AERIAL OBSERVATIONS OF OIL AT SEA

HAZMAT Report 96-7

April 1996

Modeling and Simulation Studies Branch
Hazardous Materials Response and Assessment Division
Office of Ocean Resources Conservation and Assessment
National Oceanic and Atmospheric Administration
Seattle, Washington

Disclaimer

Contents

Tables

Figures

INTRODUCTION

During the initial phases of an oil spill response, information about the release is often extremely sketchy. Although various types of remote sensing techniques are available for detecting and mapping oil distribution, the most reliable technique is visual observations from aircraft.[1] These observations are used by the response team to forecast subsequent oil movement, implement appropriate oil spill countermeasures, and inform the wider response community of the present status of pollution distribution.

Although overflights can be a valuable tool in the response effort, reports from different observers can vary widely. This problem is particularly apparent during major spills, when many observers report oil-position data from overflights. Many of these observers are untrained and have little experience identifying and quantifying oil floating on the sea. As the spill progresses, a surprising number of false positive sightings may be reported. Ice, internal waves, kelp beds, natural organics, pollen, plankton blooms, cloud shadows, jellyfish, algae, and guano washing off rocks have all been reported as oil by untrained observers. These false reports obscure knowledge of the actual location and description of the spill. Some of these problems can be minimized if observers use a common reporting standard (Pavia and Payton 1983, McFarland et al. 1993).

OIL SPILL TERMINOLOGY

For many years the Hazardous Materials Response and Assessment Divisionof the National Oceanic and Atmospheric Administration (NOAA) has tracked and forecasted the movement of oil spills. Through these experiences, we have developed in-house guidelines for aerial observations of oil slicks. The intent of this section is to provide:

- ✰ a uniform terminology for describing oil sightings,
- ✰ techniques for planning observational overflights, and
- ✰ a data format for reporting spill observations.

---

[1] A number of remote sensing systems are available (e.g., side-looking airborne radar, laser fluorescence, microwave radiometer, infrared-ultraviolet line scanner, and LANDSAT satellite systems). However, problems associated with each of these systems preclude their exclusive use during oil spills.

The terminology used to describe oil spilled in the marine environment is often inconsistent. Although attempts have been made to standardize terms (ITOPF 1981; Pavia and Payton 1983; Gillot 1988), there is no universally accepted terminology. As a result of our oil-pill experiences, NOAA has developed a general glossary of terms to describe the appearance of oil floating on the water (Table 1). To understand the significance of each of these terms, some general knowledge of the physical processes controlling the movement and fate of the oil is helpful.

Table 1. General glossary of terms to be used in oil spill observations.

Light Sheen	A light, almost transparent layer of oil. Sometime confused with windrows and natural sheen resulting from biological processes. Sometimes referred as transparent sheen.
Silver Sheen	A slightly thicker layer of oil that appears silvery or shimmers. Occasionally called gray sheen.
Rainbow Sheen	Sheen that reflects colors
Brown Oil	Typically a 0.1- to 1.0-mm thick layer of water-in-oil emulsion. (thickness can vary widely depending on wind and current conditions). Maybe referred as heavy or dull colored sheens.
Mousse	Water-in-oil emulsion often formed as oil weathers: colors can range from orange or tan to dark brown.
Black Oil	Area of black colored oil sometimes appearing with a latex texture. Often confused with kelp beds and other natural phenomenon.
Streamers	Oil or sheen oriented in lines, windrows or streaks. Brown oil and mousse can be easily confused with algae scum collecting in convergence lines, algae patches, or mats of kelp or fucus. Sometimes called streaks, stringers or fingers.
Tarballs	Weathered oil that has formed a pliable ball. Size may vary from pinhead to about 30 cm. Sheen may or may not be present.
Tarmats	Non-floating mats of oily debris (usually sediment and/or plant matter) that are found on beaches or in shallow water just offshore.
Pancakes	An isolated patch of oil shaped in a mostly circular fashion, pancakes can range in size from a few meters across to hundreds of meters in diameter. Sheen may or may not be present.

During the first few hours of a major release, the primary process affecting the movement of oil is spreading (Payne and McNabb 1984). The oil is still relatively fluid at the start of the spill and, particularly for lighter products, will spread rapidly into a thin film that is typically a few microns thick. Since the thickness of the film is on the order of the wavelength of visible light, the reflection of sunlight off the thin oil film and the resulting colors can give some indication of oil thickness. Under laboratory conditions using artificial light, standards have been developed that give approximate oil thickness based on the color or appearance of the oil film on water (Table 2) (Fingas 1979, Schriel 1987, Gillot 1988).

Although it is tempting to try to estimate the volume of oil observed on an overflight based on oil color and the surface area of the floating oil, several complicating factors make this technique unreliable. For example, very light crudes and light refined products (e.g., gasoline and diesel) will quickly spread into very thin films when spilled. Under ideal lighting conditions, these films will appear as bright colors or *rainbow sheens*.[2] As shown in Table 1, a bright color sheen is approximately 0.3 microns thick. In reality, the appearance and color of the oil sheen varies with the amount of available sunlight, sea surface state, and viewing angle. Because lighting conditions are highly variable during an actual spill, oil thickness observations based on the color of the slick are generally not reliable. Glare due to very low sun angles and sunlight directly overhead can make observations particularly difficult due to poor contrast between the oil sheen and water. Additionally, observations of the oil slick can be hampered by viewing in an up-sun direction, wearing sun glasses or face shields, or looking through Plexiglas windows.

Table 2. Oil Spill Observation Glossary*

	Approximate Layer-Thickness		Approximate Volume per Acrea	
	millimeters	inches	liters/km^2	gallons/nm^2
barely visible	0.00004	0.000002	50	40
silver sheen	0.00007	0.000003	100	75
first color trace	0.0001	0.000004	200	150
bright colors	0.0003	0.00001	400	300
dull colors	0.001	0.00004	1,200	1,000
dark colors	0.003	0.0001	3,600	3,000

*Reproduced from the "Oil Spill Slide Rule," ©1985 Government Publishing Office The Hague/The Netherlands

In our example, sheens could easily be interpreted as a *silver sheen* under low light conditions which, according to the table, is significantly thinner then a sheen containing bright colors. An estimate of quantity of oil using this method would therefore, be under

[2] Italicized terms are defined in Table 1.

estimated. Moreover, the major amounts of oil will usually be in the *black* or *brown* portion of the slick with thicknesses that can range from 0.1 millimeter to several millimeters without a change in color.

Other factors that make this technique unreliable are the on-scene weather and difficulties inherent in estimating area of coverage. Waves will increase natural dispersion during the early parts of the spill, break the surface tension that causes the oil to look "slick," and mix some of the oil into the surface layer temporarily. Under calm sea conditions, an observer will probably view most of the floating oil. A few hours later, if the wind has increased and breaking waves have developed, it is not unusual for an observer to report significantly less oil due to overwashing of the oil by waves even though the amount of floating oil probably has not changed. Observers should note that as the wind speed increases, the observers' ability to detect the oil decreases (Ministry of Transport 1992).

As the spill progresses, a combination of wind drift and surface currents (advection), rather than the initial spreading process, will dominate the thickness distribution of the oil. When the wind begins to blow over the surface of the water, wind-generated waves are formed. Energy and momentum from the smaller (capillary) waves are absorbed by the oil film causing the oil to appear "slick." Wave action will continue to stretch and recompress the oil film and, over time, the film will eventually tear apart into smaller patches. These patches often appear as streaks of oil or *streamers*. The thicker patches of oil within the streamers absorb the wave energy and momentum better than the thinner sheens, hence, heavier concentrations of oil will sometimes appear to be "leading" and sheens "trailing." Once the oil films are torn apart and compressed into streamers, thickness distribution of the oil becomes even more patchy and difficult to estimate.

After oil spends even a short time floating on the ocean surface, it starts to change its physical characteristics due to various physical, biological, and chemical processes. These processes are collectively referred to as “oil weathering.” Initially, the more volatile components of the oil evaporate and, to a lesser extent, some fraction of the oil will dissolve into the water column. This process will continue and, for very light crudes and light refined products, it may eventually account for the loss of a major fraction of the pollutant.

For heavier crude oils, the weathered oil is more likely to reach a stage where it can form a water-in-oil emulsion or *mousse*. As mousse forms, the viscosity of the mixture increases rapidly and the color changes from black to a range of colors from dark brown to tan or orange. Depending on its viscosity and age, the mousse may or may not have an associated sheen. In addition, mousse formation may lead to a water-in-oil mixture that is up to about 75 percent water. This effectively quadruples the size of the spill and, since this mixture may be as viscous as peanut butter, the problems of cleanup and recovery are magnified.

Eventually, the weathered oil will fragment into smaller patches of oil that can vary in diameter from less than one meter, referred to as *tarballs*, to hundreds of meters, called *pancakes*. At this point, visually defining the leading edge of the spill becomes very difficult as little or no visible sheen is associated with the weathered oil. If the pancakes or tarballs are overwashed by breaking waves, observations become even more difficult. As the oil continues to weather, the pancakes and tarballs may continue to break down into smaller and smaller patches (approximately coin size) that become even more widely dispersed. Usually, these tarballs are still buoyant and, therefore, constrained to the water surface. If there is a line of convergence of surface water, as often happens where large rivers flow into the ocean or where there is a sharp change in the bathymetry, the oil can be concentrated along this line. This makes it possible for oil slicks to literally reconstitute themselves as a threat even after they have dispersed to very low concentration levels. On larger spills, this can happen hundreds of kilometers from the original sources. Because these convergence lines are natural collection points for oil and oily debris, observers should carefully note their locations. The fact that oil can collect at these zones is important for oil skimming operations, particularly if the convergence zone is persistent. These zones can be identified by changes in the water color or by debris, seaweed, or foam that has collected at the surface.

In general, any oil is subject to the processes outlined above but there are significant variations for particular types of refined products and some crude oils. Light refined products such as gasoline, jet fuel, and diesel typically have very high evaporation rates and do not create persistent slicks. These types of spills typically create rainbow and silver sheens. If they reach a coastline within a few hours, a slight staining, or soot-like bathtub ring (in the case of diesel) is common.

Heavy refined products such as intermediate fuel oils (IFO) and bunkers are, in some ways, the opposite of the lighter oils. The refining process has removed the lighter components and left them somewhat pre-weathered. As a result, their properties don't change as much as lighter oils' as they age and so may result in quite persistent floating-pollutant problems. These oils can form a mousse, but usually only slowly, and after a period of days. They may not spread into thin films; rather, they often break up into smaller pancakes and then tarballs.

It is also common for these oils to have lost enough of their light ends so that they do not rapidly form sheens. The resulting tarball fields are very difficult to observe using either visual or remote sensing techniques (Pearlman et al. 1992). This, combined with the persistence of the tarballs, makes these kinds of spills quite likely to cause long-range, and occasionally unexpected, beach impacts.

There are a few crude oils and some heavier fuel oils that are heavier then water and thus don't float. These sinking oils are rare and documented observations of them are even more rare but, from the few instances where oil has sunk, what typically appears on the water surface is a *light sheen* near the source of the spill. Visual observation of submerged oil is extremely difficult unless the water is very clear and shallow.

Spill characteristics appear differently under low light conditions and under strong winds conditions. Observations in an up-sun direction are typically difficult to interpret. New observers should be trained by experienced observers in order to make the proper distinctions between oil types and to properly identify natural phenomenon.

PREPARING FOR AN OVERFLIGHT

An important key to aerial observations is preflight planning. This is particularly crucial during major spills or Spills of National Significance (SONS) where many people require access to overflights. For logistical purposes, people with varying interests may be asked to share overflights. It then becomes critical to identify the mission objectives so that the overflight is successful for everyone onboard. At the beginning of the spill, the objective may be as straightforward as verifying that a release has occurred. This involves flying directly to the incident site, and if there is a release, recording critical information as shown in Figure 1.

As the spill progresses, a number of different objectives may evolve. They may be mapping the distribution and appearance of the oil, verifying modeled forecasts of the oil movement, providing responders with an overview of the incident, or directing cleanup operations. The type and availability of aircraft, frequency of flights, fuel capacity, number of passengers, amount of equipment, and landing needs will vary depending on the reason for the flight. By first clearly defining the mission objectives, aircraft logistics can schedule aircraft best-suited to meet those objectives.

For this paper, we will assume that the mission is to map the distribution and coverage of the floating oil. As discussed in Pavia and Payton (1983), the type of platform selected for oil mapping is often limited by on-scene logistics. At a minimum, the aircraft must have space for two observers (excluding the pilot), visibility from both sides, pilot-observer communications, and adequate navigational aids with which to follow a proposed flight path. Oil that is known to be close to the coastline is best viewed from a helicopter. Ideally, a door or window is removed so that the main observer can view the oil looking straight down, without the finer details of the oil slick being obscured by Plexiglas. For oil further offshore, a multi-engine aircraft may provide a wider margin of safety, longer range, and higher speeds.

Prior to take-off, the observer should become familiar with the spill area. The detail at which this is accomplished depends on the mission objective. For example, if the observer is flying directly to the release site with the objective of seeing the the source of the spill, then familiarization with the area is not critical and a quick review of a map (preferably a nautical chart) is adequate. However, if the observer is planning to map the distribution of the oil then environmental conditions, such as on-scene winds, visibility, sea state, time of day, and surface currents are important considerations.

Oil Spill Observation Form

OBSERVER INFORMATION

Date:	Start and End Time of Overflight:	
Platform (H-65, C-130 etc.):		
Viewing Altitude:		
Filled out by:	Unit:	Phone #:

DESCRIPTION OF SPILL/INCIDENT

Location of source (latitude, longitude):	
Source (platform, vessel, etc.) leaking (Y / N):	
Fire (Y / N):	
Product spilled:	Maximum spill potential:
Orientation of slick:	Slick dimensions:
Colors of the slick:	Estimated percent coverage of oil:
Current Response Activities (on-scene skimmers, boom deployed etc.):	

ON-SCENE WEATHER CONDITIONS

Surface wind speed and direction:	
Sea state:	
Visibility:	Precipitation or fog:

ON-SCENE SURFACE CURRENTS

Surface current direction:
Stage of tide (flooding or ebbing):

Figure 1. Oil observation form.

The on-scene weather important to note during the overflight includes visibility, surface wind speed and direction, and sea state. The pilot can best estimate the surface wind speed and direction or, using the Beaufort Scale, an observer can estimate the wind speed from the sea state. This information is important for oil movement forecasting as well as determining whether the conditions for viewing oil were optimum. For example, restricted visibility due to fog would indicate poor viewing conditions so that the observer may not have seen the entire spill. Strong winds would suggest that a particular crude oil is likely emulsifying or for a fuel oil No. 6 spill, much of the oil may be difficult to view due to overwashing.

Without using current probes[3] or dye markers[4], estimating the speed of the surface current is extremely difficult from an aircraft. However, the observer can estimate the direction of the current by comparing the water movement in relation to a stationary object such as a moored buoy, navigation light or, even better, kelp or sea grass beds. By noting the time of the overflight, the stage of the tide can be estimated from the National Ocean Service (NOS) tidal current and height tables.

Based on the mission objectives, platform, and environmental conditions, an actual flight path should be planned for the area of interest. Although any kind of chart that covers the spill area will work, the most useful will be a nautical chart of an appropriate scale. This type of chart provides information, such as navigational aids, which an observer can use as a reference during the flight for plotting the location of the oil.

There is no general consensus on the best way to overfly an oil slick however, an overflight of a large spill would probably first entail an overview of the slick, perhaps from an altitude of 1,000 to 2,000 feet. At these altitudes, determining the general orientation and dimensions of the slick is much easier than flying at a lower altitude. Estimating the oil coverage and the color of the oil is probably best made by dropping down to an altitude of 200 to 500 feet or less.

---

[3] A current probe is a preassembled set of dye markers, two of which are attached to a weighted timer. As the probe enters the water, a styrofoam plug at the top of the probe is compressed and a dye marker is immediately released. The rest of the probe sinks to the bottom and, after a known amount of time (depending on how the timer was set), another dye marker is released. Assuming that the second dye marker comes to the surface at approximately the same location as the first, the current speed can be estimated by measuring the distance between the dyes.

[4] Dye markers can be deployed near a fixed reference point. The current speed can be estimated by timing the movement of the dye from the time of deployement. By flying directly over the dye, the direction of the current can be determined from the aircraft's compass.

Similarly, there is no consensus on the best time to observe an oil slick but here are some factors to consider. In the early morning or early evening there is often not enough contrast to see some oils clearly. In the middle of the day, the sun may glare off the water surface, making it hard to distinguish oil. The flight track should be set up to minimize the glare with the optimum schedule for mapping oil distribution depending on the angle of the sun (e.g., in mid-latitudes the middle of the morning or afternoon is usually a good viewing time).

REFERENCES

Fingas, M.. 1979. Remote sensing of oil spills, *Spill Technology Newsletter 4(3)*, pp. 191 - 192.

Galt, J. A. 1994. Trajectory Analysis for Oil Spills, *J. Adv. Mar. Tech. Conf. 11*, pp. 91 - 126.

Gillot, A., G. H. R. Aston, P. Bonanzinga, Y. le Gal la Salle, M J. Mason, M. J. O'Neill, J. K. Rudd, D. I. Stonor. 1988. A Field Guide to the Application of Dispersants to Oil Spills. Report No. 2/88. The Hague, The Netherlands: CONCAWE. 64 pp

ITOPF. 1981. Aerial Observations of Oil at Sea. Technical Information Paper No. 1, The international Tanker Owners Pollution Federation LTD. pp. 6

McFarland, B., Murphy, J. and D. Simecek-Beatty. 1993. Conventions for reporting and displaying overflight observations, *Proceedings from the 1993 Oil Spill Conference, (Prevention, Behavior, Control, Cleanup)*, Tampa, Florida, March 29-April 1, 1993,, pp. 789-790.

Ministry of Transport. 1992. Visibility Limits of Oil Discharges: Investigation into the Visibility Limits of Operational Oil Discharges from Ships, Ministry of Transport, Public Works and Water Management, The Netherlands, pp. 43.

Payne, J. and D. McNabb, Jr. 1984. Weathering of petroleum in the marine environment, *Marine Technical Society Journal, 18(3)*, pp. 24-42.

Pavia, R. and D. Payton. 1983. An approach to observing oil at sea, *Proceedings from the 1983 Oil Spill Conference, (Prevention, Behavior, Control, Cleanup),* San Antonio, Texas, February 28-March 3, 1983, pp. 345-348.

Schriel, R. 1987. Operational air surveillance and experiences in the Netherlands, *Proceedings from the 1987 Oil Spill Conference, Tenth Biennial, (Prevention, Behavior, Control, Cleanup),* Baltimore, Maryland, April 6-9, 1987, pp. 129-136.