

Aerial observation of oil spills at sea

Good practice guidelines for incident management and emergency response personnel



IPIECA

The global oil and gas industry association for environmental and social issues

Level 14, City Tower, 40 Basinghall Street, London EC2V 5DE, United Kingdom

Telephone: +44 (0)20 7633 2388 Facsimile: +44 (0)20 7633 2389

E-mail: info@ipieca.org Website: www.ipieca.org



International Maritime Organization

4 Albert Embankment, London SE1 7SR, United Kingdom

Telephone: +44 (0)20 7735 7611 Facsimile: +44 (0)20 7587 3210

Email: info@imo.org Website: www.imo.org



International Association of Oil & Gas Producers

London office

Level 14, City Tower, 40 Basinghall Street, London EC2V 5DE, United Kingdom

Telephone: +44 (0)20 7633 0272 Facsimile: +44 (0)20 7633 2350

E-mail: reception@iogp.org Website: www.iogp.org

Brussels office

Boulevard du Souverain 165, 4th Floor, B-1160 Brussels, Belgium

Telephone: +32 (0)2 566 9150 Facsimile: +32 (0)2 566 9159

E-mail: reception@iogp.org Website: www.iogp.org

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Preface

This publication is part of the IPIECA-IOGP Good Practice Guide Series which summarizes current views on good practice for a range of oil spill preparedness and response topics. The series aims to help align industry practices and activities, inform stakeholders, and serve as a communication tool to promote awareness and education.

The series updates and replaces the well-established IPIECA 'Oil Spill Report Series' published between 1990 and 2008. It covers topics that are broadly applicable both to exploration and production, as well as shipping and transportation activities.

The revisions are being undertaken by the IOGP-IPIECA Oil Spill Response Joint Industry Project (JIP). The JIP was established in 2011 to implement learning opportunities in respect of oil spill preparedness and response following the April 2010 well control incident in the Gulf of Mexico.

The original IPIECA Report Series will be progressively withdrawn upon publication of the various titles in this new Good Practice Guide Series during 2014–2015.

Note on good practice

'Good practice' in the context of the JIP is a statement of internationally-recognized guidelines, practices and procedures that will enable the oil and gas industry to deliver acceptable health, safety and environmental performance.

Good practice for a particular subject will change over time in the light of advances in technology, practical experience and scientific understanding, as well as changes in the political and social environment.

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Purpose of this guide

In 2008 a technical group of the International Maritime Organization's (IMO) Marine Environment Protection Committee (MEPC) was charged with developing tools and guidance to assist states in the implementation of the International Convention on Oil Pollution Preparedness, Response and Cooperation 1990 (OPRC 1990). The group agreed that a revised guide on 'Aerial Observation of Oil Pollution at Sea' would be produced jointly by Cedre, IMO and IPIECA-IOGP to provide guidance on the identification and observation of spilled oil at sea for industry and government worldwide.

This resulting operational guide was developed from the original Centre of Documentation, Research and Experiment's (Cedre's) Aerial Observation of Oil Pollution at Sea Operational Guide and represents a consensus of industry and government viewpoints, evaluated through the review process of the OPRC-HNS Technical Group of the IMO MEPC, Cedre and the IPIECA Oil Spill Working Group. The guide is intended for use by those involved in the aerial observation of oil pollution at sea and those working in pollution response centres, as well as technical support for public relations personnel.

Cedre, IMO and IPIECA-IOGP have separately published other manuals and reports on various aspects of oil spill preparedness and response, and the reader is encouraged to review the manual on Aerial Observation of Oil Pollution at Sea in conjunction with these publications.

The mission

The strategic use of observation in oil spill surveillance

Overall, the aim of ‘surveillance’ is to detect, characterize and preferably quantify spilled oil that may be present in a range of settings (on-water, in-water and onshore). This is of critical importance in enabling the incident command to effectively determine the scale and nature of the oil spill incident, make decisions on where and how to respond, control various response operations and, over time, confirm whether or not the response is effective.

This applies to all realms of the response situation, over a wide area and even extending across international borders, focusing down to different areas of potentially affected sea and coastline, and to controlling localized tactical response activities.

A variety of surveillance approaches and individual ‘tools’ can be used to deliver the information needed—from sky to seabed—and to support the ongoing response. These include:

- satellites (using optical, infrared and radar techniques);
- aerial platforms such as aircraft and helicopters (using techniques including optical, infrared and radar, photography and video, and human eye);
- unmanned aerial vehicles (using optical, infrared and radar techniques);
- vessels (using techniques including optical, infrared and radar, photography and video, and human eye);
- tethered aerostats;
- buoys, trackers, mounted systems (e.g. on rigs);
- onshore observers; and
- autonomous underwater vehicles, and remotely operated vehicles (ROVs).

Aerial observation with trained observers is a surveillance method that is often relied upon and considered critical to an effective response. However, depending on the circumstances of the oil spill incident, a range of other surveillance approaches and tools may be needed to supplement or augment this core technique, and thereby deliver a complete surveillance strategy. For example, where the area to be covered is very great, individual aircraft sorties can become a challenge or simply unfeasible with the resources available. Tools such as satellites can often offer rapid wide-area coverage to address this. Also, the use of unmanned devices may offer a solution at some locations where flight restrictions may be in place.

Depending on the oil spill incident, a variety of different factors may need to be considered. The surveillance strategy embraces the range of data needs arising from the incident, and delivers what is needed for the response, potentially utilizing a selection of surveillance tools and techniques appropriate to the circumstances.

Satellites, unmanned aerial vehicles (UAVs) and other tools offer ‘remote sensing’ options to assist with a response. Remote sensing is defined here as acquiring and collecting information about an object or phenomenon (i.e. an oil spill) without making actual physical contact with said object. Remote sensing can be used in conjunction with other surveillance techniques, including tracking buoys, to provide data about an oil spill, including location, size, direction of movement, and speed of movement.

Aerial observation—what and why

What is an aerial observation mission?

Aerial observation is the visual observation and interpretation of an oil spill, carried out from an aircraft by a human observer. A trained observer can recognize and capture many features and details of spilled oil on water and along coastlines. Photography and video may be used by the observer to record the location, nature and appearance of the oil.

Why conduct an aerial observation mission?

Aerial observation can be used for two distinct purposes as described below.

First, it can be carried out routinely as a deterrence, being able to detect and collect evidence for prosecution in cases of illicit discharge by ships or offshore installations. In this case the aims are to:

- assess the pollution (quantity and quality);
- accurately locate and describe the pollution;
- where possible, identify the polluter;
- predict the trajectory of the pollution; and
- prosecute the polluter via a pollution observation report.

Secondly, aerial observation is used to assist with, and maximize, the effectiveness of response operations at sea. The aims of the observation missions are to:

- locate all the slicks;
- accurately describe the slicks;
- map the pollution;
- monitor the pollution;
- adjust drift models;
- guide response operations each day; and
- prepare the response operations for the following days.

Aerial observation is the only means of obtaining a clear, realistic picture following an oil spill incident. It is the first link in a chain of important decisions.

Preparing the mission

All missions must be prepared. The aim is to try to predict what is likely to be encountered, including the appearance, extent and location of the slicks.

In all cases:

- Prepare basic maps of the area, on which the pollution can be mapped and observations noted during the flight.
- Clearly indicate on these maps the orientation, coastline, geographical coordinates, scale, the nature of the coast (beach, rocky shoreline, wetland, urban, industrial and harbour areas) and its uses.
- Understand the local requirements for the specific type of note-taking that should accompany photography or videography to ensure that it will be admissible as legal evidence. In some cases, templates may be available, e.g. the Standard Pollution Observation/Detection Log provided under the Bonn Agreement (see Bonn Agreement, 2004).

In the case of an oil spill incident:

- Gather as much information on the spill as possible, for example:
 - nature of the pollutant: crude, refined, light or heavy oil (its density, viscosity, pour point, etc.)
In the case of crude or light refined oil, beware of the risk of explosion (see *Flight profile*, overleaf) and make sure an explosimeter is available;
 - type of incident (sinking, grounding, explosion during operations, etc.);
 - type of spillage (isolated event, continuous flow, on surface, below surface); and
 - last slick observation (date, appearance, location, trajectory).
- Gather all the necessary data on the local conditions (weather since last observation, sea currents, sea state etc.).
- In the absence of specific instructions from a coordination centre, estimate the most probable location of the slick, by calculating its probable drift (see *Calculation of drift* on page 19), either from the spill location or the last observed position.
- Investigate the possibility that other areas, so far unobserved, may be polluted. This should be carried out taking into consideration the prevailing local circumstances, for example the shipping route before the incident, a new leak in the wreck, other pollutant contributions due to slicks, previously having reached the shore, breaking away and drifting, etc. (see the example of the *Erika* spill in Box 1, below).
- Identify from this information the zone to be covered by the mission and establish a flight profile for maximum coverage (see *Flight profile* overleaf).

Box 1 *The Erika spill, 1999*

Before breaking into two, the *Erika* had already been leaking for many hours and the spilt fuel oil arrived onshore without being observed at sea. This occurred due to a lack of specific research aimed at locating this spilt oil, as it had not been reported by the ship's master.

- Forecast slick appearance according to the characteristics of the pollutant (estimate viscosity at ambient temperatures, assess tendency to form an emulsion) or according to available observation data, and anticipate any potential detection difficulties (e.g. low floatability of the pollutant, fragmented slicks, etc.).
- Prepare and take onboard drifting buoys to be dropped on the slicks and then tracked by satellite.

Flight profile

- As oil tends to spread in bands parallel to the wind, the zone to be investigated should be covered by flying across the wind using a 'ladder search' technique, to increase the chances of detecting any slicks (see Figure 1):
 - Mist and dazzle caused by the sea surface often hamper visibility. Sometimes the best way to fly will be governed by the position of the sun.
 - The flying altitude is determined by the size of the slicks to be located, the visibility and the sea state. It is important to achieve maximum sweep while ensuring that all the details remain clearly visible.
- First of all, look for the most polluted zones (thick patches or slicks, accumulation zones). Offshore, follow thin patches or stripes (sheen, rainbow or metallic appearance) with the wind, in order to detect any possible thick patches downwind of the contaminated area.
- If a new band of pollution or recent stripes are sighted, follow them to determine the source of pollution. This source will usually be located upwind, particularly if the spillage point is fixed, but also up-current.

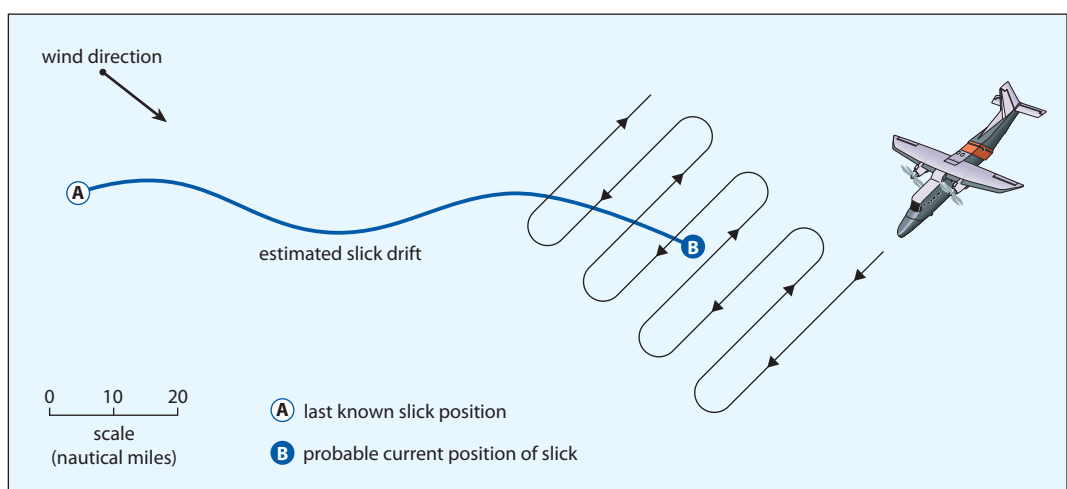
See also the section on *Formation of oil slicks at sea* on page 17.

Notes:

The use of polarized sunglasses facilitates observation.

As far as possible, observations made using non-specialized planes (e.g. maritime patrol) should be confirmed by helicopter reconnaissance (which allows more precise observation), or by a plane fitted with specialized remote sensing equipment (IR, SLAR, FLIR, UV or possibly microwave).

Figure 1 Ladder search

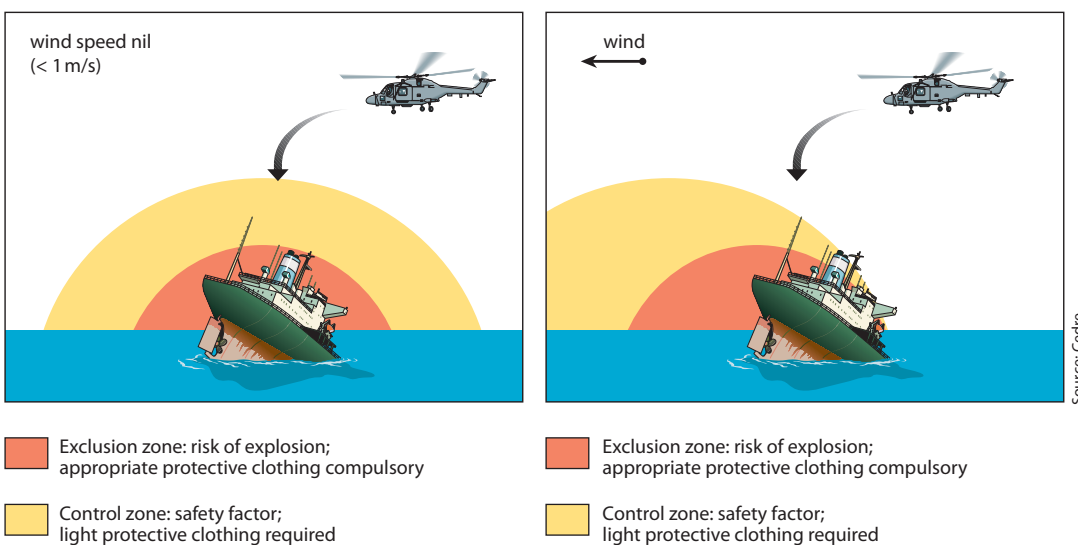


- When a significant spill of light crude oil or a light refined product occurs, a (toxic or explosive) gas cloud may form. In this case, the approach and overflights of the site must be carefully planned to avoid any possible risk for the crew. For helicopter reconnaissance missions, several recommendations should be followed (see Figure 2). The approach to the spill area should be made across the wind or with the wind at the tail, at an altitude of at least 50 metres, to avoid entering the danger zone. The helicopter crew should be equipped with respirators, an explosimeter and optionally a toximeter, to detect the presence of toxic vapours in the air. (See IPIECA, 2012 for more information on oil spill responder health and safety.) A helicopter hovering over an inflammable slick should not lower to an altitude of less than 20 metres, or 30 metres in the case of a major spill of a highly flammable product (a light oil).

Warning!

If the action of the current is stronger than that of the wind, the slick may move upwind.

Figure 2 Helicopter approaching an oil tanker in difficulties



When no in-depth assessment of the situation can be immediately carried out, protect all responders, with protective clothing and masks, within a radius of 200 m.

The values quoted here are purely to provide an indication. Each case must be assessed individually.

Different types of hydrocarbons

Oil and oil products

Note:

The emulsions formed by petroleum hydrocarbons vary in colour from dark brown to orange.

Hydrocarbons are complex associations of distinct chemical compounds. Their appearance, physical characteristics and behaviour depend on their composition. Spills at sea mainly involve the following three types of petroleum hydrocarbons, which have very different behaviours.

- Light refined products are colourless, or only slightly coloured, highly fluid products made up of the lightest oil fractions (e.g. petrol/gasoline, white spirit, kerosene, diesel oil, domestic fuel oil).
- Heavy refined products are black and often viscous, with no or few light fractions (e.g. heavy fuel oil (HFO), intermediate fuel oil (IFO), bunker fuel, bilge discharge).
- Crude oils vary in colour from brown to black. They have widely varying characteristics, depending on their composition, in particular according to the proportion of light or heavy fractions, resulting in their resemblance to either light or heavy refined products. After a certain length of time at sea, crude oils lose their light fractions through weathering (see the section on *Weathering and behaviour of oil at sea* on page 13), resulting in similar characteristics and behaviour to heavy refined products.

Table 1 *The properties of petroleum hydrocarbons*

Type of oil	Persistence / evaporation
Light refined products, e.g. petrol (gasoline), diesel, kerosene	<ul style="list-style-type: none"> ● Low or no persistence ● Rapid evaporation (in a few hours) ● Natural dispersion
Petroleum hydrocarbons with viscosity < 2,000 cSt. <ul style="list-style-type: none"> ● Slightly weathered light and medium crudes ● Slightly weathered light and intermediate fuel oils 	<ul style="list-style-type: none"> ● Low persistence ● High evaporation rate (around 40% in 24 hours)
Petroleum hydrocarbons with viscosity > 2,000 cSt. <ul style="list-style-type: none"> ● Weathered light and medium crude oils ● Heavy crude oil ● Heavy fuel oil, operational residue, e.g. Bunker C, HFO, IFO 380. 	<ul style="list-style-type: none"> ● Average persistence ● Low evaporation rate (usually less than 10%)
Paraffinic crude oils with a pour point higher than the seawater temperature	<ul style="list-style-type: none"> ● High persistence ● Solid or highly viscous hydrocarbons ● Very low evaporation rate

Basic physical characteristics

A petroleum hydrocarbon spilt at sea can be characterized by a certain number of physical parameters which provide information on its likely behaviour and weathering. The principal physical characteristics are listed below.

Density

The density of hydrocarbons is usually below 1, which means that they float on water. However, once spilt, and due to weathering phenomena (evaporation and particularly emulsification), the density increases gradually until values similar to those for sea water are reached, which makes buoyancy less probable in coastal and estuarine waters. Increased density can lead to greater likelihood of over-washing by waves in rougher seas.

Viscosity

The initial viscosity of hydrocarbons varies widely. Viscosity depends on temperature (see Figure 3 on page 12). When spilt, the viscosity of hydrocarbons progressively increases up to very high values (e.g. $>10^5$ cSt), due to weathering phenomena (evaporation and emulsification, see pages 13–14), altering the pollutant's behaviour on the sea surface (see page 15).

Pour point

The pour point of a petroleum hydrocarbon is the temperature below which it stops flowing in laboratory control conditions. This does not mean that below this temperature the hydrocarbon acts as a solid. The pour point is measured in the laboratory, in a narrow test tube. When spilled at sea, in an open area, hydrocarbons can remain liquid at temperatures even below their pour point.

Health effects of volatile organic compounds (VOCs)

At a concentration of 900 ppm (0.09%) VOCs may cause irritation to the respiratory tract and eyes after about an hour.

Explosive range

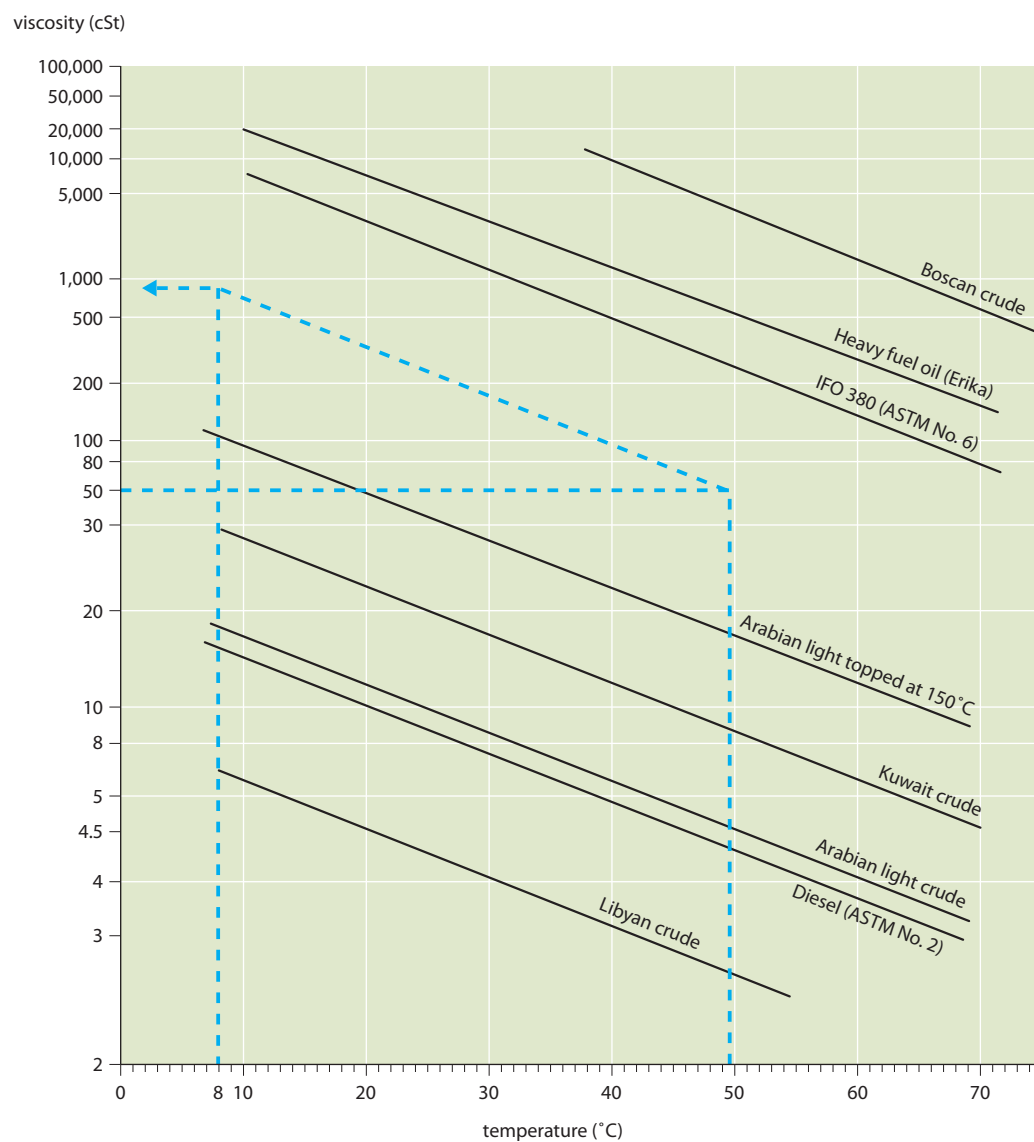
The explosive range involves minimal values of gaseous hydrocarbons in the atmosphere, ranging from 2 to 11.5%.

Two other characteristics are important: the flashpoint and the auto-ignition temperature (see glossary). These factors are particularly important in the case of refined products, for which a thorough assessment of fire and explosion risks is necessary.

Further information on the characteristics of oil can be found in the IPIECA-IOGP guidelines on oil characterization (IPIECA-IOGP, 2014a).

Figure 3 Determination of the viscosity of a hydrocarbon according to temperature**How to use this figure:**

As an example, the blue line shows that the viscosity at 8°C of a fuel which measures 50 cSt at 50°C is 800 cSt.

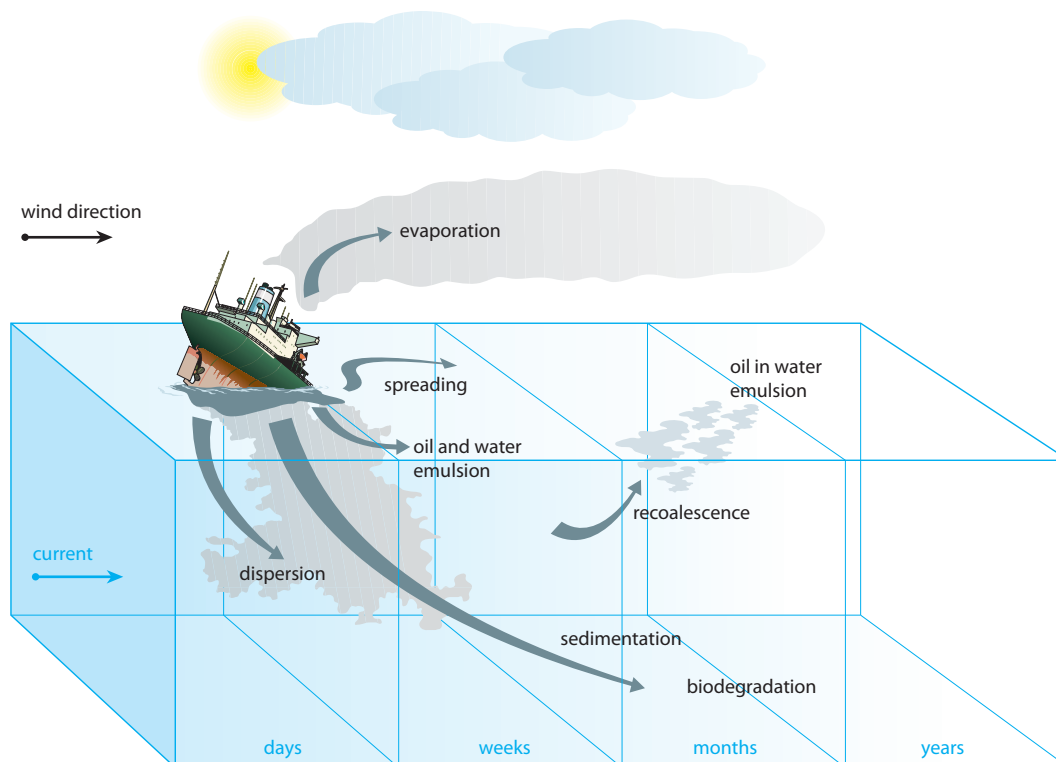


Weathering and behaviour of oil at sea

The first few days

Over time, oil spilt at sea gradually changes in appearance and behaviour—see Figure 4.

Figure 4 The fate of oil spilt in water



Warning!

Chemicals with a high vapour pressure, such as petrol (gasoline), are dangerous if inhaled, and can explode or ignite (even at a low concentration in the air).

Over the first few days, oil spilt at sea undergoes the following processes:

- **Spreading into a film** which may be very thin (e.g. less than 1 micron): thus a small quantity can cover a very large surface area (1,000 litres spread into a film of 1 micron could cover 1km²). However spreading is irregular.
- **Evaporation** of the lighter fractions: crude oils, condensates and refined products begin to evaporate immediately after a spill, and can continue to do so for a long time if the meteorological conditions are favourable. The evaporation rate depends first on the volatility of the various components of the spill mixture but



Source: BSAM, Douane française

Recent spillage (a few hours old): the fresh pollutant spreads widely to form a film with scattered thicker patches.

Over time, the slick fragments and the thickest patches are increasingly noticeable compared to the thin layers (sheen, rainbow or metallic), from a few hours to a day after the spill.



Source: ITOPF

With weathering, brick red patches of emulsion may form in the centre of thinner layers (sheen, rainbow or metallic) and thicker patches (2 to 8 days after the spill).



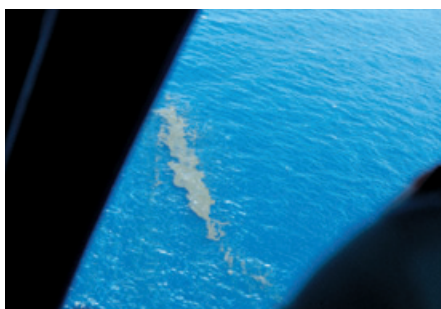
Source: Cedre

Subsequently, the films (sheen, rainbow or metallic) gradually disappear and eventually only patches or stripes of emulsion may remain (a few days after the spill), especially in a rough sea.



Source: Cedre

Iridescence can however reappear later, even several weeks or months after the spillage, if the sea is very calm and the sun is shining.



Source: Cedre

also on factors such as the quantity spilt, the water and air temperature, water turbulence, wind speed and rate of spreading of the slick.

- Up to 50% of crude oil may evaporate in the first 24 hours after a spill.
- When petrol (gasoline) is spilled at 20°C, approximately 50% evaporates within 7 to 8 minutes following the spill. Petrols, kerosene and light fuel fractions (volatile compounds with a boiling point of 200°C) disappear almost completely after 24 hours at 20°C.
- For domestic fuel oil (DFO), 30 to 50% evaporates in a day. For heavy fuel oils, such as Bunker C, loss through evaporation is estimated at a maximum of 10% of their weight.
- **Natural dispersion**, the percentage of which is mainly dictated by the nature of the hydrocarbon and the sea state. The waves and turbulence of the sea surface act on the slick and induce the formation of oil droplets of varying sizes. The smallest droplets remain in suspension in the water column, while others either coalesce with other droplets or spread into a thin layer. Recoalescence of droplets in suspension is most prevalent when the sea is calm, however in this case aerial observation is made easier. A significant proportion of a spill's volume can disperse naturally (e.g. the *Braer* oil spill incident, 1993).
- **Emulsification** occurs mainly with crude oils or black refined products, after a few days, or even a few hours if the sea is rough. The emulsion formed varies in colour from dark brown to orange. This phenomenon increases the apparent volume of pollutant, reduces spreading (by forming thick patches) and eventually increases the apparent density of the pollutant until it is almost equal to that of sea water. It may therefore remain below the surface, or even sink, especially in coastal or estuarine waters, due to the presence of matter in suspension and reduced salinity.

Further information on the weathering and behaviour of oil at sea can be found in the ITOPF Technical Information Paper No. 2, *Fate of Marine Oil Spills*.

Appearance of oil slicks

Depending on the angle of observation it can be difficult to discern sheen from thicker oil. The colour of thick patches and stripes may also vary depending on the luminosity, the colour of the sky and the observer's position in relation to the sun.



Source: Cedre

General overview

Light refined products

- Rapid spreading over very large surface areas in a fairly homogeneous, thin film.
- Substantial evaporation and natural dispersion causing disappearance in two or three days, or even a few hours.
- Colourless or only slightly coloured products, mainly visible with a small angle of incidence. Slicks show up as shinier patches.



Source: ITOPF

Slick of light refined product rapidly spreading into a thin film.

Heavy refined products or crude oil

- Irregular spreading, rapidly forming thick patches or stripes, which are black or dark brown/black (or possibly greenish) surrounded by a dark, unbroken thin film.
- Over time (and after the loss by evaporation of the light fractions of the pollutant), the patches thicken and pile up (several millimetres thick), turning brown/orangey brown, while the unbroken film becomes thinner and eventually transforms into sheen, rainbow or metallic appearance. Within a few days, the thin layers eventually disappear altogether. However in calm, sunny conditions iridescence may reappear.
- Thin, unbroken films are clearly visible with a small angle of incidence (shiny patch) whereas thick patches are best seen with a large angle of incidence.



Source: Cedre

Crude oil slick (Nassia accident, Bosphorus, Turkey, 1994).



Source: ITOPF

Crude oil slick (Great Bitter Lake, Egypt, 2006).

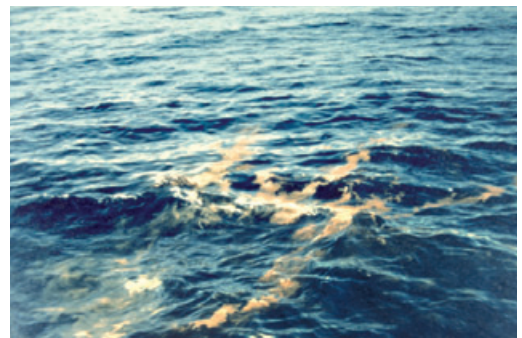
Special cases

- Oil treated with dispersant: the dispersed oil appears as an orange to light brown (or sometimes dark brown) plume, just below the water surface.
- Congealed petroleum products at seawater temperature (mainly concerns products containing heavy paraffins): these can form into thick or lumpy patches possibly surrounded by thin sheen, rainbow or metallic layers.
- Petroleum hydrocarbons forming little or no emulsion, for instance a light crude oil or refined product: only thin films remain, which gradually break up and disappear.

The photograph immediately right shows oil treated with dispersant products.



Source: Cedre



Source: Cedre



Source: Cedre

Right: oil in ice



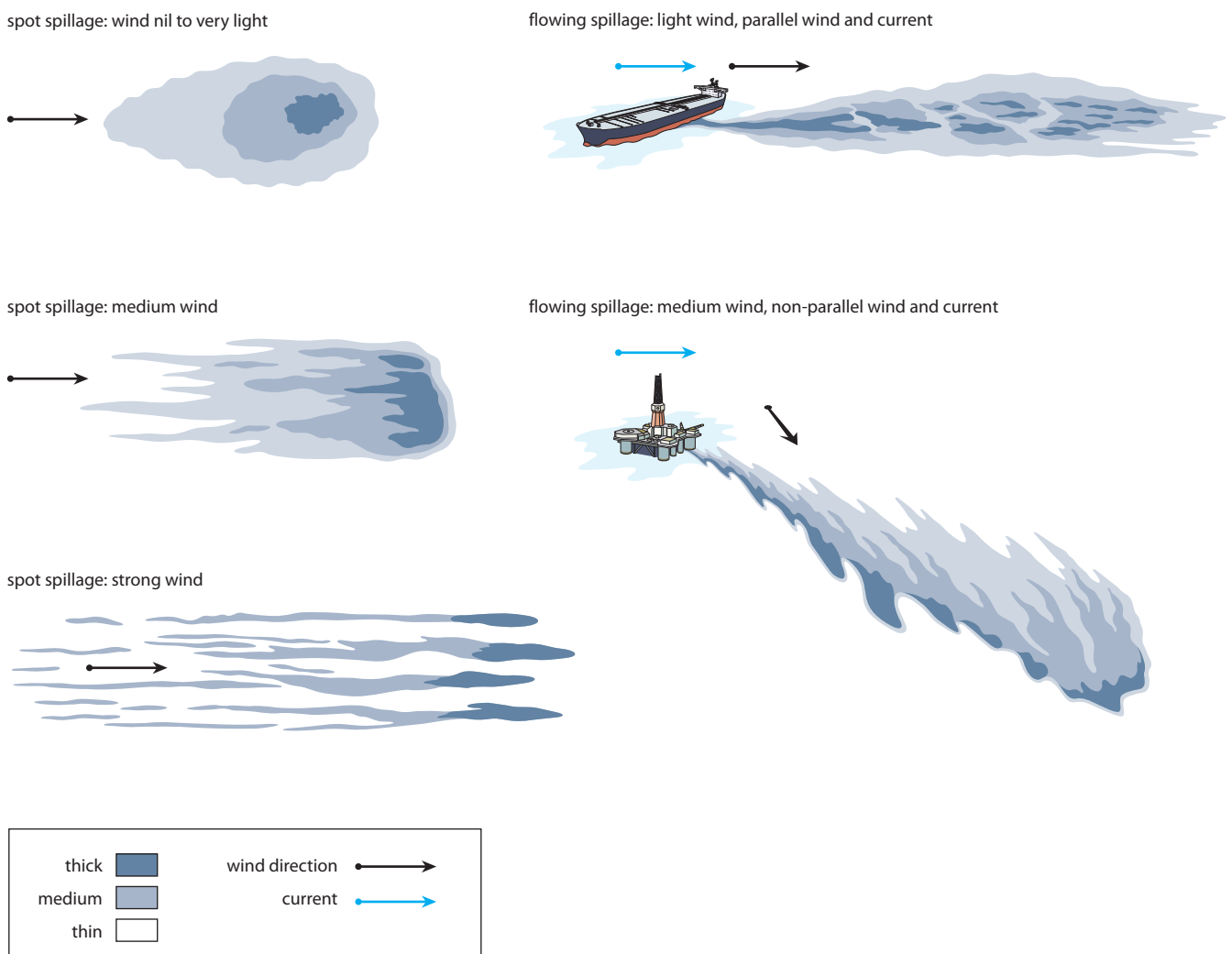
Source: ITOPF

Above: congealed paraffinic oil: close up, the patches can be seen to be made up of lumps.

Formation of oil slicks at sea

- For fairly fresh slicks (several hours to a few days old), the shape and thickness distribution (thick, medium, thin) depend mainly on the wind. The wind spreads and elongates slicks, eventually cutting them up into windrows and then fragmenting them. The thickest patches lie furthest downwind. When the wind is very strong, the iridescent zones (sheen–rainbow–metallic) tend to disappear.
- For weathered slicks (several days old or more), sheen, rainbow or metallic films gradually disappear. Only very thick, highly emulsified patches remain, barely floating on the surface. In the case of violent storms, even extensive slicks may not be visible, but may reappear when the conditions become calmer. Breaking waves may also fragment these patches so that they gradually become scattered and increasingly difficult to observe. The oldest slicks often become mixed with floating debris.

Figure 5 *The formation of oil slicks at sea*



Note:

Small quantities of oil or fragmented slicks which arrive on the coast are very difficult to identify from aircraft, especially in rocky areas.

Arrival of oil on the coast

- Slicks or floating patches accumulate in coastal areas exposed to the wind (coves, bays, inlets, etc.).



Source: Cedre

Arrival of weathered emulsion on the coast, from the Erika's cargo of heavy fuel oil (Le Croisic, Loire-Atlantique, France, December 1999)

- Pollutant is deposited in accumulation zones, with the ebb and flow of the tides in the form of a more or less continuous band, along the high tide line.



Source: ITOPF

Arrival of oil in a natural accumulation area

- The pollutant is often mixed with varying quantities of waste and debris, in particular seaweed.



Source: Cedre

Arrival of an emulsion of fuel from the wreck of the Prestige on the coast, combined with seaweed (Galicia, November 2002)

- The pollutant may be carried away if the wind or currents change direction.



Source: ITOPF

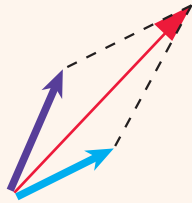
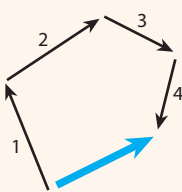
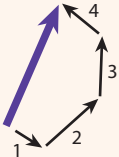
Remobilization of fuel which was trapped in rocks

Drift of oil slicks

Calculation of drift

Oil slicks drift on the water at 3–4% of the wind speed and 100% of the speed of the current. The actual route covered by a slick (or ‘course made good’) can be determined graphically by vectorial addition of the speed of the current and 3–4% of the wind speed, established on an hourly basis.

Table 2 Calculation of drift over two hours

	Current	Wind	Drift
First hour	1.5 knots at 340°	12 knots x 3/100 = 0.36 knots at 300°	
Second hour	1.5 knots at 60°	30 knots x 3/100 = 0.9 knots at 230°	
Third hour	1 knot at 110°	25 knots x 3/100 = 0.75 knots at 185°	
Fourth hour	1 knot at 190°	20 knots x 3/100 = 0.6 knots at 130°	
			

In the table above, the black arrows show the successive effects of the current (100%) and the wind (3%) on the slick each hour. The blue arrows show the resultant drift after 4 hours. The red arrow shows the overall resultant drift.

Slick movement and drift models

Computer software exists for calculating the movement or drift of oil slicks. It can be useful in preparing a mission.

Surface oil trajectory modelling

Surface oil trajectory modelling can be conducted using mathematical models integrating metocean data. The model input is based on pollution observation data (usually from aerial observation), for which the appearance (degree of fragmentation, floatability), the dimensions, the position and the time have been recorded.

The model must be regularly adjusted using observation data. Buoys can be dropped onto the slicks to help to locate them in relation to predictions. The reliability of meteorological data allows routine forecast for 3 to 4 days ahead and drift backtracking for up to 3 days, depending on the model.

Figure 6 Example of slick drift forecast for experts (raw data output from model)

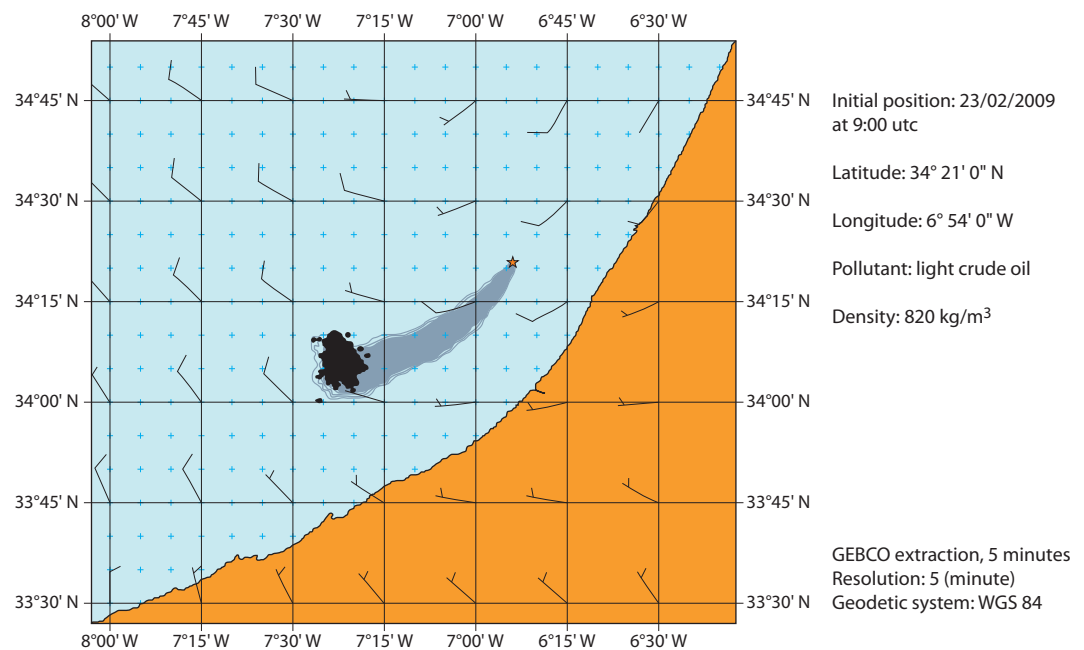
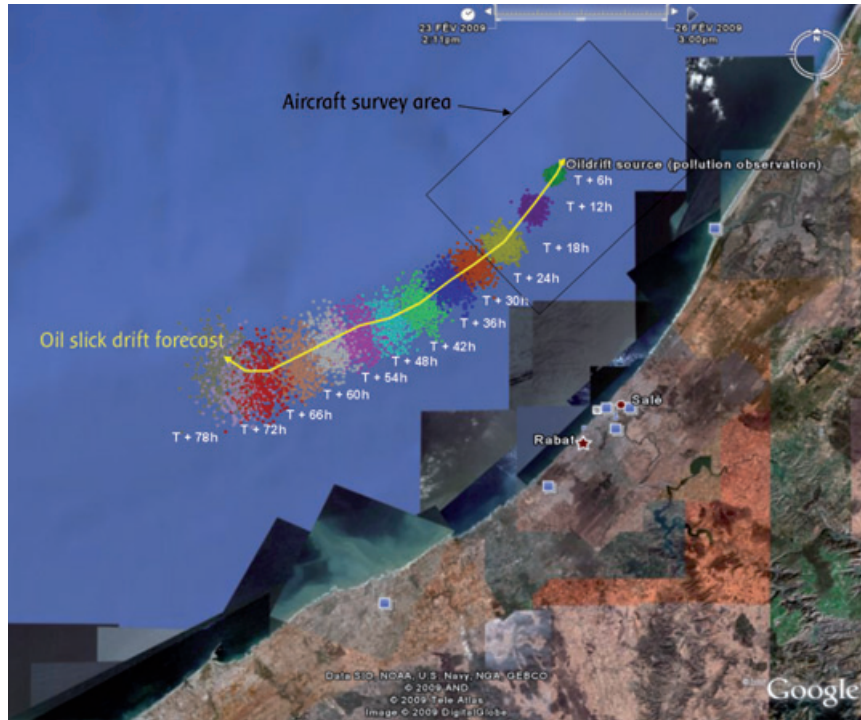


Illustration of the output from MOTHY (Modèle Océanique de Transport d'Hydrocarbures) at Météo-France

In the event that a major oil pollution incident affects a vast sea area, drift model output, such as the example on the previous page, is used to design maps which draw together all the observation data for that day and the drift predictions for the coming days. The observations are accompanied by indications of the overflight zones of the different aircraft, showing which areas have been explored and those which have not.

The quality of current data and weather forecasting is critical to the accuracy of these models.



Infographic processing of the raw data output from the slick prediction model shown on the previous page provides a more useable format for operational personnel and communications teams

Use of drifting buoys

It is important to be aware of an oil slicks' drift patterns and to be able to anticipate its movements, in order to direct pollution response vessels at sea and to inform the onshore response authorities as soon as the pollutant threatens to arrive onshore. In addition to aerial observation and satellite images, satellite-tracked drifting buoys (often referred to as 'drifters') can be deployed.

Experience of past pollution incidents (e.g. major spills, illicit discharge, wrecks) has shown that drifting buoys dropped from aircraft or from boats have a number of advantages:

- The drift can be followed from a distance (useful when poor conditions prevent overflights and observation operations).
- If slicks disappear from view they are not lost.
- The grounding location of small amounts of pollution from illicit discharges can be identified.
- Information can be provided about the fate of potential pollution from wrecks.



Source: Cedre

Left: surface drift buoys: independent, floating Argos beacons which can be dropped from aircraft

Sampling buoys

Sampling buoys which can be dropped directly from an aircraft onto a slick have recently been developed. They contain a piece of Teflon® material, which can absorb oil for subsequent analysis. The buoys can be identified by a light and a radio signal.

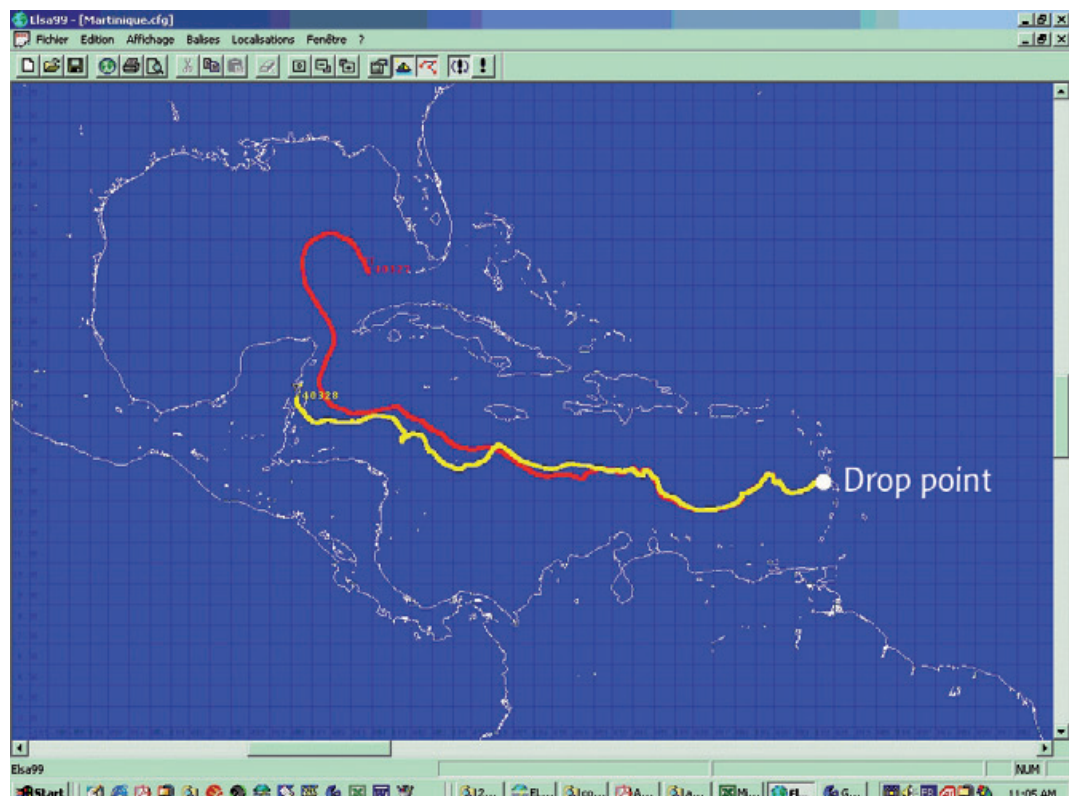
Box 2 The Prestige spill, 2002

Drogued satellite-tracked drifting buoys were deployed by SHOM (the French Naval Hydrographic and Oceanographic Service) to measure the seasonal current, known as the 'Navidad' current, which was believed by some to be likely to pull the slicks along like a river. The drifting buoys showed that the current was not developed and that the drift of the slicks was mainly dictated by the wind.

Cedre provided surface drifting buoys for use by the French Navy, SASEMAR (the Spanish maritime rescue and safety organization in charge of response at sea in Spain) and AZTI (the Basque expert technology centre specializing in marine and food research). These drifting buoys were tested by Cedre (a series of tests starting in 1996) and their drift was almost identical to that of oil slicks. Some of these buoys were used in December 1999 during the response to the *Erika* oil spill. It was in this way that the drift movements of the slicks in the Bay of Biscay could be tracked in the medium term. One of the drifting buoys which were launched at the beginning of February 2003 off the coast from the Arcachon Basin was found three months later at the tip of Brittany.

The Portuguese Oceanographic Institute, and then SASEMAR, in collaboration with Cedre, also placed surface drifting buoys above the wreck of the *Prestige* on a monthly basis, as of the 23 February 2003. None of the buoys entered the Bay of Biscay in the following 12 months, highlighting the fact that the risk was higher for the Portuguese and Moroccan coasts than for the French coasts in the event of a leak from the wreck of the *Prestige*.

An example of an experiment to monitor surface buoys in the Caribbean area. In yellow and red, the trajectory of two buoys dropped at the same point.



Information and data transmission

In pollution management, many factors must be taken into consideration, including aerial observation data (position of the pollution, remarks about observations, initial and actual flight plans, photos, remote sensing imagery, etc.), drift prediction and signals sent by drifting buoys dropped at sea (see *Use of drifting buoys* on page 21). This information is exchanged between operational personnel by various means (fax, telephone, email, internet). To optimize data transmission and exploitation, computer-based methods should be prioritized (e.g. pollution reports in a spreadsheet document, the use of digital cameras or a different system coupled with a global positioning system (GPS)).

It is important to:

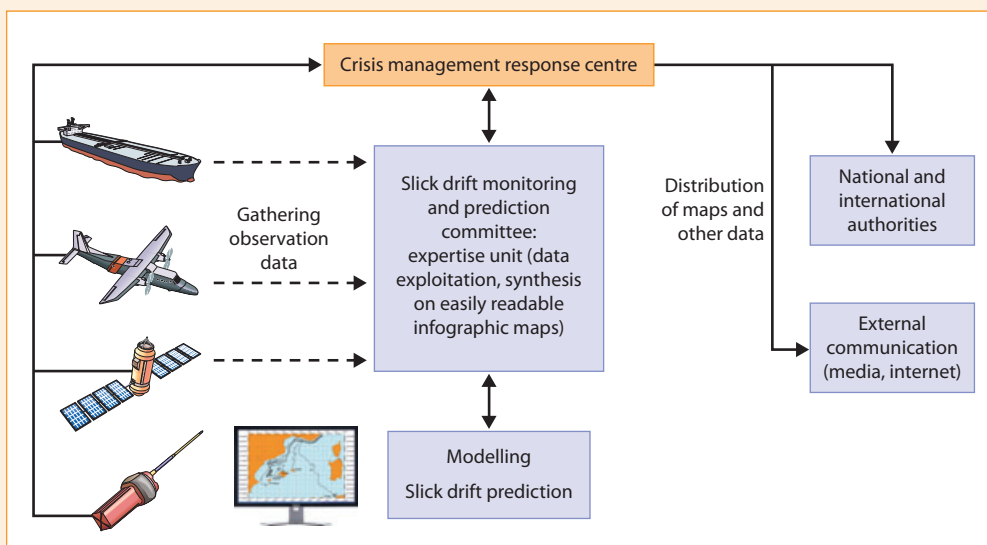
- computerize as much information as possible;
- use digital photographic equipment; and
- prioritize real-time transmission of information using the internet.

Box 3 Benefits of a coordinated approach

Experience from major oil spills shows the benefits of gathering subject matter experts from various organizations to:

- analyse the observation data (aerial, nautical and satellite observations);
- transmit selected data to modelling specialists to forecast oil slick trajectories;
- provide advice for future observation flights;
- update the location map daily and send it to responders; and
- propose study and experimentation programmes which could be used to reinforce predictions.

Such an approach has contributed to a marked improvement in the quality of predictions and facilitated the authorities' decision-making processes. It is a valuable innovation in the field of information and communication.



Oil spill observation

Observation criteria

The observation criteria for oil spills are:

- the degree of coverage (see page 43) and the dimensions of the slicks or patches, which provide information about the overall extent of the spill;
- the position and time of observation; and
- the appearance (i.e. the shape, colour and formation) which provides information about the type of pollutant and its degree of weathering.

Box 4 Appearance of spilled oil

The appearance may be one of the following:

- Thin films (sheen, rainbow or metallic) which are silvery and/or coloured (in the case of light refined products or small widely-spread spills), with a thickness of a few microns ($< 50,000 \text{ l/km}^2$).
- Slicks of varying thicknesses with dark discontinuous colour (black or brown depending on the hydrocarbon), often surrounded by thin films (sheen, rainbow or metallic), depending on the degree of weathering; thicknesses range from 50 to 200 μm ($50,000$ to $200,000 \text{ l/km}^2$):
 - black slick and thin film indicates recent pollution, little weathering;
 - brown to red slick with gradual disappearance of thin films indicates emulsion weathered by several days at sea.
- Thick patches with clear edges, usually dark brown to orange in colour and sometimes surrounded by thin films (patches of emulsion well weathered by a week or more at sea), and of substantial thickness, i.e. 0.2 to 3 cm and more, i.e. $200,000$ to $3,000,000 \text{ l/km}^2$, or more in the case of extremely viscous oil or emulsions.
- Tarballs of emulsion resulting from the fragmentation of thick patches into smaller elements, which are then increasingly difficult to detect.
- Brown and orange (or sometimes black) cloud-like patches can sometimes be seen below the surface of the water, indicating the presence of oil dispersed by treatment with dispersant.

Note:

Discontinuous true colour (see the Bonn Agreement Oil Appearance Code on the following page) is caused by the appearance of thicker slicks edge to edge with thinner (metallic) slicks. It is an effect created more by the combination of two appearances than of one specific appearance.

The colour of the slicks, patches and stripes will vary according to the luminosity, the colour of the sky and the observer's position in relation to the sun.

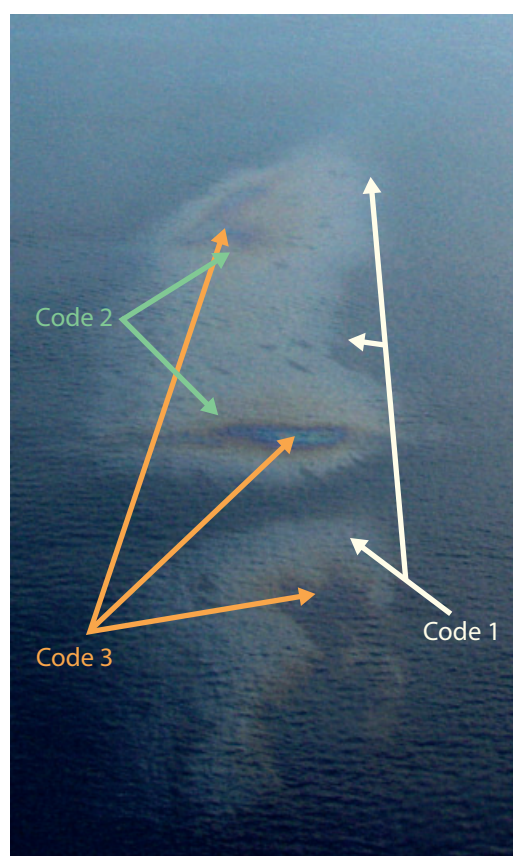
Oil slicks may adopt various random behaviour patterns or lie in windrows, parallel to the wind direction.

Bonn Agreement Oil Appearance Code

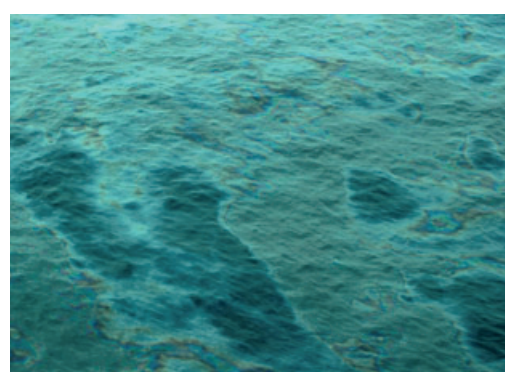
The Bonn Agreement Oil Appearance Code (BAOAC) is the result of a scientific programme aimed at determining the quantities of oil spilled using visual aerial observation. Studies carried out under the auspices of the Bonn Agreement led to the adoption of a new Appearance Code, applicable since January 2004, which replaces the former Colour Code. The BAOAC should be used in preference to other existing codes such as that of the Paris Memorandum of Understanding.

Table 3 Bonn Agreement Oil Appearance Code (applicable since January 2004)

Appearance	Layer thickness interval (μm)	Litres per km^2
Code 1: Sheen (silvery/grey)	0.04–0.30	40–300
Code 2: Rainbow	0.30–5	300–5,000
Code 3: Metallic	5–50	5,000–50,000
Code 4: Discontinuous true colour	50–200	50,000–200,000
Code 5: Continuous true colour	> 200	> 200,000

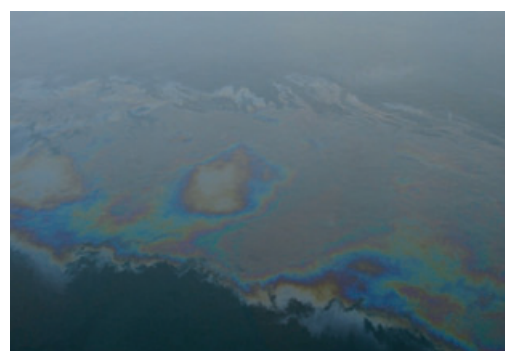


Source: Douane française



Metallic appearance, mainly Code 3

Source: Douane française



Appearance Codes 1, 2, 3 and 4)

Source: Marine nationale

Note:

The Oil Appearance Code allows thin layers to be characterized and the extent of spills to be assessed.

Table 4 *Oil slick Appearance Codes as defined in the Bonn Agreement Aerial Surveillance Handbook*
(www.bonnagreement.org)

Code 1: Sheen (< 0.3 µm)
The very thin films of oil reflect the incoming white light slightly more effectively than the surrounding water and will therefore be observed as a silvery or grey sheen. The oil film is too thin for any actual colour to be observed. All oils will appear the same if they are present in these extremely thin layers. Oil films below approximately 0.04 µm thickness are invisible. In poor viewing conditions even thicker films may not be observed. Above a certain height or angle of view the observed film may disappear.
Code 2: Rainbow (0.3 µm–5 µm)
Rainbow oil appearance represents a range of colours: yellow, pink, purple, green, blue, red, copper and orange. This is caused by an optical effect which is independent of the type of hydrocarbon involved. The colours will range from pale to highly luminous according to the angle of view and the thickness of the layer. Oil films with thicknesses near the wavelength of different coloured light, 0.2 µm–1.5 µm (blue 0.4 µm, red 0.7 µm), exhibit the most distinct rainbow effect. This effect will occur up to a layer thickness of 5 µm. Poor light conditions can lead to reduced appearance of colours. A level layer of oil in the rainbow region will show different colours through the slick because of the change in angle of view.
Code 3: Metallic (5 µm–50 µm)
The appearance of the oil in this region cannot be described as a general colour, as it will depend on the type of hydrocarbon as well as oil film thickness. Where a range of colours can be observed within a rainbow area, metallic will appear as a quite homogeneous colour that can be blue, brown, purple or another colour. The 'metallic' appearance is the common factor and has been identified as a mirror effect, dependent on light and sky conditions. For example blue can be observed in blue sky.
Code 4: Discontinuous true colours (50 µm–200 µm)
For oil films thicker than 50 µm the true colour of the oil will gradually dominate the colour that is observed. Brown oils will appear brown, black oils will appear black. The broken nature of the colour, due to thinner areas within the slick, is described as discontinuous. This is caused by the spreading behaviour under the effects of wind and current. 'Discontinuous' should not be mistaken for 'coverage'. Discontinuous implies colour variations and not non-polluted areas.
Code 5: Continuous true colours (> 200 µm)
The true colour of the specific oil is the dominant effect in this category. A more homogenous colour can be observed with no discontinuity as described in Code 4. This category is strongly oil type dependent and colours may be more diffuse in overcast conditions.

Appearance at sea



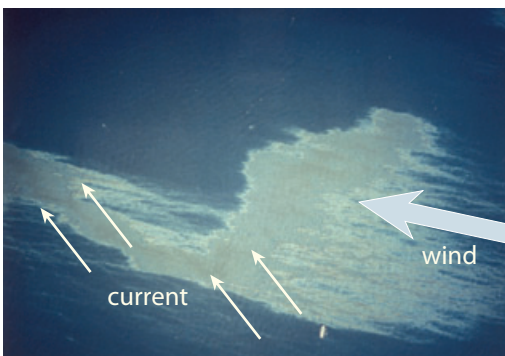
Source: Marine nationale

Sheen, rainbow, metallic.



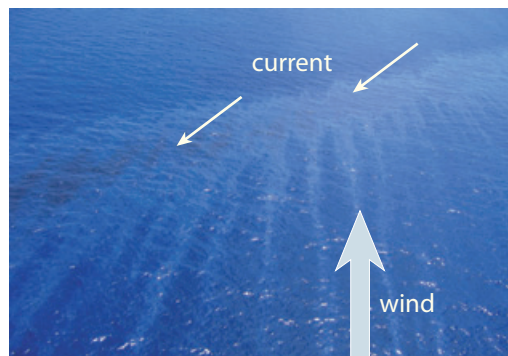
Source: Cedre

Fresh slick spreading widely.



Source: Cedre

As the slick weathers, thicker zones appear downwind.



Source: ITOPF



Source: Cedre

First thick patches of emulsion begin to appear.

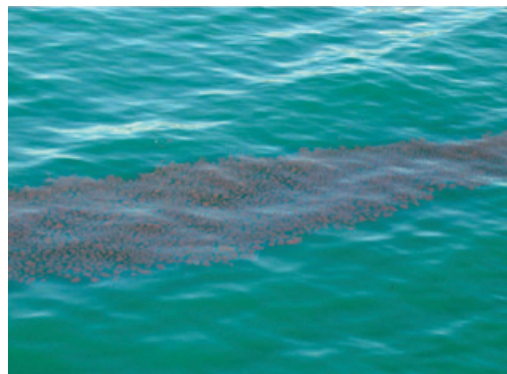


Source: Cedre

After a few days, the thin layers have been dispersed and only patches of emulsion remain.

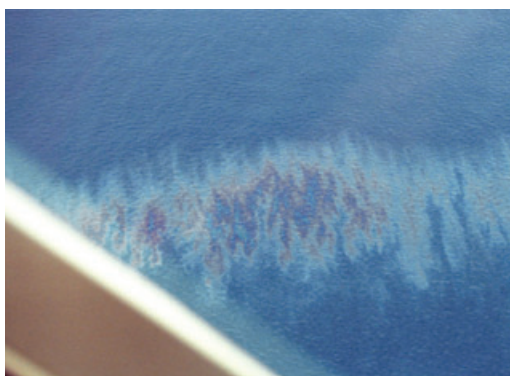


Source: AZTI



Source: ITOPF

The patches of emulsion fragment and form small tarballs which are only visible close up.

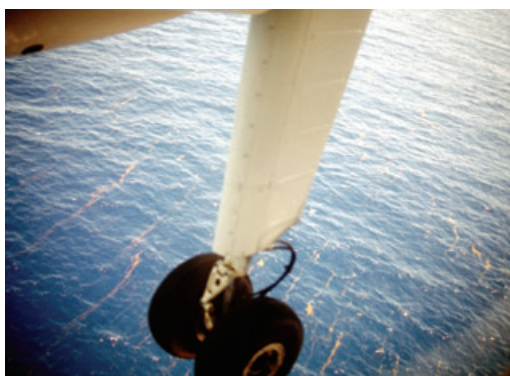


Source: Association Intervention

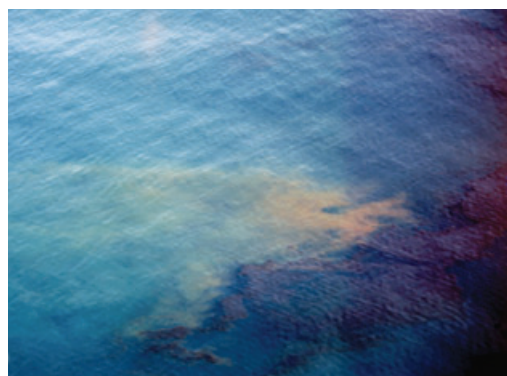


Source: Association Intervention

The wind slices the slicks into windrows. If the wind is strong, iridescences may disappear.



Source: Cedre



Source: Cedre

Weathered emulsion arranged in parallel stripes by the wind.

Oil slick partly dispersed by chemical dispersant.

Observation from a ship, sea cliff or platform

If aerial observation means are not available, we must sometimes make do with observation from a ship, a sea cliff or an exploration or production platform. In these situations, when at a distance, it is difficult to effectively discern the edges of the slick, its thickness and to control the position in relation to the sun.

Some practical common sense rules are required, for example:

- observe from the highest point of the ship, platform or cliff, as authorized by the site's safety rules;
- use polarized sunglasses; and
- if possible, conduct observations around midday (solar time).

It is important to:

- specify the surface area of accumulations;
- indicate whether the pollution is floating or has settled (observe attenuation of the height and breaking of waves to get an idea of the thickness of the pollutant, which may be as much as several centimetres); and
- describe the morphological characteristics of the type of coast affected, a factor that will determine the response techniques.

Note:

New remote sensing systems using standard ship navigation radar or on-board sensors, from one or several ships operating on a spill, can be used to detect slicks and help to position response vessels.



Source: ITOPF

Left: arrival of heavy crude oil on the coast.

Photographic and video imagery

Along with visual observation, it is useful to capture imagery of a spill to help identify and quantify the slick during the response. The imagery can also be used later on as evidence for prosecution in cases of illicit discharge. Cameras are used to take photography or video of a spill and use the visible light range of the electromagnetic spectrum to create true colour imagery. Cameras may be hand held by an observer or fitted to the aircraft and have the capability to geo-reference any imagery taken.

Box 5 *Aerial photography: technical specifications*

With the generalization of digital reflex cameras, with a sensor resolution of more than 10 million pixels, high quality images can now be obtained.

Thanks to digital technology, certain valuable information can easily be obtained, including the date, time and GPS position of the shot.

If the camera is not directly equipped with GPS, a small GPS unit can be clipped on to tag photos with the location of where the photo was taken. The geographical coordinates collected can then be used to position the photos on digital maps. After saving images in their original format, they can be transferred by email in smaller file formats.

Helpful hints

- Before the assignment, set the date and time on the digital camera. If necessary, synchronize the date and time on the camera with the GPS device.
- During the flight, do not lean against the inner wall of the aircraft, or lean the camera against the cabin window (to avoid vibrations).
- Place the camera very close to the window (about 1 cm away) and parallel to its surface to avoid any coloured reflections.
- Pay attention to the position in relation to the light, as well as the colours of the sea and sky which may be difficult to distinguish.
- If possible, take photographs around midday (solar time), avoid dawn and dusk (when the light may affect the colours).
- Take the tide level into account for photographs of the shoreline.
- For best results fly at low altitude.
- After the flight, carefully archive the photos taken. All photos should be index-linked and traceable.

Characteristics

- Digital reflex camera:
 - Lenses: 28 mm, 35 mm, 50 mm, 55 mm
- Accessories:
 - lens hood
 - filters (polarizing, anti-UV)
 - GPS unit
- Settings:
 - manual or high speed setting
 - focus set to infinity
 - 200 to 400 ISO, or even 800 ISO (ideal for foggy or overcast conditions, while ensuring a very high quality and a fine grain)
 - speeds used: from 1/500° to 1/2000° (highest shutter speed possible to avoid a streak effect)
 - aperture: f.8 to f.16 for a maximum depth of field.

Other types of imagery

In addition to photography and video imagery, there are other types of sensors that can be used to collect imagery and data by using wavelengths outside of the visible light range. As visible light is restricted by the time of day and can also be affected by weather conditions, there are several advantages to using sensors other than cameras, i.e. they can:

- be used during day or night time;
- be used in cloudy weather conditions;
- determine other properties about a slick and surrounding environment; and
- assist in minimizing the number of false alarms.

Sensors can be categorized into two different sensing techniques: active and passive. Active sensors transmit a signal that is then returned after coming into contact with, and then being reflected by, a particular feature; examples of active sensors include 'radio detection and ranging' (RADAR) and 'light detection and ranging' (LIDAR). Passive sensors do not transmit a signal but simply use the radiation emitted by a feature's surface; this includes the use of visible light in cameras, and the detection of thermal infrared radiation and ultraviolet light. Both types of sensors can be mounted onto systems on aircraft, vessels and satellites.

The use of sensors on aircraft, vessels and satellites to collect information about a spill play an important part in the overall surveillance of oil spills alongside aerial observation. Work is currently being conducted by the industry to understand further the role that both aerial platforms and satellites have in providing information about oil spills, including how they can be applied operationally during a response. The ongoing work is seeking to assess and clarify the advantages and limitations of the different methods, platforms and sensors, and aims to provide an overall recommendation of how they could be used (along with visual observation) as part of the remote sensing toolkit. This includes a recent report published by the American Petroleum Institute on *Remote sensing in support of oil spill response: planning guidance* (API, 2013) and two IPIECA-IOPG Good Practice Guidelines, *An Assessment of Surface Surveillance Capabilities for Oil Spill Response using Satellite Remote Sensing* (IPIECA-IOPG, 2014b) and *An Assessment of Surface Surveillance Capabilities for Oil Spill Response using Airborne Remote Sensing* (IPIECA-IOPG, 2014c).

See Table 5 (overleaf) for a summary of other sensors.

Table 5 Summary of different types of sensors that can be used to collect oil spill imagery and data

Remote sensing system	Active/passive	Sensing means	Range	Layer thickness interval detected	Limitations
Side-looking airborne radar (SLAR)	Active	Detects dampening by oil of capillary waves generated by the wind.	During reconnaissance flights (from 1,500 to 4,000 feet), SLAR can detect oil from a distance of 15 to 20 NM, on either side of the plane, except in the 'blind spot' directly below the plane, which is equal in width to the altitude of the plane. This gap can be covered by an infrared scanner.	Over 3 to 5 μm (to produce a dampening effect on capillary waves).	Penetrates the cloud layer. If the sea is too calm (0 to 1 on the Beaufort scale), the waves created by the wind are not high enough. On the other hand, if the sea is too rough (over 7 or 8 on the Beaufort scale), the oil layer will not dampen the capillary waves. The results must always be confirmed by visual observation and/or IR/UV scanning.
Infrared (IR) line scanner	Passive	Detects thermal radiation with a wavelength in the band of 8 to 12 μm .	Zone scanned is equal to twice the altitude of the plane. Compensates for the 'blind spot' of the SLAR. In practice, scanning should be carried out at 1,500 feet, allowing a width of approximately 1,000 m.	Over 10 μm . Slicks appear black or white on the screen depending on their thickness and temperature.	Difficulties of interpretation over 10 μm of thickness.
Ultraviolet (UV) line scanner	Passive	Detects the ultraviolet component of light from the sun reflected by oily liquids.	Zone scanned is equal to twice the altitude of the plane. Compensates for the 'blind spot' of the SLAR. In practice, scanning should be carried out at 1,500 feet, allowing a width of approximately 1,000 m.	Below 1 μm .	Cannot distinguish between different thicknesses; only daylight operations are possible.
Microwave radiometer (MWR)	Passive	Similar to the IR line scanner. Has the advantage of being able to measure the thickness, and therefore volume, of slicks detected.	Zone scanned is equal to twice the altitude of the plane. Compensates for the 'blind spot' of the SLAR. In practice, scanning should be carried out at 1,500 feet, allowing a width of approximately 1,000 m.	From 100 μm .	Calibration is necessary to determine volumes. For thick slicks and emulsions, the surface area of the slick can be calculated, but the thickness must be determined using other methods, such as by ships involved in the response operations.

continued ...

Table 5 Summary of different types of sensors that can be used to collect oil spill imagery and data (continued)

Remote sensing system	Active/passive	Sensing means	Range	Layer thickness interval detected	Limitations
Forward-looking infrared scanner (FLIR)	Passive	Detects thermal radiation with a wavelength in the band of 3 to 5 or 8 to 12 μm .	Depends on the altitude of the plane and the field of view selected by the operator, as well as the hygrometry.	From Code 2 or 3	FLIR cannot be used as a principal pollution research sensor. FLIR recordings can be used as a complementary method in addition to other observation means.
Laser fluorosensor (LFS)	Active	Laser beam		0.1 to 20 μm	Calibration is necessary. A petroleum hydrocarbon is identifiable only if integrated in the system. Operational LFSs can identify 13 different oils.

Using imagery as evidence of illegal discharge

In certain countries, photographic and video imagery acts as evidence for prosecution in cases of illicit discharge. Ideally, all the necessary information can be provided in three complementary shots:

- A detailed shot of the slick, taken almost vertically, from an altitude of less than 300 metres with the sun at the photographer's back.
- An overall, long-range shot of the ship and the slick, showing that the oil came from the ship in question.
- A detailed shot of the ship for identification purposes (colour of the hull and funnels, name, etc.).

In practice, a series of photographs should be taken, showing the ship and her polluted wake, the extent of the wake (without discontinuity), the name of the ship, and finally the surroundings (including in particular, if possible, other ships with 'clean' wakes for comparison) to clearly show that it is the ship in question which is responsible for the pollution. A shot showing where the discharge seems to have originated can also be added, even if this could potentially lead to confusion. Whatever the case may be, do not claim definitively that it is the discharged pollutant that is visible in the photograph. It is important to remember that ships can also discharge non-pollutant liquids (cooling water).

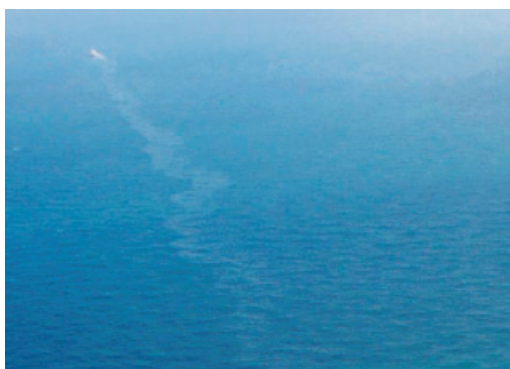
For preference, a polarizing filter should be used, which allows more selective visualization of thin films and thick layers than the naked eye.

In addition to photography and video, other sensors can be used to allow oil detection by night.

Various types of equipment can provide the identification of the ship involved, including AIS (automatic identification systems), new generation IR or electro-optic systems, and LLLTV (low-light level television) cameras.

In the absence of photos, the case file transferred to the legal authorities will include at least the following elements: the SLAR images, the infrared thermography of the wake, and the identification of the ship.

Right: a ship and her wake: the surrounding area is clean.



Source: Marine nationale



Source: Douane française

Right: close-up of a wake.



Source: Douane française

Above: the characteristics of a ship can begin to be distinguished at this distance.

Guiding response operations

Guiding a pollution response vessel

As the vessel crew cannot easily detect pollution on the water surface, they have to be guided in order to be effective in treating and recovering the pollutant. The best method involves providing detailed (map-based) descriptions of the pollution in the zone where the vessel or fleet are to operate. This means that it is not necessary to have a guidance aircraft permanently in operation.

Basic guidance implies directing the vessel to the thickest parts of the slicks by indicating the azimuth angle/distance, for example: 'a slick 20 m wide by 200 m long is located 30° right at 200 m'.

It is important to note the following:

- The plane (or preferably helicopter) in the area must inform the vessels of the location and shapes of the slicks, indicating the thick zones (or patches) on which response operations should focus.
- Guidance can be carried out directly via indications transmitted by marine band radio.
- When flying time in the area is limited, it is preferable to transmit to the vessel an exact description of the slick(s) and their position.
- Guidance can be improved by indicating the position of marker buoys or smoke floats in relation to the slick.



Source: Douane française

French Customs performing aerial guidance to direct the French response vessel, Ailette (pollution from the Prestige, Galicia, 2002).

Box 6 *An example of guidance during the Prestige response*

The Spanish Basque fishermen were very involved in the operations at sea to recover the fuel oil from the oil tanker *Prestige*. Their efforts were in addition to those of the pollution response vessels, when the pollution had become too geographically dispersed for these operations to be efficient enough. The fishing boats therefore had to be guided to the accumulations of fuel as soon as they were spotted.

A plane belonging to the regional authorities conducted flights over the zone, flying perpendicular to the coast. As soon as the plane was close enough to land, the positions of the slicks (taken using GPS) and estimations of their surface area or their volume were transmitted to AZTI, the Basque Technological Foundation, by mobile phone. A database, developed by AZTI, was used to reference all the vessels involved in response operations (180 fishing boats, 15 to 30 m long) with their storage capacity, the quantities recovered, the coordinates of their positions, and the number of people onboard (real-time transmission of information by satellite radio).

The AZTI operator was then able to determine which vessels were closest to the identified slick and whether or not the vessel had enough space to store the pollutant. He then informed them of the positions of the slicks by VHF (almost real-time transmission). These boats then recovered the pollution and once the recovery was completed the skipper of each boat contacted the AZTI response centre by VHF to inform them of the tonnage recovered. The vessel then continued on to another slick or headed into the harbour. This system was set up rapidly, thanks to the routine cooperation of the Basque fishermen and of AZTI during the fishing season.



Basque fishing boat involved in response operations for the Prestige pollution.

Source: AZTI

Reconnaissance report

POLREP (pollution report)

To quickly and efficiently transmit initial information on oil pollution at sea, a standardized pollution report (POLREP) format can be used, as illustrated in Box 7, below.

Box 7 Initial POLREP signal message format

Addressee for action: *relevant MRCC*

Addressee for information: *relevant authorities*

Title/subject: POLREP

A: Classification of report:

Doubtful—probable—confirmed

B: Date and time pollution observed/reported

C: Position and extent of pollution

If possible, state range and bearing of a prominent land mark or GPS position, and estimated amount of pollution (i.e. the size of the polluted area, number of tonnes spilled, or number of containers/drums lost). Where appropriate, give position of observer relative to pollution.

D: Tide, wind speed and direction

E: Meteorological conditions and sea state

F: Characteristics of pollution

Give type of pollution, e.g. oil (crude or otherwise), packaged or bulk chemicals, sewage. For chemicals give proper name or United Nations number if known. For all, provide information on appearance, e.g. liquid, floating solid, liquid oil, semi liquid sludge, tarry lumps, weathered oil, discolouration of sea, visible vapour. Any markings on drums, containers etc. should also be given.

G: Source and cause of pollution

For example, from vessel or other undertaking. If from vessel, say whether as a result of a deliberate discharge or a casualty. If the latter, give brief description. Where possible, give name, type, size, nationality and port of registry of polluting vessel. If vessel is proceeding on its way, give course, speed and destination.

H: Details of vessels in the area

To be given if the polluter cannot be identified, and the spill is considered to be of recent origin.

I: Whether photographs have been taken, and/or samples for analysis.

J: Remedial action taken or intended, to deal with the spillage.

K: Forecast of likely effect of pollution (e.g. arrival on beach) with estimated timing.

L: Names of other States and organizations informed.

M: Any other relevant information (e.g. names of other witnesses, reference to other instances of pollution pointing to source).

Mapping pollution

All the observations made during a reconnaissance mission must be recorded on one or several map(s). This operation should be carried out carefully, either during the flight or afterwards, depending on what is possible for each case. Mapping should be standardized so that the various observations made during a series of flights can be easily interpreted. Particular attention should be paid to marking the most heavily polluted areas (thick patches or slicks, pollutant accumulation zones), so that the extent of pollution can be estimated (see page 43) and response operations directed.

The method proposed in this section is derived from the internationally adopted method for observing icebergs in the polar areas.

Box 8 Map identification

In a corner of the map, the following should be recorded:

- date and times of the flight
- flyover zone
- map number (where several maps are produced during the flight)
- name of the observer and of the organization to which he belongs
- type of aircraft and the sensors used
- meteorological conditions: cloud cover, colour of the sky and the sea, the sea state

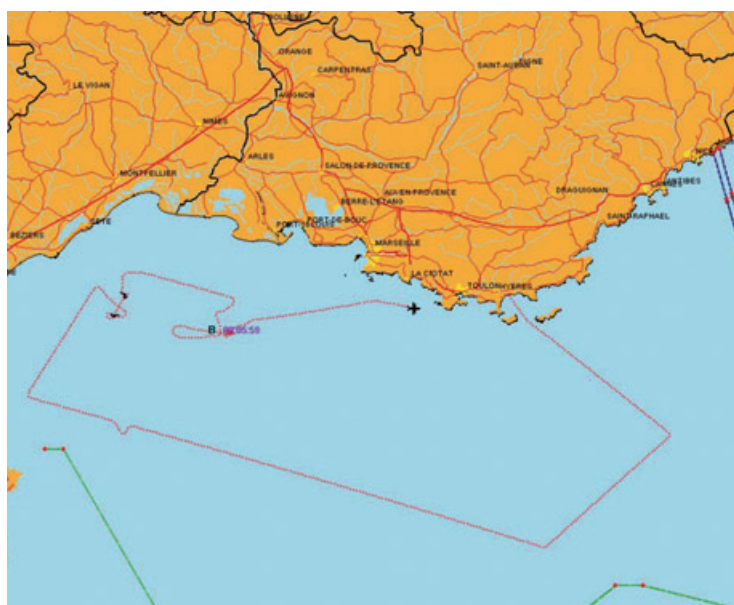
Box 9 Observation log

On a basic map prepared prior to the mission:

- mark the contours of each polluted zone observed with a continuous line
- specify the nature of the slick for each zone according to the criteria explained on the following page (use the given abbreviations)
- trace the plane's route with a dotted line

This log will contribute to the post-assignment report. Note-taking during the flight can be adapted to the circumstances and the practices of the observer.

Airplane navigation system linked to cartography provides a mission report with the flight route and the observed spills.



Box 10 *Description of the pollution*

Description	Abbreviation
Colour/appearance (see pages 25–26):	
• Sheen	Code 1
• Rainbow	Code 2
• Metallic	Code 3
• Discontinuous true colour	Code 4
• Continuous true colour	Code 5
For Codes 4 and 5, indicate colour:	
• Black	bl
• Brown	br
• Orange	or
Type:	
• Slick (\emptyset or L > 30 m)	sl
• Patch (50 cm < \emptyset or L < 30 m)	ptc
• Patty (10 cm < \emptyset < 50 cm)	ptt
• Tarball (\emptyset indiscernible)	tb
State of pollutant:	
• Fresh oil	fo
• Dispersed oil	disp
• Emulsion	emul
Arrangement:	
• Random	•
• Parallel stripes	//
Debris	deb

Box 11 *Slick dimensions*

The average dimensions for patches of emulsion (or potentially for slicks of fresh oil) are expressed in metres.

The information about the slick is reported as a list in the following order:

- type and arrangement
- coverage
- dimensions

Example of notation: pollution in the form of rainbow stripes, covering 40% of the sea surface, combined with patches covering 3% of the sea surface, average size of the patches: 10 m:

- ptc + code 2 //
- 40% code 2–3% ptc
- 10 metres

For clarity, these indications can be recorded on the edge of the map, taking care to show, using arrows, to which point on the map they refer.

If the same description applies to several different zones, the descriptive criteria should be recorded in a corner of the map with an identification by letter, and this letter noted in each of the zones concerned (see the example in Figure 7 on page 40).

When a slick spreads beyond the horizon, the limit of visibility should be shown using a dotted line.

Box 12 *Degree of coverage*

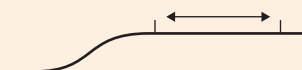
The degree of coverage is indicated as a percentage, with reference to the schematic representations (see page 43). If both thick patches and thin layers (sheen, rainbow, metallic) are present, if possible, specify their respective coverage (e.g. 5% ptc—30% Code 3).

Box 13 *Other indications*

- Show the route followed using dashes and crosses, e.g.:

- + - + - +

- Show the parts of the coast affected, e.g.:



- Also give the points at which the oil surfaces (in the case of a pipeline leak or a sunken wreck), e.g.:



- Various remarks and observations may be noted on the edge of the map or on an attached sheet, making sure that the place they refer to is clearly identified on the map by a letter at the appropriate point, e.g.:



(J = polluted pebbles at the top of beach)

Figure 7 *Mapping pollution—an example*

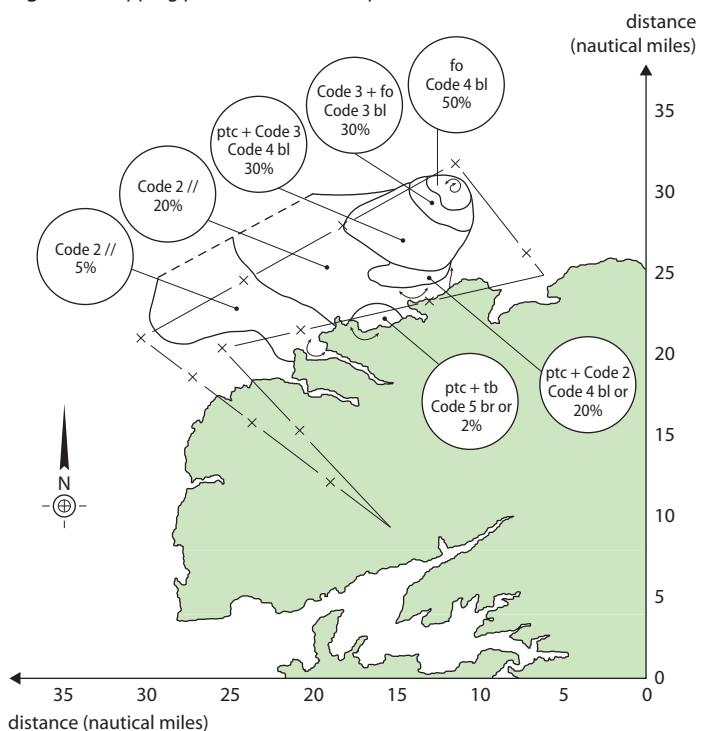


Figure 7 provides an example of a summary map using the abbreviations discussed in this section.

Estimating the quantity of pollutant

Although estimating the quantity of pollutant is no easy task, it is nevertheless a necessary one. Estimations are made using maps, taking into consideration the polluted surface and the thickness of the slicks.

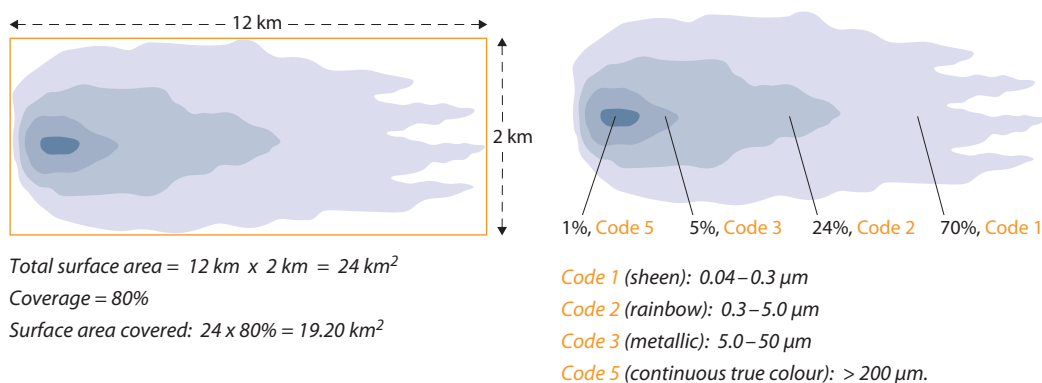
Estimation at sea

- Surface
 - The surface area is obtained by multiplying the overall surface area of each zone by its degree of coverage (thick patches).
 - The surface area of a slick or an accumulation of tarballs can be calculated directly using an onboard GPS system, SLAR or an IR/UV scanner.
- Thickness
 1. Visual observation:

For a major oil spill, as a first estimation to inform operational decision making (e.g. resource mobilization or escalation) and in the absence of indications to the contrary, it is recommended that the higher value of the range provided in the Bonn Agreement Oil Appearance Code is used. (See pages 25–26 for more information on the Oil Appearance Code.)
 2. Calculation with instruments:

Use of a microwave radiometer (MWR) or a laser fluorosensor (LFS) is recommended.

Figure 8 Example: estimating the volume of spilled oil at sea* using the Bonn Agreement Oil Appearance Codes



Total surface area = 12 km x 2 km = 24 km²
 Coverage = 80%
 Surface area covered: 24 x 80% = 19.20 km²

a) Minimum estimation

Code 1 19 x 70% x 0.04 = 0.532 m³ (532 litres)
 Code 2 19 x 24% x 0.3 = 1.368 m³ (1,368 litres)
 Code 3 19 x 5% x 5.0 = 4.75 m³ (4,750 litres)
 Code 5 19 x 1% x 200 = 38 m³ (38,000 litres)

Total: 44.65 m³ (44,650 litres)

b) Maximum estimation

Code 1 19 x 70% x 0.3 = 3.99 m³ (3,990 litres)
 Code 2 19 x 24% x 5.0 = 22.8 m³ (22,800 litres)
 Code 3 19 x 5% x 50 = 47.5 m³ (47,500 litres)
 Code 5 19 x 1% x 200 = 38 m³ (38,000 litres)

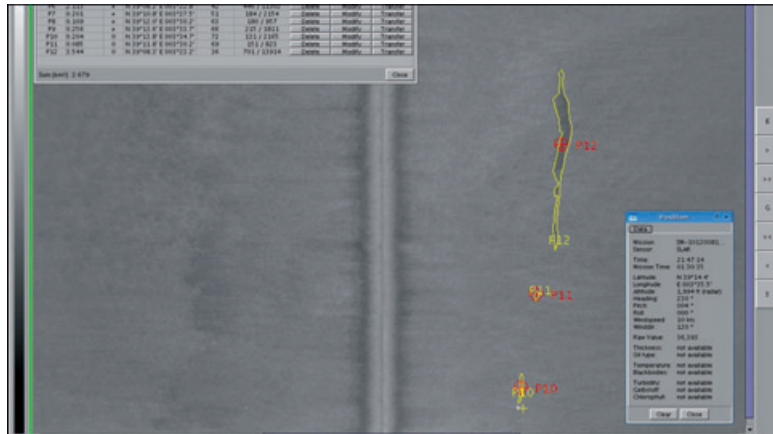
Total: 112.29 m³ (112,290 litres)

The Bonn Agreement Oil Appearance Code (BAOAC) Handbook suggests that the minimum volume estimate should be used for legal (enforcement) and statistical purposes. It further suggests that, in general terms, the maximum quantity should be used, together with other essential information such as location, to determine any required response actions.

However, it is emphasized that each national authority will determine how to use the BAOAC volume data within its own area.

(*Design: J-P Castanier, French Customs; calculation: Alun Lewis, consultant)

*Slick mapping—
example of surface
calculation by the
SLAR system.*



Source: Sasemar

Onshore estimation

Although the surface area of pollution can be estimated fairly quickly (by multiplying the stretch of the coastline affected by the width of the zone covered), the thickness may vary widely (from a few millimetres to several decimetres).

Moreover, on the coast, the risk of error and confusion is increased by the presence of other factors such as waste, seaweed, etc. (see *Arrival of oil on the coast*, on page 18).

For greater accuracy, the assessment of coastal pollution requires on-land reconnaissance (see the IPIECA-IOGP Good Practice Guide on oiled shoreline assessment (SCAT) surveys (IPIECA-IOGP, 2014d).

*Arrival of emulsified heavy
fuel oil on land following
the Prestige spill (Galicia,
Spain, 2002).*



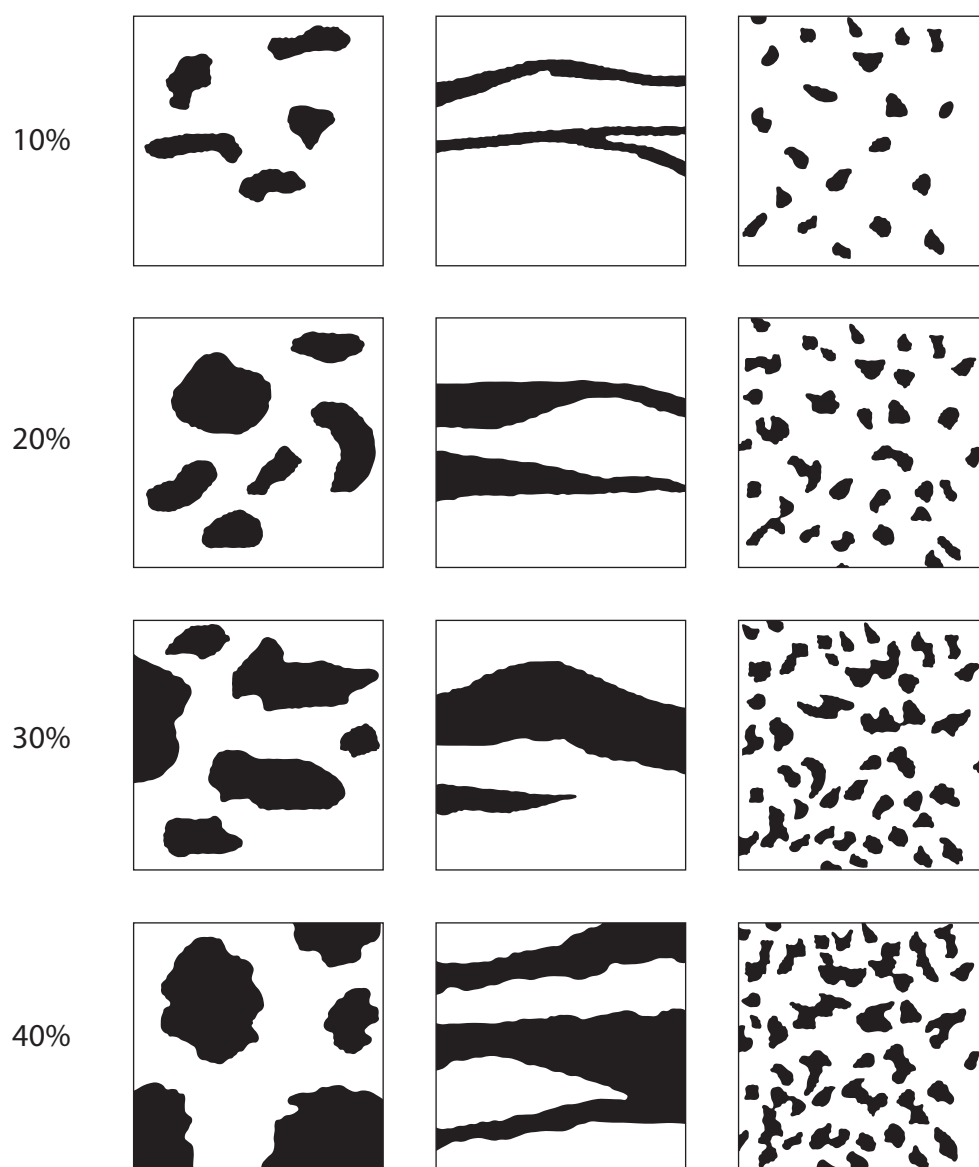
Source: Cedre

Note:

Evaluations based on aerial observations can only provide an order of magnitude. Uncertainties about the true thickness of slicks can lead to estimations of volume that vary up to a factor of ten. Nevertheless, minimal estimations should be considered a reliable source of information in determining the minimum quantity that was spilled in reality.

Extra caution should, however, be used when using the Bonn Agreement Oil Appearance Code during major incidents involving large quantities of thick oil and/or heavy oils or when emulsion is present. Air crews should use all the available information or intelligence, such as oil thickness measurements taken by surface vessels, to estimate the volume.

Degree of coverage*



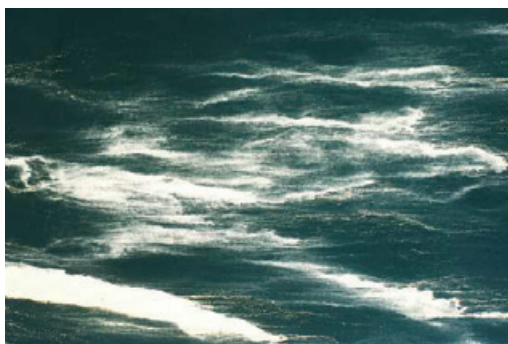
Source: E. H. Owens and G. A. Sergy, 1994)

* This is a rough schematic representation designed to serve as a visual aid only.
See also the section on the Bonn Agreement 'Appearance code' on pages 25–26.

Other products and natural phenomena

Other products

Images of various chemicals and food products spilled at sea can be confused with images of oil slicks. It is therefore useful to have a number of reference images to avoid interpretation errors. Vegetable oil and certain chemicals also show up on remote sensing equipment.



Source: Cedre

Emulsion of palm oil in the form of white patches (Allegra accident, Western Channel, October 1997).



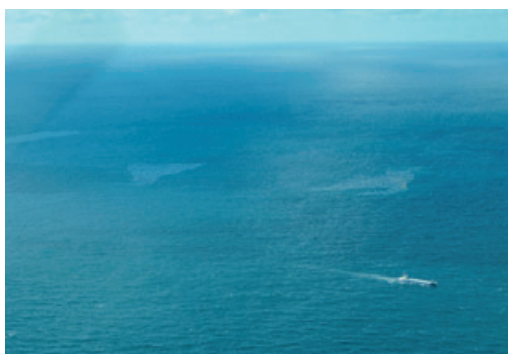
Source: Douane française

Styrene slick observed by a French Customs plane (Ievoli Sun accident, Les Casquets, France, October 2000).



Source: ITOPF

Molasses spill.



Source: Douane française

Palmar I experiment (France, October 1998): from left to right: soya bean oil; fuel oil; palm oil.



Source: Marine nationale

Vegetable oil release.

Natural phenomena

Various floating objects and other phenomena can be mistaken for oil slicks. For instance, the following have been known to give rise to confusion:

- Shadows of clouds making darker zones on the surface of the water.
- When the sea is relatively calm, surface currents or convergence of cold and warm water can, with a small angle of incidence, give the appearance of a film (sheen, rainbow, metallic).
- Muddy waters at river mouths, in bays or simply near to the coast, can catch the eye because of their beige appearance in comparison to the surrounding water (coloured water without any sign of a film—sheen/rainbow/metallic—on the surface cannot be an oil slick).
- Floating algae, phytoplankton blooms or pollen stripes may look like coloured slicks.
- Shoals which look like dark slicks.
- Calm areas.

When observing by helicopter, check for the presence of an oil slick when in doubt by hovering low; if the sighting is an oil slick, the turbulence created by the rotor will cause it to drift away.

Wherever possible, observations carried out by plane should be ultimately confirmed by helicopter reconnaissance (allowing closer observation), or by a plane fitted with special remote sensing equipment (IR, SLAR, FLIR, etc.). If still in doubt, samples can be taken to remove all uncertainty, if the weather conditions and available techniques allow it. In this case, samples should be taken as quickly as possible and exclusively from the slick observed. The aim is to prove that the substance spilt at sea is indeed a hydrocarbon. It is, however, difficult to take representative samples at sea from an aircraft.

Note:

If any doubt, observe the area from a closer distance to confirm or dismiss the presence of oil.

Photographic examples of natural phenomena (continued overleaf)



Source: ITOPF

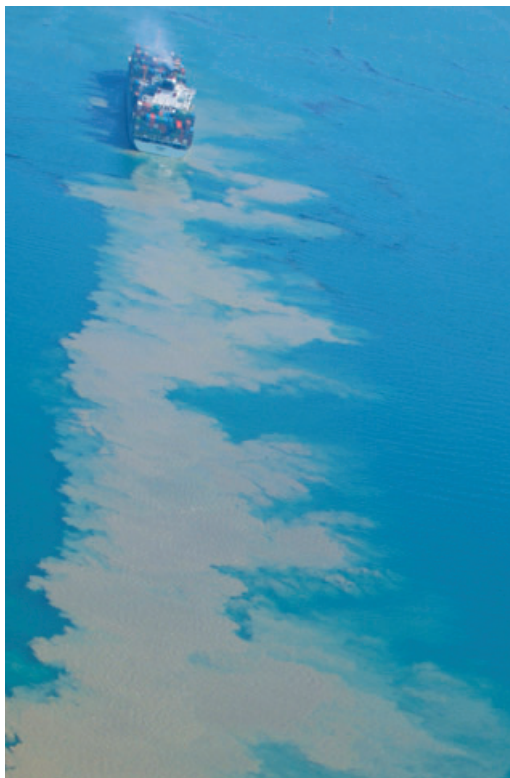
Shadows formed by clouds give an impression of floating oil.



Source: Cedre

This surface effect is caused by the presence of two water masses with different temperatures.

Near right: muddy water near the coast. Silt from the seabed becomes suspended in the water due to the movement of the propellers.



Source: ITOPF



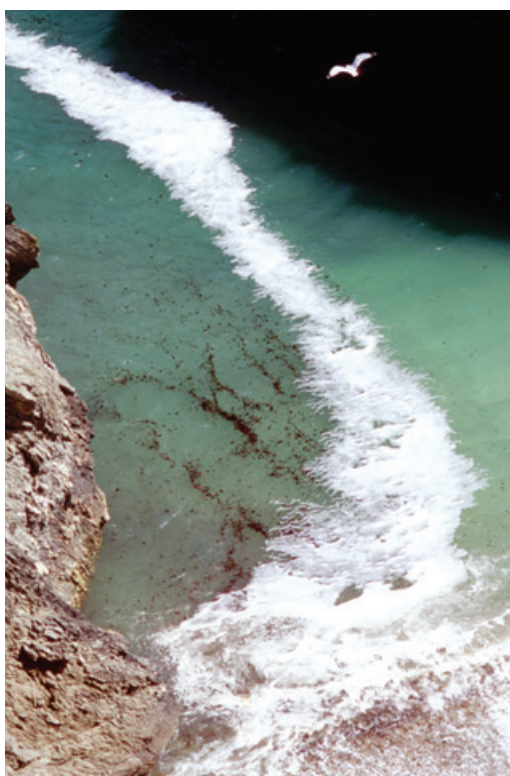
Source: ITOPF

Above: Peat on the water surface.

Below: Algal bloom.



Source: Ocean and fisheries



Source: Cedre

Near right: seaweed near the coast.



Source: Douane française

Clumps of seaweed drifting at sea.



Source: Cedre



Source: ITOPF

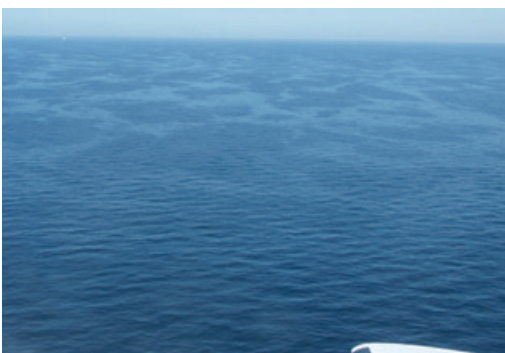


Source: Cedre



Source: ITOPF

Above: four examples of slick-like effects due to the presence of sand banks, seaweed, coral reefs etc.



Source: Douane française



Source: Marine nationale

Left: coloured stripes due to the development of phytoplankton (observation from a hovering helicopter; note the effect of the wind made by the rotor demonstrating that in this case it is not an oil slick).

Above: Calm patches can be confused with a thin film of oil.



Source: Cedre

Left: plankton bloom.

Glossary

AIS	Automatic Identification System.
Argos beacon	A transmitter used in conjunction with the Argos satellite-based location and data collection system that enables information to be gathered on any object equipped with such a transmitter, anywhere in the world.
Auto-ignition temperature	Minimum temperature at which vapours spontaneously ignite.
AZTI Tecnalia	Oceanographic Foundation, involved in the social and economic development of several aspects of food industry, as well as the protection of the marine environment and fishing resources.
Cedre	Centre of Documentation, Research and Experimentation on Accidental Water Pollution.
cSt	Measure of viscosity; 1 cSt (centistoke) = flow of 1 mm ² /s.
Density	Quotient of the volumic mass of a substance and the volumic mass of water for a liquid or of air for a gas.
Dispersant	Product containing a solvent, used to condition active matter and to diffuse it in the water. A mixture of surfactants ensures the dispersal of oil into small droplets in the marine environment.
Dispersion	Formation of oil droplets of varying sizes, due to wave action and turbulence on the sea surface. These droplets either stay in suspension in the water column, or resurface to form another slick. This natural process can be encouraged by the use of dispersants, depending on the viscosity of the petroleum hydrocarbon and on whether the geographical and bathymetric situation makes their use possible.
Emulsification	Emulsification refers to the formation of an oil-and-water emulsion. This emulsion may be made up of a large proportion of water (often 60%, can be up to 80%). It varies in colour from brown to orange and is often referred to as 'chocolate mousse', which gives an indication of its consistency.
Evaporation	Transformation of a liquid into a vapour via its free surface, at a particular temperature. The rate of evaporation of oil depends mainly on the proportion of volatile products and the combination of hydrocarbons, as well as other factors such as the wind speed, the water and air temperature, the roughness of the sea surface and extent of spreading. The lightest fractions evaporate first, and the least volatile fractions form a residue, with a higher density and viscosity than the original hydrocarbon.

Explosimeter	Appliance used to measure the concentration of inflammable gas in the atmosphere.
FLIR	Forward-Looking Infrared: an infrared sensor used for remote sensing of oil slicks. In optimal atmospheric conditions, it can detect a slick approximately 20 nautical miles from the aircraft when flying at 3,500 feet. It can detect Bonn Agreement Oil Appearance Code 2 (rainbow) slicks, and has no upper thickness limit. It can also be used to read the name of a vessel at night.
GIS	Geographical Information System.
GPS	Global Positioning System.
HFO	Heavy Fuel Oil.
IFO	Intermediate Fuel Oil.
Ifremer	French Research Institute for Exploitation of the Sea.
IR	Infrared.
LFS	Laser Fluoro Sensor.
LLLTV	Low Level Light Television.
Microwave radiometer (MWR)	Sensor used for remote sensing of oil slicks. The detection method makes it an all-weather sensor. It can also determine the thickness of slicks.
MOTHY	Météo France's Oceanic Oil Transport Model, a drift prediction model for oil slicks and objects at sea.
MRCC	Marine Rescue Coordination Centre.
Phytoplankton bloom	Vigorous proliferation of plankton
POLREP	POLLution REPort.
Pour point	Temperature below which a hydrocarbon stops flowing. If a substance's pour point is above room temperature, it is less fluid. Pour points are measured in laboratory conditions and are not an accurate representation of the behaviour of a particular hydrocarbon in an open environment.

Remobilization	Remobilization is the process in which the sea reclaims grounded or beached pollutant, or pollutant buried or trapped in sediment near the coast.
Remote sensing	Collection of techniques used to detect and identify phenomena from a certain distance, either through human capacities or special sensors. In the case of aerial observation of oil pollution, remote sensing relies on the use of detection systems, including SLAR, FLIR, infrared and ultraviolet scanners and microwave radiometers.
SAR	Synthetic Aperture Radar.
SASEMAR	Sociedad de Salvamento y Seguridad Marítima (Spanish maritime rescue and safety organization). Spanish organization in charge of search and rescue services at sea, as well as pollution response for the Spanish state, within its responsibility zone which covers approximately 1,500,000 km ² . Since 2009, SASEMAR has been known as Salvamento Marítimo.
SG Mer	French General Secretariat for the Sea.
SHOM	French Naval Hydrographic and Oceanographic Service.
SLAR	Side-Looking Airborne Radar, used to detect oil slicks.
Surfactant	A wetting agent which can increase spreading of a liquid (which is dependent on surface tension).
UV	Ultraviolet.
Viscosity	Property of resistance to uniform pouring without shaking a substance, inherent in the mass of a substance.
VOC	Volatile Organic Compound—the term covers a wide variety of chemicals which are all compounds of carbon and are volatile at room temperature.

References and further reading

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OSRL (2011). *Aerial Surveillance Field Guide: A guide to aerial surveillance for oil spill operators*. Version 2, December 2011. Oil Spill Response Limited, Southampton, UK.

Useful websites

Bonn Agreement: 'Surveillance' and 'Meetings and documents' sections. www.bonnagreement.org

Cedre (Centre of Documentation, Research and Experimentation on Accidental Water Pollution).
Discharge at sea. www.cedre.fr

CIS (Community Information System). European Union website explaining the national organization for response to accidental marine pollution and means available for each member state. http://ec.europa.eu/echo/files/civil_protection/civil/marin/cis/cis_index.htm

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www.itopf.com

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IPIECA

IPIECA is the global oil and gas industry association for environmental and social issues. It develops, shares and promotes good practices and knowledge to help the industry improve its environmental and social performance; and is the industry's principal channel of communication with the United Nations. Through its member led working groups and executive leadership, IPIECA brings together the collective expertise of oil and gas companies and associations. Its unique position within the industry enables its members to respond effectively to key environmental and social issues.

www.ipieca.org



The International Maritime Organization (IMO) is the United Nations' specialized agency responsible for the improvement of maritime safety, and the prevention and control of marine pollution. There are currently 153 member states and more than 50 non-governmental organizations (NGOs) participating in its work which has led to the adoption of some 30 conventions and protocols, and numerous codes and recommendations concerning maritime safety and marine pollution. One of the most important goals of the IMO's Strategy for the Protection of the Marine Environment is to strengthen the capacity for national and regional action to prevent, control, combat and mitigate marine pollution and to promote technical cooperation to this end.

www.imo.org



IOGP represents the upstream oil and gas industry before international organizations including the International Maritime Organization, the United Nations Environment Programme (UNEP) Regional Seas Conventions and other groups under the UN umbrella. At the regional level, IOGP is the industry representative to the European Commission and Parliament and the OSPAR Commission for the North East Atlantic. Equally important is IOGP's role in promulgating best practices, particularly in the areas of health, safety, the environment and social responsibility.

www.iogp.org.uk

