Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part D: Florida Straits

Section D-III.2

by

Deborah French McCay, Nicole Whittier, Colleen Dalton, Jill Rowe,
S. Sankaranarayanan and Hyun-Sook Kim
Applied Science Associates
70 Dean Knauss Drive
Narragansett, RI 02882
Voc: 401-789-6224
Fax: 401-789-1932

Donald Aurand, Russell Piovesan and Michael Hitchings
Ecosystem Management & Associates, Inc.
Ship Point Business Park
13325 Rousby Hall Road
Lusby, MD 20657

Jacqueline Michel and Christine Lord
Research Planning, Inc. (RPI)
P. O. Box 328
Columbia, SC 29202

Robert Unsworth and Rachel Levine
Industrial Economics Inc. (IEC)
2067 Massachusetts Ave.
Cambridge, MA 02140

for Submission to:
National Transportation Systems Center (DTS-852)
55 Broadway
Kendall Square
Cambridge, MA 02142

ASA 00-246

August 2004

Table of Contents

List of Tables

D-III.2 Air Concentrations from In-Situ Burning

Section A.5.2 of Part A describes the methods used to evaluate emissions from ISB and their potential effects on air quality. For scenarios involving ISB, the maximum potential amount of oil burned was assumed to be 25% by volume of the amount of oil mechanically removed (see Section A.3.7). The amount burned was calculated for each scenario since the percent of oil mechanically removed varies for each of the 100 stochastic runs. The 50th and 95th percentiles of the volumes mechanically cleaned up (for the 100 stochastic runs) were multiplied by 0.25 to calculate the 50th and 95th percentile volumes burned by ISB. The atmospheric concentrations of compounds and particulates released by an in-situ burn are dependent upon both the distance from and the area of the fire. All chemicals in the emissions that might be of concern are considered in the analysis.

D-III.2.1 Medium Volume Spills

The estimated distances from an in-situ burn to thresholds of concern are tabulated below. The maximum burn areas for each scenario were calculated by dividing the burn volume by the minimum oil thickness required for burning (3 mm). Burn areas were calculated for all 100 runs for each scenario. Table D-III.2-1 shows, for each of the three medium volume scenarios, the percentage of simulations whose calculated burn area (burn volume divided by 3 mm) is less than the maximum possible burn area of 500 m^2. For these three scenarios, some of the individual simulations have burn areas smaller than 500 m^2. The effect of the dispersant application on the area of oil requiring burning is apparent from the numbers in the table. When no dispersant is applied (0% dispersant efficiency), 9% of the simulations have burn areas smaller than 500 m^2. For 45% dispersant efficiency, 93% of the burn areas are smaller than 500 m^2, and the same is true for 80% dispersant efficiency. Therefore, the results show that the more efficient the dispersant, the smaller the area of oil is that needs to be burned. This is not a surprising result, as dispersant removes oil from the surface of the water, decreasing the amount of oil that remains on the surface, and thereby decreasing the area of oil that needs to be burned.

Table D-III.2-1. Percentile where burn volume, divided by 3 mm, is less than the maximum burn area of 500 m^2, for each medium volume scenario.

Scenario	Percentile
Medium Volume, 0% Dispersant Efficiency	9%
Medium Volume, 45% Dispersant Efficiency	93%
Medium Volume, 80% Dispersant Efficiency	93%

Table D-III.2-2 shows, for each medium volume scenario, the number of burns that would be necessary to burn the entire amount of oil that was designated for burning. A range of oil thicknesses are shown in Table D-III.2-2: between 3 mm and 10 cm (100 mm). Three mm is the minimum thickness of oil required for in-situ oil burning (Buist et al., 1994). However, 10 cm is a more preferable oil thickness for burning (Allen, 2002). If one burn can be accomplished at less than 10 cm thick and 500 m^2 of area (i.e., the burn volume is < 50 m^3), it is assumed that this occurs and the actual thickness is calculated from volume burned divided by 500 m^2. However, if the calculated thickness for one burn is <3mm, the minimum (i.e., the burn volume is < 1.5 m^3), the burn area is instead the burn volume divided by 3 mm.

Table D-III.2-2. Assumed burn thickness for medium volume spill scenarios and number of burns needed to burn the oil, assuming the maximum burn area is 500 m^2.

Scenario		Total Volume Burned (m^3)	Burn Area (m^2)	Oil thickness (mm)	Number of Burns
Medium Volume, 0% Dispersant Efficiency	50th Percentile	14.7	500	30	1
	95th Percentile	23.4	500	47	1
Medium Volume, 45% Dispersant Efficiency	50th Percentile	0	500	-	0
	95th Percentile	1.82	500	4	1
Medium Volume, 80% Dispersant Efficiency	50th Percentile	0	500	-	0
	95th Percentile	1.82	500	4	1

In all cases (Table E.5.12-2), the burn volumes are less than 50 m^3, the maximum volume for a single burn. For cases where there is a burn, none of the burn volumes are less than 1.5 m^3, so all the burn areas are 500 m^2. The distance-to-threshold calculations reported below assume an area per burn of 500 m^2.

Table D-III.2-3 reports calculations of distance to the air quality thresholds for the chemicals of concern that are released when oil is burned. There are three thresholds in these tables: IDLH, TWA, and EPA NAAQS (Primary and Secondary Standards). These thresholds were described and listed in Table A.5-5. The chemicals listed in Table D-III.2-3 were designated by Fingas, et al. (2001) as being of concern, and they are split into five chemical classes: total particulates, fixed gases, carbonyls, PAHs, and VOCs. For those chemicals for which U.S. air quality standards were not available, we have assumed the lowest of the available thresholds within that chemical class. For example, we do not have an IDLH threshold value for butane, a member of the VOC chemical class, but we do have IDLH values for several other members of the VOC class. We selected the lowest of the available IDLH values for the VOCs and used that value as an IDLH threshold for butane and other chemicals in the VOC class for which we are missing threshold values. We used the same strategy for the PAH chemical class as well. This substitution method provides an estimate of the distance to the threshold for those chemicals for which threshold data are not available. However, because those threshold values are just assumed estimates, the distance values in the following tables that were derived using these threshold values are shaded gray.

It should also be noted that three different TWA threshold values were obtained for this study: ACGIH TLV, OSHA PEL, and NIOSH REL. We calculated the distance to the threshold for each of these, but we present only the maximum of the three distances in these tables. For example, in Table D-III.2-3, for formaldehyde, the distance to the ACGIH TLV threshold is 237 m, to the OSHA PEL threshold is 0 m, and to the NIOSH REL threshold is 89 m. The maximum of these three distances is 237 m, which is the TWA value reported in the table.

Table D-III.2-3 shows the distance-to-threshold calculations for an individual 500 m^2 burn. In the table, the calculated distances represent the distance (from the center of the fire) at which the concentration of each chemical has decreased to the threshold level. In the case of sulphur dioxide in Table D-III.2-3, the distance at which the concentration of sulphur dioxide in the air equals the IDLH threshold is essentially zero, meaning that the concentration of sulphur dioxide produced by the 500-m^2 fire never exceeds the IDLH threshold. However, for the other thresholds in the table (TWA and EPA NAAQS), the concentrations do exceed the thresholds and do not decrease to the threshold level until 331 m, 471 m, and 440 m from the center of the fire.

Table D-III.2-3 shows that, for a 500-m^2 burn area, the total particulates, fixed gases, and carbonyls are of the greatest concern (i.e., the distances from the fire to the threshold level are greatest). The majority of other chemicals have distances of zero meters to the threshold level, meaning that their concentrations never exceed the threshold. Acetone has the largest distance to the threshold, at 710 m, and acetaldehyde and the total particulates are the next largest.

In Table D-III.2-3 there are four additional chemicals with distances to the threshold that stand out: 2-methylbutane, 3-methylhexane, 3-methylpentane, and methylcyclopentane. However, as can be seen from the tables, these values are shaded gray because we did not have a regulatory threshold value for them. Instead, we used the lowest threshold value from within their group (VOCs). From this, we can conclude that their distance to threshold values *may* represent that they are chemicals whose concentrations will still be above threshold levels far from the fire, or it may be that the threshold estimates used for the distance-to-threshold calculation are unreasonably low and our estimate method is not suitable for these chemicals.

Table D-III.2-3. Estimated distances (m) from fire to the thresholds of concern for the 50th and 95th percentile volumes for ISB for burn area of 500 m^2. For those chemicals for which U.S. air quality standards were not available, the smallest of the available thresholds within that chemical class is assumed, and the results are shaded in gray.

	Distance to the Threshold (m)			
Substances	**IDLH**	**TWA**	**EPA NAAQS**	
			Primary Standard	**Secondary Standard**
Total Particulates				
10-um particle			514	514
2.5-um particle			523	523
Fixed gases				
Sulphur Dioxide	0	331	471	440
Carbon Dioxide	0	0		
Carbon Monoxide	0	0	0	
Carbonyls				
Acetaldehyde	0	525		
Acetone	0	710		
Formaldehyde	0	237		
PAHs				
1- Methylnaphthalene	0	0		
1-Methylphenanthrene	0	0		
2,3,5-Trimethylnaphthalene	0	0		
2,6-Dimethylnaphthalene	0	0		
2-Methylnaphthalene	0	0		
Acenaphthene	0	0		
Acenaphthylene	0	0		
Anthracene	0	0		
Benz(a)anthracene	0	0		
Benzo(a)pyrene	0	0		
Benzo(b) fluoranthene	0	0		
Benzo(e) pyrene	0	0		
Benzo(g,h,I) perylene	0	0		

Biphenyl	0	0		
Chrysene	0	0		
Dibenz(a,h)anthracene	0	0		
Dimethylnaphthalenes	0	0		
Fluoranthene	0	0		
Fluorene	0	0		
Indenol(1,2,3-cd)pyrene	0	0		
Methylphenanthrenes	0	0		
Naphthalene	0	0		
Perylene	0	0		
Phenanthrene	0	0		
Pyrene	0	0		
Trimethylnaphthalenes	0	0		
VOCs				
1,2,3-Trimethylbenzene	0	0		
1,2,4-Trimethylbenzene	0	0		
1,3,5-Trimethylbenzene	0	0		
1,4-Diethylbenzene	0	0		
2,2,3-Trimethylbutane	0	0		
2,2,4-Trimethylpentane	0	0		
2,2,5-Trimethylhexane	0	0		
2,2-Dimethylbutane	0	0		
2,2-Dimethylpropane	0	0		
2,3,4-Trimethylpentane	0	0		
2,3-Dimethylbutane	0	1		
2,3-Dimethylpentane	0	1		
2,4-Dimethylhexane	0	0		
2,4-Dimethylpentane	0	0		
2,5-Dimethylhexane	0	0		
2-Ethyltoluene	0	0		
2-Methylbutane	0	165		
2-Methylheptane	0	4		
3-Methylhexane	0	42		
3-Methylpentane	0	85		
4-Ethyltoluene	0	0		
4-Methylheptane	0	0		
Benzene	0	0		
Butane	0	1		
c-1,3-Dimethylcyclohexane	0	0		
c-1,4/t-1,3-Dimethylcyclohexane	0	0		
c-2-Butene	0	0		
Cyclohexane	0	0		
Cyclopentane	0	0		

Decane	0	0		
Dodecane	0	0		
Ethylbenzene	0	0		
Heptane	0	0		
Indan (2,3-Dihydroindene)	0	0		
Isobutane (2-Methylpropane)	0	0		
m,p-xylene	0	0		
Methylcyclohexane	0	0		
Methylcyclopentane	0	92		
Naphthalene	0	0		
n-Butylbenzene	0	0		
Nonane	0	0		
n-Propylbenzene	0	0		
Octane	0	0		
o-Xylene	0	0		
p-Cymene (1-Methyl-4-iso-propylbenzene)	0	0		
Pentane	0	0		
Propane	0	0		
Propene	0	0		
2,2-Dimethylpentane	0	0		
iso-Butylbenzene	0	0		
Isoprene (2-Methyl-1,3-Butadiene)	0	0		
iso-Propylbenzene	0	0		
Undecane	0	0		

The ISB effects are summarized in Table D-III.2-4. The affected area is calculated by assuming the circular area around each burn is affected to the maximum distance to any air quality threshold (i.e., this distance is the circle radius) and multiplying the circular area per burn by the number of burns. The percent of the region of interest is calculated using the province area in Table A.4-4.

Table D-III.2-4. Estimation of area affected by ISB, for medium volume spills by dispersant scenario and for 50th and 95th percentile burn volumes.

Dispersant % Efficiency		**0**	**45**	**80**
Burn Area (m^2)	50th	500	0	0
	95th	500	500	500
Maximum Distance (m) to Threshold (1 burn)	50th	710	0	0
	95th	710	710	710
# of Burns	50th	1	0	0
	95th	1	1	1
Area (km^2) Exposed (assuming circle with radius = maximum distance)	50th	1.584	0	0
	95th	1.584	1.584	1.584
Percent of Province Area	50th	0.004	0.000	0.000
	95th	0.004	0.004	0.004

D-III.2.2 Large Volume Spills

The estimated distances from an in-situ burn to thresholds of concern for the large volume scenarios are below. Burn areas were calculated for all 100 runs for each scenario. Table D-III.2-5 lists, for each of the three large volume scenarios, the percentage of simulations whose calculated burn area (burn volume divided by 3 mm) is less than the maximum burn area of 500 m^2. This table shows that for the three scenarios in which the large volume of 40,000 bbl of crude oil was released, burn areas are larger than 500 m^2, regardless of the dispersant efficiency, with the exception of 1% of cases for the 80% dispersant efficiency.

Table D-III.2-5. Percentile where burn volume, divided by 3 mm, is less than the maximum burn area of 500 m^2, for each large volume scenario.

Scenario	Percentile
Large Volume, 0% Dispersant Efficiency	0%
Large Volume, 45% Dispersant Efficiency	0%
Large Volume, 80% Dispersant Efficiency	1%

Table D-III.2-6 shows, for each large volume scenario, the number of burns that would be necessary to burn the entire amount of oil that was designated for burning. The number of burns was calculated by dividing the burn volume (Table D-III.1.7) by the assumed oil thickness of 10 cm and then dividing this number into the maximum area allowed per burn (500 m^2).

The large volume cases with a thickness greater than 100 mm (Table D-III.2-6) will require multiple burns (1 – 10) to remove all the oil. The effectiveness of dispersant application in reducing the amount of oil needing to be burned can be seen in Table D-III.2-6. The table shows that the more efficient the dispersant is, the fewer the number of burns required to remove the oil.

Table D-III.2-6. Assumed burn thickness for large volume spill scenarios and number of burns needed to burn the oil, assuming the maximum burn area is 500 m^2.

Scenario		Total Volume Burned (m^3)	Burn Area (m^2)	Oil thickness (mm)	Number of Burns
Large Volume, 0% Dispersant Efficiency	50th Percentile	367.6	500	100	8
	95th Percentile	464.8	500	100	10
Large Volume, 45% Dispersant Efficiency	50th Percentile	46.2	500	93	1
	95th Percentile	105.1	500	100	3
Large Volume, 80% Dispersant Efficiency	50th Percentile	18.1	500	37	1
	95th Percentile	32.3	500	65	1

Table D-III.2-3 shows distance-to-threshold calculations, in meters, for an individual 500-m^2 burn. Descriptions of Table D-III.2-3 and its results can be found in the previous section.

The distances to the threshold would apply to each burn. Thus, the effect is proportional to the number of burns. Table D-III.2-6 indicates that on average (50th percentile) the air quality effect is reduced by 7/8 if dispersant is applied with either 45% or 80% efficiency.

The ISB effects are summarized in Table D-III.2-7. The affected area is calculated by assuming the circular area around each burn is affected to the maximum distance to any air quality threshold (i.e., this distance is the circle radius) and multiplying the circular area per burn by the number of burns. The percent of the region of interest is calculated using the province area in Table A.4-4.

Table D-III.2-7. Estimation of area affected by ISB, for large volume spills by dispersant scenario and for 50th and 95th percentile burn volumes.

Dispersant % Efficiency		**0**	**45**	**80**
Burn Area (m^2)	50th	500	500	500
	95th	500	500	500
Maximum Distance (m) to Threshold (1 burn)	50th	710	710	710
	95th	710	710	710
# of Burns	50th	8	1	1
	95th	10	3	2
Area (km^2) Exposed (assuming circle with radius = maximum distance)	50th	12.67	1.58	1.58
	95th	15.84	4.75	3.17
Percent of Province Area	50th	0.03	0.00	0.00
	95th	0.04	0.01	0.01