PROMOTING EFFECTIVE
SPILL RESPONSE

AERIAL OBSERVATION OF MARINE OIL SPILLS

TECHNICAL INFORMATION PAPER

1

Introduction

Aerial reconnaissance is an important element of an effective response to most oil spills, for assessing the location and extent of oil contamination and verifying predictions of the movement and fate of oil slicks at sea. Aerial surveillance provides information facilitating deployment and control of operations at sea, the timely protection of sites along threatened coastlines and the preparation of resources for shoreline clean-up.

This Technical Information Paper presents advice and guidance on conducting effective aerial reconnaissance.

Strategy for aerial observation

At the outset of an incident, reports from reconnaissance flights are often vital to establish the nature and scale of the pollution. Where appropriate, arrangements for flights should be made as a high priority in the initial stages of a response. The strategy for aerial observation and contact details of appropriate agencies and aircraft operators should be key entries in relevant contingency plans.

Following initial mobilisation, subsequent flights should be made regularly (*Figure 1*). These are commonly timed at the beginning or end of each day, so that the results can be used at decision meetings to plan response operations. The flights, including their time-tabling and flight paths, should be coordinated to avoid unnecessary duplication between agencies. As the pollution situation is brought under control the need for flights will reduce and come to an end.

Safety considerations are paramount and the aircraft pilot should be consulted on all aspects of the reconnaissance operation prior to departure. Those taking part in a flight should be regularly and thoroughly briefed beforehand on the safety features of the aircraft and procedures to be followed in the event of an emergency. Suitable personal protective equipment, such as life jackets, should be available and used.

When selecting the most appropriate aircraft, consideration needs to be given to the location of the spill, the nearest airstrip, access to fuel and the distance to be covered in a reconnaissance flight. Any aircraft used for aerial observation must feature good all-round visibility and carry suitable navigational aids. For example, for fixed-wing aircraft, better visibility is afforded by high-mounted wings (*Figure 2*). Over near-shore waters the flexibility of helicopters is an advantage, for instance in surveying an intricate coastline with cliffs, coves and islands. However, over the open sea, there is less need for rapid changes in flying speed, direction and altitude, and the speed and range of fixed-wing aircraft are more advantageous. Aircraft selection should take into account the operating speed, for if this is too fast the ability to observe and record oil will be reduced, and if it is too slow the flying distance will be limited. For surveys over the open sea, the extra margin of safety afforded by a twin or multi-engine aircraft is essential and may, in any case, be required by government regulations.

▲ *Figure 1: Aerial observation will allow the nature and scale of the pollution to be rapidly determined. However, thorough preparation is required to gain the full benefit of flying time.*

The type and size of an aircraft will limit the number of people able to take part in a flight. For small fixed-wing aircraft, and helicopters in particular, the number of passengers can substantially affect fuel consumption and thus the endurance of the aircraft. If there are two or more observers on a surveillance flight, they should work closely together to compare and confirm sightings. The lead observer directing the pilot should be experienced in aerial surveillance and be able to reliably detect, recognise and record oil pollution at sea. There should be a consistency of at least one observer throughout a series of flights, so that variations in reports reflect changes in the state of oil pollution and not differences between the perceptions of the observers.

Figure 2: Twin engine fixed-wing aircraft with high wings are ideal platforms for aerial observation of oil at sea. Helicopters may be preferable for observation closer to shore due to their greater manoeuvrability and slower speeds.

Preparations for aerial observation

Flights should be planned to start and finish with sufficient light to afford observation of the sea surface or shoreline. Weather conditions such as fog, mist, low cloud, snow and heavy rain can also affect surveillance and may mean flying is impractical.

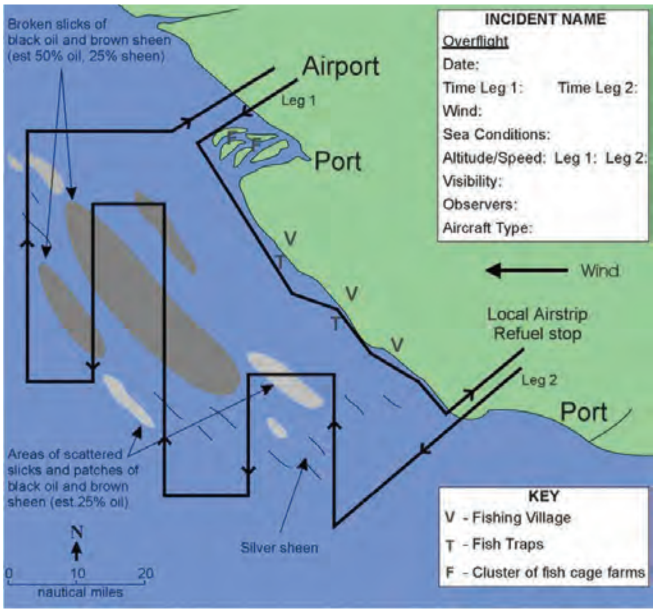


Figure 4: An example map showing the flightpath and extent of observed oil. A range of other features may also be observed and recorded during a reconnaissance flight. These might include response and clean-up activities at sea and on shore, the location of sensitive environmental resources such as wildlife and special habitats, together with commercial interests including amenity areas, industrial sites and mariculture facilities. Drawing the flightpath on the map serves to show which areas have been surveyed. The ladder search pattern shown above was adapted to meet expected oil distribution, visibility and light conditions.

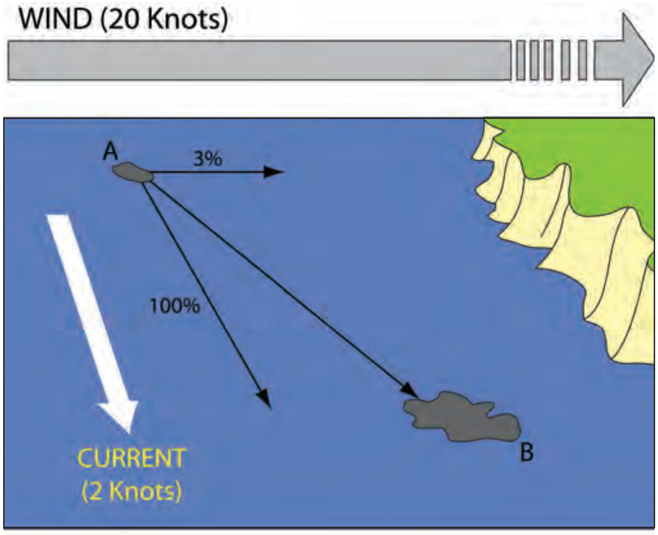


Figure 3: Influence of wind and current on the movement of oil at sea.

A flight plan should be prepared in advance and agreed with the pilot and relevant authorities as appropriate, prior to boarding. This should take account of any available information that may reduce the search area as much as possible, such as the last known sightings and the expected trajectory of the oil. In addition any flight restrictions should be noted, some of which may be specifically imposed as a result of the spill. For example, it may be prohibited to fly over the shipping casualty, foreign or military airspace or

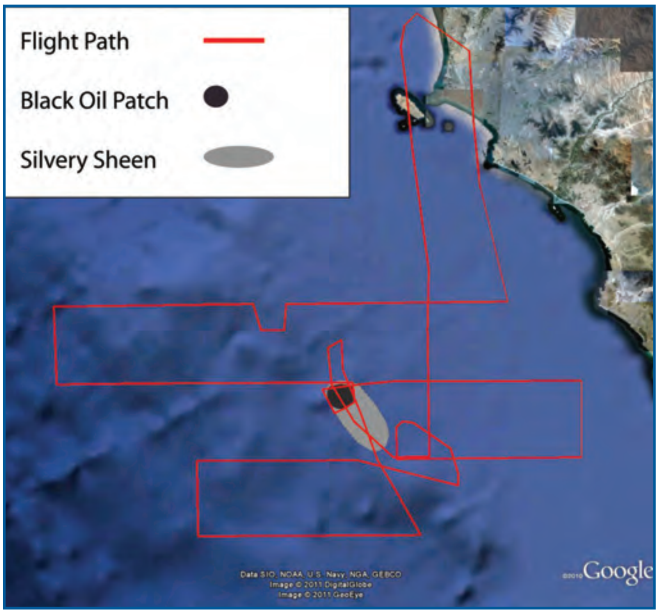


Figure 5: The flight path from an incident in South America mapped onto Google Earth. A basic ladder search from the north was undertaken to locate the oil. The aircraft then circled around the oil to allow closer observation with a subsequent continuation of the ladder search further south to determine the full extent of the slick.

certain environmentally sensitive areas where wildlife may be disturbed (e.g. breeding colonies of birds or seals).

Observations can be recorded on a laptop or tablet computer with relevant maps downloaded from online mapping websites or using electronic shipping charts. A linked portable GPS (Global Positioning System) receiver can be used to mark waypoints to identify the location of observed oil and other notable features. As a back-up to any computer based system, extracts or copies of paper maps and charts of an appropriate scale should be obtained for annotation during the flight. Some basic data may be usefully highlighted, such as the location of the spill source and pertinent coastal features. It may be useful to draw a grid onto the paper map so that any position can be easily identified by grid reference or alternatively by reference to the distance and bearing of a radio beacon.

The task of predicting the position of the oil is simplified if data on winds and currents is available since both contribute to the movement of floating oil. It has been found empirically that floating oil will move downwind at about 3% of the wind velocity. In the presence of surface water currents, an additional movement of the oil at 100% of the current velocity will be superimposed on any wind-driven motion. Close to land, the strength and direction of any tidal currents must be considered when predicting oil movement, whereas further out to sea the contribution of other ocean currents predominate over the cyclic nature of tidal movement. Thus, with knowledge of the prevailing winds and currents, it is possible to predict the speed and direction of movement of floating oil from a known position, as illustrated in Figure 3. Computer based oil spill trajectory models of varying sophistication will plot anticipated trajectories. However, the accuracy of both computer models and simple manual calculations depends on the accuracy of the hydrographic data used and the reliability of forecasts of wind speed and direction.

In view of the errors inherent in oil movement forecasting, it is usually necessary to plan a systematic aerial search to ascertain the presence or absence of oil over a large sea area. A 'ladder search' is frequently the most economical method of surveying an area (*Figures 4 & 5*). When planning a search, due attention must be paid to visibility and altitude, the likely flight duration and fuel availability, together with any other advice the pilot may give. Floating oil has a tendency to become elongated and aligned parallel to the direction of the wind in long and narrow 'windrows' typically 30–50 metres apart. It is advisable to arrange a ladder search across the direction of the prevailing wind to increase the chances of oil detection. The distance between the 'rungs' of the ladder search will be determined by the visibility during the flight.

Figure 6: Features and landmarks (such as promontories and lighthouses) provide clear reference points when surveying a coastline.

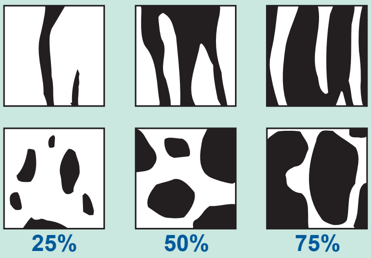
Figure 7: Communication between the aircraft crew and all observers is important to confirm sightings and to discuss changes in the flight plan in the light of observations.

Other considerations are haze and light reflection off the sea, which can affect visibility of the oil. Spotting oil is often easiest with the sun behind the observer and it may prove more profitable to fly a search pattern in a different direction to the one originally planned. Sunglasses with polarising lenses can assist the detection of oil at sea under certain light conditions.

Recording and reporting

Despite making careful predictions and planning a systematic ladder search, the actual pollution observed during the flight may still be different to the situation envisaged. It is important, therefore, for contingencies to be borne in mind and adjustments made during the flight, to maximise the chances of finding the oil and plotting its full extent, while still trying to maintain a logical and efficient flight plan.

The search altitude is generally determined by the prevailing visibility. Over open sea areas, in clear weather 1,000–1,500 feet (300–450 metres) frequently proves to be optimal for maximising the scanned area without losing visual clarity. However, it is necessary to drop to half this height or lower in order to confirm any sightings of floating oil or to analyse its appearance. For helicopters, when used closer to shore, and in the absence of any restrictions imposed by the pilot or by the nature of the coastline, a flight speed of 80–90 knots and an altitude of 400–500 feet (120–150 metres) often proves a useful starting point. Further adjustment may

Feature	Data	Comment
Location and extent	Latitude and longitude (preferably by GPS) for location of slicks GPS readings for centre or edges of large slicks	It is important to retain a sense of scale so that what is observed on the water is not exaggerated when being recorded. It is worth establishing a mental picture of distance on the outward leg of a flight by observing and noting recognisable land features. When observing large areas affected by oil, the presence of any ships is useful in gauging the scale of slicks. Regular reference to GPS readings is useful to confirm estimates made visually.
Colour	For oil slicks: Black, Brown, Orange For sheen: Silver, Iridescent (rainbow)	Colour offers an important indication of oil thickness. For oil slicks, a brown or orange colour indicates likely presence of water-in-oil emulsion. In terms of oil spill response, sheen may be disregarded as it represents a negligible quantity of oil, cannot be recovered or otherwise dealt with to any significant degree by existing response techniques, and is likely to dissipate readily and naturally. Depending on the circumstances, sheen may often be omitted from the final report prepared after the flight.
Character	Windrow, Slick, Patch, Streak	Observers should avoid too many descriptive phrases and should apply their selected terms consistently throughout.
Features	Leading Edge	If the thick oil characterising the leading edge of a slick can be identified, it should be denoted by a heavier line on maps and referenced in accompanying reports.
Coverage		For response efforts to be focused on the most significant areas of oil pollution, it is important to have information on the relative and heaviest concentrations. To avoid distorted views it is necessary to look vertically down on the oil when assessing the distribution. It is difficult to make an accurate assessment of the % coverage and it is advisable not to try to be too precise with the estimation. The diagrams may be used as a reference guide. More experienced observers may be able to interpolate intermediate coverage.

The adoption of common terms can also provide an indication of the amount of oil present in a given area. In combination, the estimate of % coverage together with selected terms, provides a consistent and flexible method of describing the amount of oil in an area to a degree of accuracy sufficient for response decisions to be made.

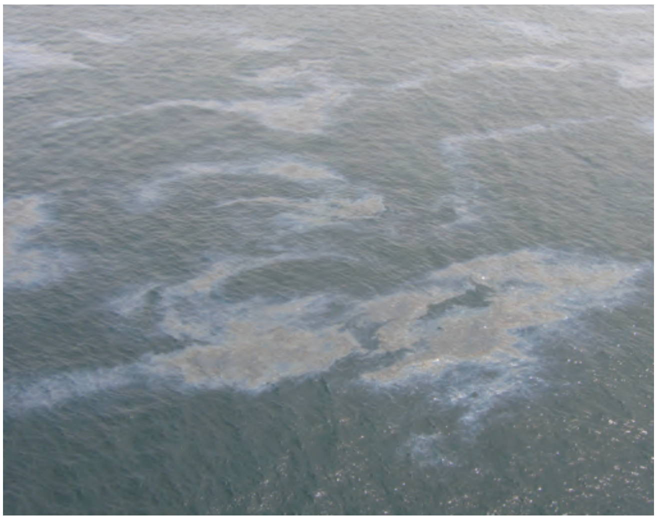
Traces	Scattered	Patchy	Broken	Continuous
<10%	25%	50%	75%	>90%

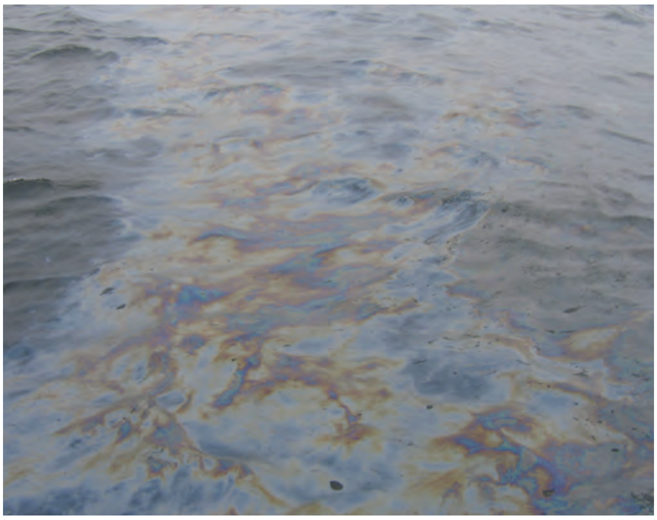
▲ *Table 1: Main features that should be recorded during a surveillance flight.*

then be made as appropriate during the course of the flight.

Portable GPS receivers or GPS fitted within the aircraft enable observers to keep track of the geographic position of the aircraft, so that progress may be monitored allowing any changes that might be necessary in the light of the circumstances noted during the flight. Features and landmarks along the coast may be compared against charts when surveying a shoreline but over open water, away from any obvious reference points, it is easy to become disorientated (*Figure 6*). As a back-up, observers may have the opportunity of consulting aircraft instrumentation to ascertain speed and direction. It is worth ensuring beforehand that reading these instruments will present no difficulty.

Throughout the flight, communication with fellow observers and the pilot is important to monitor progress, confirm observations and to discuss and agree any desired and appropriate adjustments to the flight (*Figure 7*). Instruction from the pilot on the use of headsets should be sought prior to take-off to avoid disruption of the communications with other aircraft and the traffic control authorities.

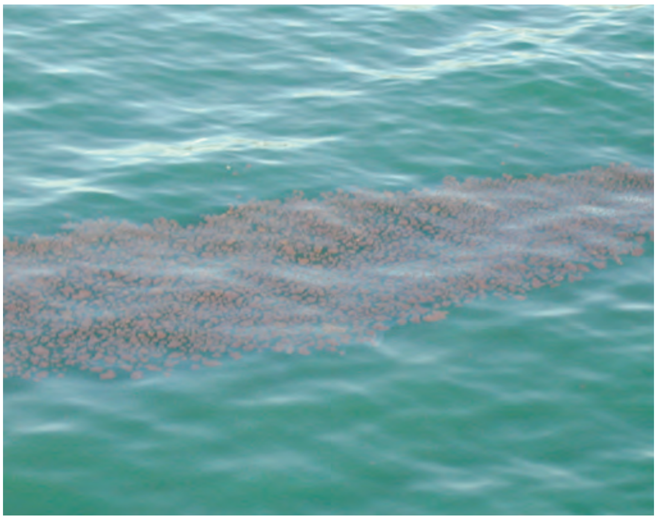




▲ *Figures 8 & 9: Large patches of sheen from a spill of intermediate fuel oil (IFO 180) observed from an aircraft (left) and later the same day at close quarters from a vessel (right). The patches contain areas of thin layers of oil spreading to areas of iridescent sheen and thence to silver sheen.*

▲ *Figure 10: A band of black oil is observed from left to right of the picture. The wind, blowing across the oil, is pushing this band away from the observer resulting in perpendicular windrows of varied sheen.*

▲ *Figure 11: Very large broken slicks of heavy fuel oil - note the absence of sheen.*



▲ *Figure 12: Part of a large slick of brown/orange emulsified heavy fuel oil (IFO 600). After 3–4 weeks at sea the slick started to fragment and after further time has eventually broken up to a large number of small plates and tarballs.*

▲ *Figure 13: Heavy fuel oil spilled as a result of the catastrophic failure of a bulk carrier. The cargo has mixed with the oil making realistic estimations of the volume of spilled oil difficult to determine.*

▲ *Figure 14: Cloud cover resembling patches of black floating oil.*

▲ *Figure 15: Heavy fuel oil arriving at the shoreline. Benthic seagrass and seabed rock formations can confuse estimations of the amount of oil.*

▲ *Figure 16: Patches of fringing coral reef may lead to mistaken reports of oil.*

▲ *Figure 17: Sediment plumes disturbed by currents in a shallow area, resembling patches of emulsified light crude oil.*

▲ *Figure 18: Freshwater run-off from a narrow creek meeting turbid brackish water giving the appearance of significant local pollution.*

▲ *Figure 19: Emulsified heavy fuel oil held against the shore by wind and waves. The thickness of the oil is difficult to estimate as the extent to which the oil is pooling in crevasses between the rocks cannot be readily determined from the air.*

Figure 20: *It is helpful to include vessels or other features in a photograph to give an idea of the scale of the pollution.*

Figure 21: *Light reflection off the sea can sometimes be a problem when taking aerial photographs; UV and polarising filters may help to sharpen the visual definition of oil.*

Digital photographs provide an invaluable record of oil pollution. Whenever possible, features such as ships and the coastline should be included to give an idea of scale (*Figure 20*). Relatively fast shutter speeds (1/500th second) are recommended to avoid blurring from the motion and vibration of the aircraft. UV and polarising filters are often useful to cut down glare and can sometimes assist in sharpening the visual definition of oil on the water, although some polarising filters produce colour distortions through aircraft windows made of plastics (*Figure 21*). Cameras with in-built GPS are useful to maintain a log of photographs taken. Digital images can be rapidly disseminated to a wide audience to assist command and control of the response.

The observations and conclusions on the extent of oiling should be reported promptly after the flight and should provide a clear depiction of the nature and extent of oil pollution at sea and close to the shore. By comparing records from previous flights, an understanding may also be gained on how the situation has developed over time. The nature of the information collected and the way it needs to be recorded and presented will vary depending on the scale of the incident and the level of detail needed to meet the intended purpose of the surveillance flight. The main features of the observed oil that should be recorded are provided in Table 1 (page 5). Working sketches and annotations will need to be formalised either by hand or electronically, to produce a final map for presentation. The original sketches and notes should be retained for subsequent reference.

Video cameras can provide an additional tool for recording observations, but filming by observers may prove difficult in turbulence and during aircraft manoeuvring. The use of hand-held cameras is also constrained by the limited field of view through the eyepiece which reduces the ability of the observer to quickly scan the sea surface. An additional observer for video recording is therefore preferable. If available, video cameras built-in to an aircraft may be alternatively utilised for recording.

Hand-held video cameras allow the addition of commentary, which if not added in sufficient detail with suitable location references, may make later co-ordination of the video with other observations difficult – especially if extended footage has been produced and editing time is unavailable. Video is best used to supplement rather than replace briefings made by experienced observers.

Appearance of oil

Crude and fuel oils spilled at sea undergo marked changes in appearance over time as a result of weathering processes. It is important for observers to be familiar with these processes

Oil Type	Appearance	Approximate thickness	Approximate volume (m³/km²)
Oil sheen	Silver	>0.0001 mm	0.1
Oil sheen	Iridescent (rainbow)	>0.0003 mm	0.3
Crude and fuel oil	Brown to black	>0.1 mm	100
Water-in-oil emulsions	Brown/orange	>1 mm	1,000

Table 2: A guide to the relation between the appearance, thickness and volume of floating oil. Whilst the figures for the thicknesses and volumes listed are indicative only, they serve to show that even large areas of sheen contain relatively small amounts of oil. Actions should therefore focus on areas of black or brown oil and emulsion to maximise the effectiveness of the response.

so that the presence of spilled oil can be reliably detected and its nature accurately reported.*

Most oils spread rapidly over wide areas of the sea surface. Although the oil may initially form a continuous slick this usually breaks up into fragments and windrows due to circulation currents and turbulence (*Figures 8–12*). As the oil spreads and the thickness reduces, its appearance changes from the black or dark brown colouration of thick oil patches to iridescent and silver sheen at the edges of the slick (*Figures 8 & 9*). Sheens consist of very thin films of oil and whilst these areas can be widespread they represent a negligible quantity of oil (*Table 2*). In contrast, some crude oils and heavy fuel oils are exceptionally viscous and tend not to spread appreciably, but remain in coherent patches surrounded by little or no sheen. A common feature of spills of crude oil and some heavy fuel oils is the rapid formation of water-in-oil emulsions which are often characterised by a brown/orange colour and cohesive slicks (*Figure 12*).

Large amounts of debris in the water or spilled cargo (*Figure 13*) may mix with the oil to mask its appearance. Furthermore, from the air it is difficult to distinguish between oil and a variety of other phenomena commonly confused with oil (*Figures 14–18*). Phenomena that most often lead to mistaken reports of oil include: cloud shadows, ripples, differences in the colour of two adjacent water masses, suspended sediments, floating or suspended organic matter, floating seaweed, algal/plankton blooms, seagrass and coral patches in shallow water, and sewage and industrial discharges.

Quantification of shoreline oiling from the air presents additional problems (*Figure 19*). The extent to which oil has penetrated shoreline substrates, pooled in rocky crevasses, entered mangrove stands etc. cannot be ascertained from the air. Furthermore, many shoreline features, for example vegetation or changes in rock strata, viewed from a distance bear a close resemblance to oil.**

Initial sightings of suspected oil should be verified by over-flying at a sufficiently low altitude to allow positive identification. In instances where doubt exists, aerial observations should be confirmed by closer inspection from a boat (*Figures 8 & 9*) or on foot.

Quantifying oil volumes

An accurate assessment of the quantity of oil observed at sea may not be possible due to the difficulties of gauging thickness and coverage. However, by considering certain factors it may be possible to estimate the volume of oil in a slick to an order of magnitude so that the required scale of the response can be planned. Because of the uncertainties involved, all such estimates should be viewed with considerable caution.

Oils with a low viscosity spread very rapidly and so oil layers quickly reach an average thickness of about 0.1mm. However, the thickness of the oil layer can vary considerably within a slick or patch of oil, from less than 0.001mm to more than 1mm. For more viscous oils the oil thickness may remain well in excess of 0.1mm. The appearance of the oil can give some indication of its thickness (*Table 2*). Some oils form an emulsion by the inclusion of tiny droplets of water, which increases their volume. A reliable estimate of the water content is not possible without laboratory analysis, but figures of 50–75% are typical. The thickness of emulsion can vary considerably depending on the oil type, the sea conditions and whether the emulsion is free-floating or held against a barrier such as a boom or the shoreline. A figure of 1mm may be used as a guide, but thicknesses of 1cm and significantly greater can sometimes be encountered. Gauging the thickness of emulsion and of other viscous oils is particularly difficult because of their limited spreading. When the sea surface is rough, it can also be difficult or impossible to see less buoyant oil types, particularly if weathered, as they can be swamped by waves, and remain just sub-surface for much of the time. In cold water some oils with high pour points will solidify into unpredictable shapes and the appearance of the floating portions may disguise the total volume of oil present. The presence of ice floes and snow may obscure large amounts or all of the oil and will confuse the picture yet further (*Figure 22*).

▲ *Figure 22: Spills in icy waters are difficult to quantify.*

In order to estimate the amount of floating oil it is necessary not only to determine thickness but also the coverage of the various types of oil pollution observed (*Table 1*). Due account needs to be taken of the patchy incidence of floating oil so that an estimate may be made of the actual area of coverage relative to the total sea area affected. The extent of the affected sea area needs to be determined during the flight. Portable GPS receivers are again useful to accurately record the limits of the main areas. If GPS equipment is not available, the extent of oil must be established by a timed overflight at constant speed.

** Please refer to the separate Technical Information Paper on the Fate of Marine Oil Spills.*

*** Please refer to the separate Technical Information Paper on Recognition of Oil on Shorelines.*

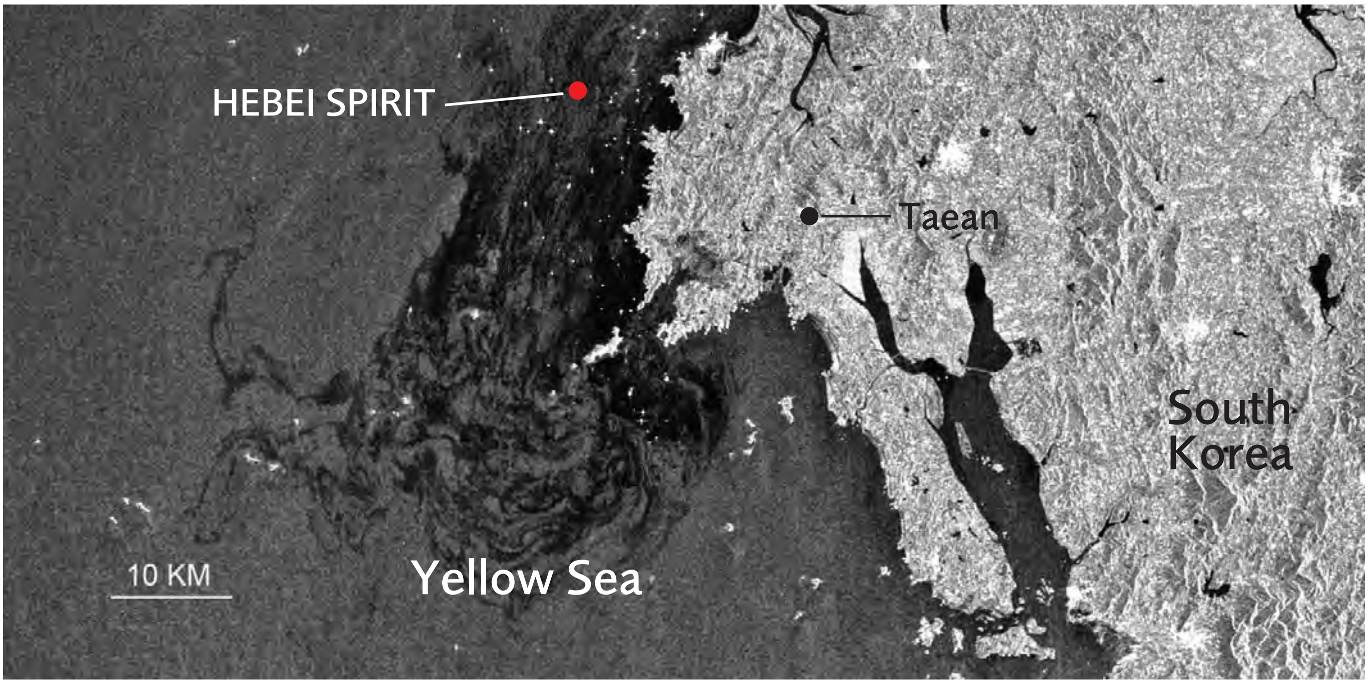


Figure 23: An Advanced Synthetic Aperture Radar (ASAR) satellite image of the eastern Yellow Sea, taken approximately 3.5 days after the release of crude oil from the tanker HEBEI SPIRIT, following a collision off Taean county in South Korea. The oil is moving in a generally southerly direction with the wind and current to spread over a wide area. The image was acquired by the Envisat satellite on 11th December 2007 and is kindly provided by European Space Agency (ESA). All rights reserved.

The following example provides an illustration of the process of estimating oil quantities.

During aerial reconnaissance flown at a constant speed of 250 km/hr, crude oil emulsion and silver sheen were observed floating within a sea area, the length and width of which required respectively 65 seconds and 35 seconds to overfly. The percentage cover of emulsion patches was estimated at 10% and the percentage cover of sheen at 90%. From this information it can be calculated that the length of the contaminated area of sea is:

$$\frac{65\text{ (seconds)} \times 250\text{ (km/hr)}}{3600\text{ (seconds in one hour)}} = 4.5\text{ km}$$

Similarly, the width of the sea area measured is:

$$\frac{35 \times 250}{3600} = 2.4\text{ km}$$

This gives a total area of approximately 11 square kilometres or 3.2 square nautical miles.

For the example given: the volume of emulsion can be calculated as 10% (coverage) of 11 (km^2) x 1,000 (approximate volume in m^3 per km^2 from Table 2). Since 50-75% of this emulsion would be water, the volume of oil present would amount to approximately 275-550m^3. A similar calculation for the volume of sheen yields 90% of 11 x 0.1, which is equivalent to approximately 1 m^3 of oil.

This example also serves to demonstrate that although sheen may cover a relatively large area of sea surface, it makes a negligible contribution to the volume of oil present. Consequently, for accurate reporting, an observer must be able to distinguish between sheen and thicker patches of oil.

Remote sensing

Cameras relying on visible light are widely used to record the distribution of oil on the sea but can be supplemented by airborne remote sensing equipment which detects radiation outside the visible spectrum and provides additional information about the oil. Airborne remote sensing systems are routinely used to detect, monitor and identify the source of marine discharges but can also be used to monitor accidental oil spills. These sensors work by detecting different properties of the sea surface which are modified by the presence of oil. The most commonly employed combinations of sensors include Side-Looking Airborne Radar (SLAR), downward-looking thermal Infra-Red (IR) and Ultra-Violet (UV) imaging systems. Other systems such as Forward Looking Infra-Red (FLIR), Microwave Radiometers (MWR), Laser Fluorosensors (LF) and Compact Airborne Spectrographic Imagers (CASI) may provide additional information. All sensors require highly trained personnel to operate them and interpret the results, particularly as discharges other than oil or natural phenomena may give similar results. While advances in technology have reduced the size of equipment, many remote sensing systems are bulky and can only be used from dedicated aircraft into which they are installed. However, handheld FLIR cameras are available which can provide a portable remote sensing system that is not limited to dedicated aircraft.

UV, thermal IR, FLIR, MWR, and CASI are passive sensors, measuring emitted or reflected radiation. With the possible exception of MWR, they are unable to penetrate cloud cover, fog, haze or rain. Their use is consequently limited to clear weather periods. SLAR and LF incorporate an active source of radiation and rely on sophisticated electronic analysis of the return signal to detect oil and, in the case of LF, provide some indication of the type of oil. MWR can provide information on the thickness of oil on the sea surface but are unable to do so if the oil has emulsified. MWR and LF imaging systems are research tools and more often sensors relying on this technology can only provide information on oil along a narrow track immediately beneath the aircraft. MWR, LF and IR sensors can all be used at night in clear skies. Radar systems can penetrate cloud and fog, day or night and can operate under most conditions although they are less effective in both calm conditions and strong winds.

A combination of different devices is usually adopted to overcome the limitations of individual sensors and to provide better information about the extent and nature of the oil. Combined SLAR and IR/UV systems have been used fairly widely during oil spills. SLAR can be flown at sufficient altitude to provide a rapid sweep over a wide area, up to 20 nautical miles either side of the aircraft. However, SLAR is unable to distinguish between very thin layers of sheen and thicker oil patches, and the images thus need to be interpreted with caution. Aircraft equipped with a combination of SLAR and IR can define the total extent of the slick using SLAR and then once the oil has been located, provide qualitative information on slick thickness and the areas of heavier pollution with images from the IR sensors. In daylight an IR/UV sensor combination can fulfil a similar function although the range is limited compared to SLAR. The UV sensor detects all the oil covered area, irrespective of thickness, whilst the thermal IR sensor is capable, under appropriate conditions, of delineating the relatively thick layers.

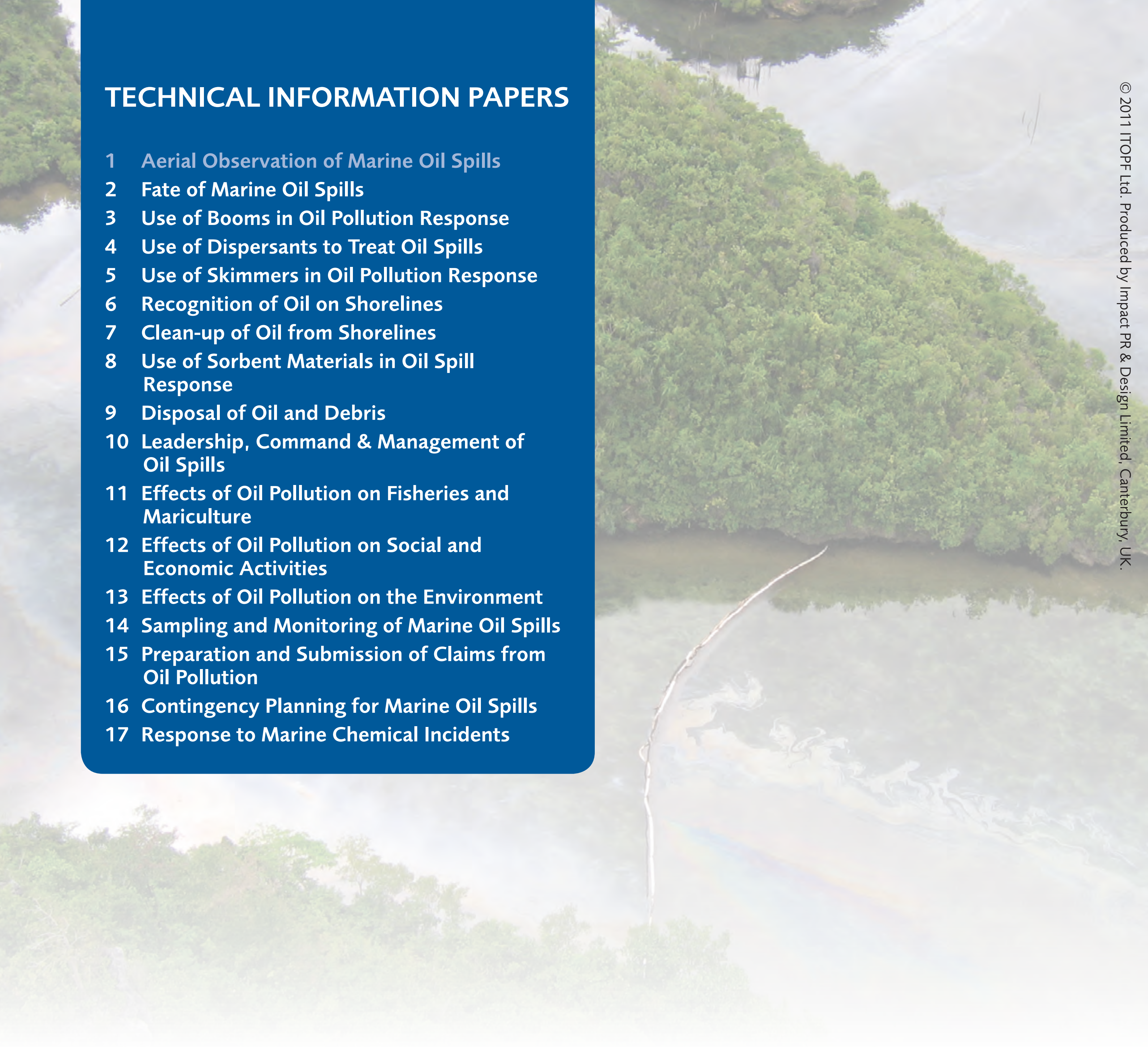
Signals from all types of sensor are usually displayed and recorded on equipment onboard the aircraft. For the resulting images to be used effectively in the management of the response operations, they would need to be relayed to the command centre, correctly interpreted and then presented in a concise and understandable format. In order that the results from remote sensing systems are correctly interpreted it is usually advisable to confirm the findings with visual observations.

Satellite-based remote sensors can also detect oil on water and because such images cover extensive sea areas, they can provide a comprehensive picture of the overall extent of pollution (*Figure 23*). The sensors used include those operating in the visible and infrared regions of the spectrum and synthetic aperture radar (SAR). Optical observation of oil requires daylight clear skies, thereby severely limiting the application of such systems. SAR is not limited by the presence of cloud and since it does not rely on reflected light also remains operational at night. However, radar imagery often includes a number of anomalous features, or false positives, that can be mistaken for oil, such as sea ice, algae blooms, wind shadows and rain squalls and so requires expert interpretation. A further limitation of all satellite imagery is that the frequency with which a satellite passes over the same areas ranges from a few days to weeks depending on the particular orbit. This delay can be partially overcome by interrogation of more than one satellite platform and, where possible, by selectively positioning the angle of a satellite's antenna. In addition, the systems on board usually have to be instructed to acquire the imagery from the area of interest, requiring an element of forward planning.

Once acquired, imagery is transmitted from a ground receiving station for the interpretation necessary to eliminate any false positives. However, for many satellites this inherent delay is minimal allowing a near real time service. Consequently, satellite imagery may provide an effective operational tool in the management of spill response.

Key points

- An initial assessment of a spill is essential to determine the extent of pollution to allow responders to define the clean-up strategy. This is best done from the air.
- Aerial observations can allow the movement of oil, its appearance and estimated volume to be determined.
- Thorough preparation prior to boarding an aircraft will ensure the maximum benefit is obtained from the flight.
- The correct interpretation of oil observations can be hindered by unrelated phenomena and difficulties in estimating oil thickness.
- Remote sensing equipment can supplement visual observation but should be used with caution because these systems also detect other features which may be confused with oil.



TECHNICAL INFORMATION PAPERS

1 Aerial Observation of Marine Oil Spills
2 Fate of Marine Oil Spills
3 Use of Booms in Oil Pollution Response
4 Use of Dispersants to Treat Oil Spills
5 Use of Skimmers in Oil Pollution Response
6 Recognition of Oil on Shorelines
7 Clean-up of Oil from Shorelines
8 Use of Sorbent Materials in Oil Spill Response
9 Disposal of Oil and Debris
10 Leadership, Command & Management of Oil Spills
11 Effects of Oil Pollution on Fisheries and Mariculture
12 Effects of Oil Pollution on Social and Economic Activities
13 Effects of Oil Pollution on the Environment
14 Sampling and Monitoring of Marine Oil Spills
15 Preparation and Submission of Claims from Oil Pollution
16 Contingency Planning for Marine Oil Spills
17 Response to Marine Chemical Incidents

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