locations in Prince William Sound. This preliminary report will be used to establish the response limits used in the analysis.

In February 2007, the PWSRCAC Board of Directors approved a report by Nuka Research, "Response Gap Estimates for Two Operating Areas in Prince William Sound," which analyzed the response gap for mechanical response operations using data from two National Oceanic and Atmospheric Administration (NOAA) buoys located in the Central Sound and at Hinchinbrook Entrance and civil twilight tables. The same data sets will be used for this subsequent analysis, which will estimate the response gap for two non-mechanical response methods: dispersants and in-situ burning.

Purpose of this Report

This report recommends operational limits to dispersant and in-situ burning in terms of wind, sea state, air temperature, and visibility. These limits are proposed for the consideration and approval of the PWSRCAC Oil Spill prevention and Response Committee and Scientific Advisory Committee prior to conducting the response gap analysis.

For further information on the methodology to be used in this analysis, please refer to the February 2007 report referenced above (Nuka Research 2007).

Literature Review

As specified in the scope of work, the literature review used as a starting point the 2004 report submitted to PWSRCAC by Merv Fingas entitled, "Weather Windows for Oil Spill Countermeasures." This report provided many useful references, some of which are cited as found in Fingas, if they not available in full.

The literature review included scientific articles, both peer-reviewed and not, operational guidance documents, and the Prince William Sound Oil Spill Prevention and Contingency Plans (Tanker C-plans) from the past several years[1]. The limits described by the plan holders are included in this discussion.

The literature review focused on the environmental factors used in mechanical response gap estimate, and did not consider other factors such as water temperature, salinity, precipitation, or visibility other than darkness vs. daylight. There is also extensive literature (based primarily on laboratory-scale testing) on the relationship between oil weathering and dispersant or in-situ burn effectiveness; this was not included either.

Dispersants

Studies on the relationship between chemical dispersant use and the relevant environmental factors have focused primarily on the need for wave energy, which is related to the interconnected factors of wind and sea state. The importance of wave energy to dispersant effectiveness creates both maximum and minimum limits for dispersant use based on wind and sea state.

Many statements about environmental factors and response limits for dispersants are too vague for the purposes of identifying response limits for a gap analysis. These have been omitted, except those from the Tanker C-plan.

Table 1 summarizes the ways in which the selected environmental factors can impact dispersant application and efficacy. Both aircraft and vessels are included as the dispersant application platforms; in order to function correctly, these platforms must be able to operate safely, visualize and access the spill area, and target the spilled oil with the sprayed dispersant. The actual dispersion of the oil requires an accurate application and sufficient mixing energy to be effective. If there is inadequate wave energy, the dispersant will not mix with the oil and chemical dispersion will not be achieved. On the other hand, if wave energy is high enough, then the dispersant will provide no added benefit over natural dispersion.

The PWS Tanker C-plan and associated SERVS Technical Manual submitted in June 2007 specifies some limits to non-mechanical response as required in the Realistic Maximum Response Operating Limits section of state-mandated contingency plans [18 AAC

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[1] Only the most recent version is cited: there has been no change in the response limits cited in the c-plans.

75.425(e)(3)(D)]. These are shown in **bold.** At the time this writing, the Tanker C-plan has not yet been approved; however, the limits stated have been consistent since the 1995 C-plan.

Table 1 focuses on conditions at the scene of the spill, however the conditions would also have to be amenable to transporting dispersants from stockpiles in Valdez and/or Anchorage. The fixed-wing aircraft listed in the 2007 SERVS Technical Manual is based in Anchorage; dispersants are in both Anchorage and Valdez.

Table 1. Impact of Select Environmental Factors on Dispersant Use

Factors	Application by Aircraft or Vessel	Dispersion of Oil
WIND (knots)	*Aircraft:* Maximum 25 knots, according to ARPEL guidelines (2007), but no basis given. Maximum 30-35 knots (ExxonMobil 2000 in Fingas 2004). **Maximum 27 knots** (2007 Tanker C-plan submittal). *Vessel:* Maximum 7-21 knots (ExxonMobil 2000 in Fingas 2004). Maximum 29 knots for spray boom, based on workers' observations that dispersant application was "relatively unaffected" up to this speed (Lichtenthaler and Daling 1983 in Fingas 2004).	*Minimum* 4-6 knots, or Beaufort 2 (Allen 1988[2]). *Minimum* 5-23 knots (Scholz et al. 1999 in Fingas 2004). Maximum 22-27 knots (Beaufort 6), or natural dispersion will be equally effective (Allen 1988). Maximum 25 knots, per EPA Region 6 guidelines (Fingas 2004).

[2] Allen provides one of the more comprehensive overviews of the impact of environmental factors on different response mechanisms, which appear to be based on his (at the time) 20 years of experience, not experiments or trials.

Factors	Application by Aircraft or Vessel	Dispersion of Oil
SEA STATE (feet)	<u>*Aircraft:*</u> Maximum 17-23 ft. (ExxonMobil 2000 in Fingas 2004). <u>*Vessel:*</u> Maximum 1-9 ft. (ExxonMobil 2000 in Fingas 2004).	*Minimum* 0.3-6.5 ft. (Scholz et al. 1999 in Fingas 2004). *Minimum:* 0.5 ft. (Allen 1988). Maximum 10 ft. (Beaufort 6), or natural dispersant will be equally effective (Allen 1988).
AIR TEMP. (ºF)	**No appreciable impact** (2007 Tanker C-plan). **Subzero temperatures may require equipment modifications** (2007 SERVS Technical Manual).	Several (laboratory) studies show that as water temperature is lowered, dispersant effectiveness is reduced. Daling (1988) tested Norwegian oils; other studies (Daling et al. 1995, Brandvik et al. 1991 in Fingas 2004) were not directly reviewed. However, Farmwald and Nelson (1982) found a no clear correlation between air temperature and dispersibility in wave tank tests of Prudhoe Bay crude.
VISIBILITY (nautical miles)	<u>*Aircraft:*</u> **"May preclude air operations"** (2007 Tanker C-plan). 2.2 nm required for helicopter, as with burning (Buist 2003). 0.9 nm required for fixed-wing aircraft Dispersant application at night is unreliable because it is hard to track oil for the accurate application of dispersant[3] (Salt 2001). Federal Regulations require fixed-wing aircraft operating under visual flight rules (VFR) in daylight hours to have 1 statute mile visibility and remain clear of clouds in un-controlled air space. At night the limits increase to 3 stature miles visibility; and 500 feet below and 2000 feet horizontally away from clouds. (14 CFR 91.155) **Cannot apply dispersants at night** (2007 Tanker C-plan).	Not applicable.

In-situ Burning

Like dispersant use, the effectiveness of in-situ burning is impacted by numerous factors, including the environmental factors selected for the response analysis as well as oil weathering, precipitation, and oil thickness. Oil slicks usually require containment to create a thick enough slick to burn, subjecting in-situ burning to some of the same constraints as mechanical open-water recovery in terms of wind and waves impacting the containment boom.

Slick thickness and oil weathering are considered to be the critical factors in determining the effectiveness of in-situ burning, and have been the focus of the literature to date. These topics are not included in this analysis; while sea state could be an indicator of how quickly spilled oil will weather, this cannot be extrapolated from the data available.

One report shows a link between the relative impact of sea state depending on the degree of emulsification of the oil. In wave tank tests at Prudhoe Bay, "increasing wave steepness (or wave energy) appeared to reduce both burn rates and burn efficiencies of the unemulsified oil slicks. For emulsified slicks, increasing wave steepness did not appear to appreciably affect the oil burning rates, but did reduce the oil removal efficiencies" (Buist et al. 1997).

The success of an in-situ burn relies on tracking the slick, accessing it for ignition (from an aircraft or vessel), successful ignition, and a sustained burn that achieves the desired result. Conditions therefore need to be amenable during the course of the burn and, if required, for subsequent residue collection (Buist et al. 2003).

Table 2 summarizes the ways in which the selected environmental factors can impact in-situ burning.

Table 2. Impact of Select Environmental Factors on In-situ Burning

Factors	Containment	Ignition Platform	Ignition and Burning
WIND (knots)	Conditions are "unfavorable" at 20 knots and marginal from 10-20 knots (Buist et al. 2003 15-18 knots for boom failure (Tedeschi 1999 in Fingas 2004).	No literature to cite.	Maximum 20 knots or it is difficult to ignite oil and sustain a burn, due in part to the wind-driven waves created (Buist et al. 2003). Maximum 11-16 knots (Allen 1988 in Fingas 2004). Maximum 16-21 knots (no waves[4]) for pools of oil or 19-23 knots for large slicks (Buist 2003, Buist 1999). 17-21 knots (Allen and Ferek 1993). Less than 20 knots (In-Situ Burning Guidelines for Alaska 2001[5] and ACS 2007). **Maximum 20 knots to ignite or maintain burn** (2007 Tanker C-plan, ASTM 2003). Maximum 40 knots (Fingas 2004).
SEA STATE (feet)	3 ft. (Fingas and Punt 2000). 3.2 ft. (ASTM 2003). "Unfavorable" at 5 ft. seas. Marginal from 3-5 ft., or if very long-period swells, then 6 ft. (Buist et al. 2003). **Maximum 10 ft. waves with strong tides/currents** (2007 Tanker C-plan).	No effect on aircraft. For vessel application, must be safe to operate the vessel in use.	2-3 ft. (Florida DEP 1999 and ACS 2007). 3 ft. if choppy, 5.7 ft. if swells (In-Situ Burning Guidelines for Alaska 2001). 3-6.5 ft. significant wave height or less, assuming containment is achieved and maintained (Buist 2003, Buist 1999) 4 ft. (Allen 1988). 4.1-8.2 ft. (Allen and Ferek 1993).

Factors	Containment	Ignition Platform	Ignition and Burning
AIR TEMP. (ºF)	2007 Tanker C-plan submittal says **"no appreciable impact."**	No literature to cite.	Successful *in situ* burns have been conducted at ambient temperatures from 30.2º - 59º, with little or no loss of efficiency (NRT 1997). This does not define a limit, however.
VISIBILITY (nautical miles)	**Not in darkness if can't see to tow, contain, ignite, and monitor burn; but c-plan doesn't specifically restrict burning to daylight hours though says UC might** (2007 Tanker C-plan submittal).	Helicopter: 2.2 nm visibility required per Visual Flight Rules (Buist 2003, Buist 1999).	In general, burning should be done in daylight only, not in heavy rain or if rain is forecasted during the burn (Buist et al. 2003).

Recommended Response Limits

As with mechanical response, specifying environmental conditions which would preclude a non-mechanical response is largely subjective. Based on the findings shown in Tables 1 and 2 and best professional judgment, Nuka Research proposes the following response limits for use in the non-mechanical response gap estimate.

It is important to note that much of the information on non-mechanical response comes from laboratory or small-scale tests; however, it is appears that the better-established limits related to containment and the platforms anyway.

Dispersants

The limits will be based on dispersant application by aircraft, rather than vessel. For aircraft application, ceiling is a key limiting factor that is omitted from this gap analysis due to lack of data. It is also important to note that flying conditions must be suitable at the take-off from Anchorage or Valdez and en route, but the response gap analysis conducted will focus only on conditions at the hypothetical spill site. Weather conditions could also limit or preclude accurate monitoring operations. Finally, both dispersants stockpiled by the PWS shippers must be stored at -30ºF or above (EPA 2007).

Response limits for the purpose of the response gap analysis are proposed for dispersant use in Table 3.

Table 3. Response Limits for Dispersants

Environmental Factor	Green Response Not Impaired	Yellow Response Impaired	Red Response Not Possible/Effective
Wind (knots)	≥ 6 to < 22	≥ 0 to < 6 or ≥ 22 to < 28	≥ 28
Sea State (feet)	≥ 1 to < 11	< 1	≥11
Temperature (ºF)	No practical limits		
Visibility (nautical miles)	> 2 (daylight)	≥ 1 to ≤ 2	< 1 (civil twilight darkness)

In-situ Burning

Response limits for the purpose of the response gap analysis are proposed for in-situ burning in Table 4.

Table 4. Response Limits for In-situ Burning

Environmental Factor	Green Response Not Impaired	Yellow Response Impaired	Red Response Not Possible/Effective
Wind (knots)	< 15	≥15 to <20	≥ 20
Sea State (feet)	< 3	≥ 3 to < 6	≥ 6
Temperature (ºF)	≥ 26 at any wind speed, or otherwise as not included in yellow or red conditions	>16 to < 26 and wind speed ≥ 12 knots	≤ 16 and wind speed ≥ 5 knots
Visibility (nautical miles)	≥ 0.5 (daylight)		< 0.5 (civil twilight darkness)

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