Exploring for Offshore Oil and Gas

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FINDING OIL UNDER THE SEA

Many of the world's potential reserves of hydrocarbons lie beneath the ocean. The hydrocarbon industry has developed techniques suited to conditions found in the offshore, both to find oil and gas (known as exploration) and to successfully extract it for human use.

Modern exploration for oil and gas relies on a solid foundation of geological and technical knowledge. In addition, today's capabilities with computers and advanced electronics, drilling techniques and methods of project management, have increased our ability to find hydrocarbons, and the speed at which projects can be developed.

Companies earn the right to explore the seabed by competitive bidding, under a legal process that grants exploration licences to areas of the sea floor that might hold hydrocarbons. In waters off Nova Scotia, the Canada Nova Scotia Offshore Petroleum Board regulates this process.

A company may or may not have prior information about the geology of its licence area, but at the very least it has enough data to suggest that the potential is great enough to invest time and money in surveys and exploratory drilling. Usually, company geologists infer this from geological similarities to areas where hydrocarbons have been found before. Nonetheless, companies always run the risk of coming up empty-handed at the end of an exploration program.

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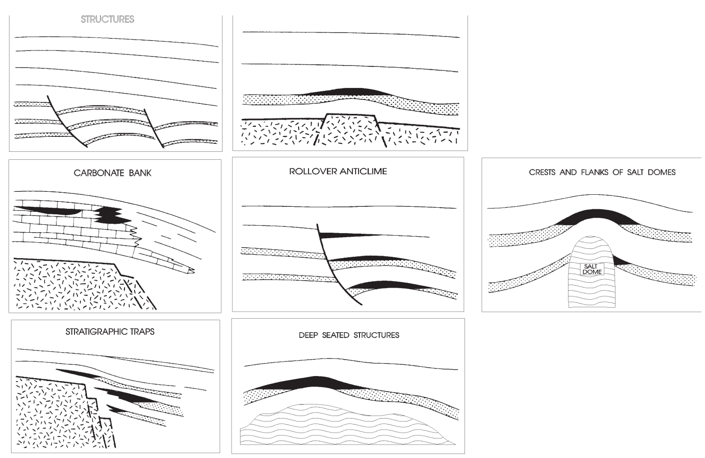
This fact sheet describes oil and gas exploration in the offshore, and outlines its typical environmental effects. Companion papers describe the basics of hydrocarbon resources, and what happens during the production phase of an offshore project.



some of the rock formations that trap hydrocarbons; geologists and geophysicists look for these when searching for oil and gas

EXPLORATORY TECHNIQUES

ABOUT SEISMIC SURVEYS

Seismic surveys allow geophysicists to get a picture of underground rock formations. Sound waves are created by the explosive release of compressed air from an array of air guns towed behind *seismic vessels* (specialized ships), firing every 5 - 12 seconds.

The waves bounce off layers of rock under the ocean floor, and the timing of these echoes when they are received by *hydrophones* (towed microphones), shows the shape and location of the geological features.

Hydrophones are on long cables (streamers), usually at 12.5 m intervals. One or many streamers can be used; the type using a smaller number is called a *2-D* survey, as it gives a two-dimensional profile. Streamers can be up to 6 km long and are stored on a large winch.

The seismic ship records the data from all the hydrophones, including accurate coordinates for the ship and its hydrophones. The most sophisticated surveys employ numerous streamers and many hydrophones, providing enough data to give a detailed 3-dimensional profile of the rock layers; these are called *3-D* surveys.

Oil companies use a combination of two basic methods — seismic surveys and exploratory drilling—to look for hydrocarbons under the sea.

Seismic Surveys

The term 'seismic' is derived from '*seism*', a Greek word for earthquake. It refers to the technique used to map rock layers and properties without having to drill a well. Geophysicists set off powerful sound sources in the ocean and record the echoes as they bounce back from rock layers beneath the sea floor. The time for each echo to return depends on the depth and properties of the rock layers.

The sound source for seismic surveys is an array of air guns, each of which creates underwater sound by sudden simultaneous release of high pressure air. Typical seismic surveys can map rock layers over 10 kilometres into the seabed.

Shallow seismic surveys of the upper few hundred metres of the seabed are often carried out to determine the structure of the sediments and scan for potential hazards to drilling (e.g., shallow gas pockets).

Exploratory Drilling

Although seismic surveys and geological knowledge can paint a picture of the rock structure, the properties of the rocks, as well as the presence of hydrocarbons, can only be determined by drilling into the rock layers. This is known as exploratory drilling.

Exploratory drilling in the offshore is carried out by mobile drilling platforms. Of the many types of mobile drilling platforms, two in particular — jack-up and semi-submersible rigs — are likely to be used if drilling were to take place on Georges Bank.

Mobile platforms are ideal for exploratory wells because they can be easily moved from one location to another. Jack-up rigs consist of self-contained legs lowered to contact the seabed and are typically used in water depths less than 130 m.

Semi-submersible drilling rigs, which rival a battleship in weight, are platforms which have large diameter cylindrical legs that provide flotation; they permit exploratory work in

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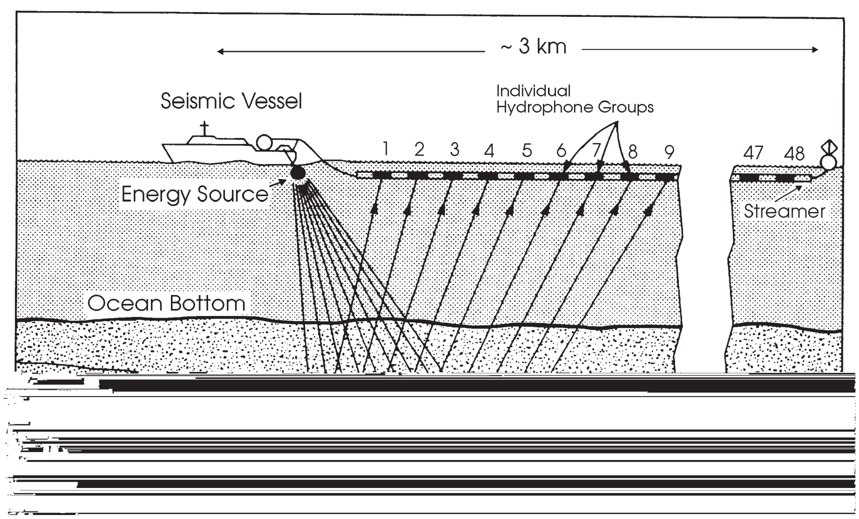

seismic vessel and array mapping rock layers beneath the ocean

Drilling Basics

The drill is a string of threaded sections of pipe with a drill bit mounted at the end. Motorized equipment rotates the drill pipe, causing the bit to cut into the rock. Different bits are available for different types of rock; a bit can wear out in only hours if hard rock are encountered.

During drilling, geologists on the drilling platform routinely examine fragments of rock to assess the location of the bit and characteristics of the rock. The drill can also be equipped to recover columns of rock, known as cores, to provide more detailed information on rock characteristics.

The first 60 to 1200 m of a well is drilled directly into the sediments and rock, with no casing, in a process known as *spudding*. Later, the drill string is removed and a pipe—the well casing—is inserted into the well. As drilling progresses, the well is lined with additional casing both to prevent rock from crumbling into the hole and to contain any high pressure gases and liquids.

The well also contains blow-out preventers—devices on the top of the casing that can close off the well in the event of uncontrolled pressures. Each new section of well casing is smaller in diameter; typically the diameter of the hole decreases with depth. Sensors inserted in the drill pipe monitor conditions in the well.

During drilling, a continuous flow of drilling ‘mud’ is circulated in the well. This mud is actually a thick mix of clay and other chemical additives in water or mineral oil, as well as barite (barium sulphate), which adds weight.

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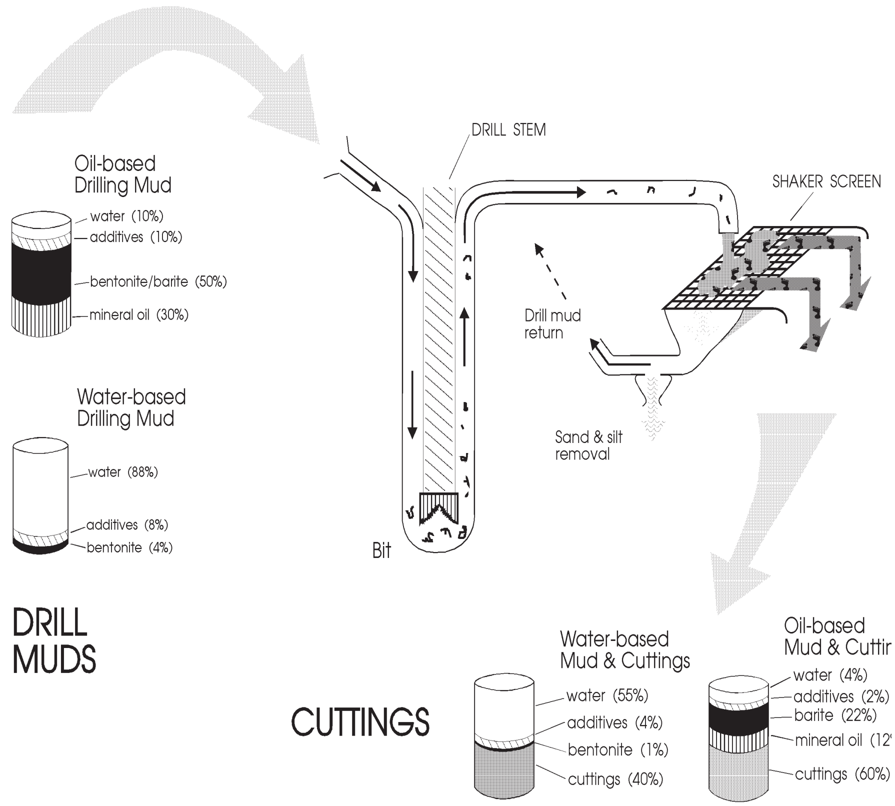


DRILLING FLUIDS

Two basic types of drilling fluids, or *muds,* are used in offshore exploration and production: water-based and oil-based muds.

Water-based mud is made up of clay (bentonite) and water; it may include barite, a heavy mineral used as to add weight. Chemical additives are mixed in to stabilize the drilling fluid during use, and to reduce corrosion and bacterial activity.

Some chemicals, called *coagulants* thicken and others, known as *anticoagulants*, thin the mud. Water-based mud is increasingly used for most offshore wells and in the shallower parts of deep wells.

Oil-based mud is a mixture of barite, mineral oil, and chemical additives. Oil-based muds are used for deeper well sections, and in cases where the well is drilled at an angle (directional drilling), where there is an increased likelihood for a drill pipe to stick. Oil-based mud is more expensive and has more negative environmental effects compared to water-based mud.

A new family of synthetic-based muds has become available in which the mineral oil component is replaced by artificial oil-like substances. These new muds were developed in the hope of better environmental performance than oil-based muds. However, they are not widely used because they are expensive, and because it is still unclear whether their performance meets expectations.

HOW HAS OFFSHORE EXPLORATION CHANGED IN THE PAST FEW DECADES?

The hydrocarbon industry worldwide has matured considerably as more experience has been gained in offshore drilling. There are technology advances for exploration and development, better control of environmental impacts, increased efficiency, and improved understanding of the marine environment. Several key areas of improvement are outlined below.

Seismic surveying now has improved instrumentation, more accurate positioning techniques, and increased computer capability for processing and interpreting data. Computers have assumed many of the more labour intensive and manual activities associated with seismic studies. This has improved the efficiency and accuracy of assessments while reducing costs.

Seismic surveys completed with more sensitive equipment and computer analysis allow subsurface rock structures to be mapped in finer detail, often with less ship time. Improved technology has also led to more precise positioning of wells.

Drilling fluids have also been improved, chiefly in the reduction of contaminants. Heavy metals (which are potentially harmful to marine organisms) have been reduced or removed from some parts of drilling fluids, and more environmentally-friendly alternatives substituted.

For example, chromium has been removed from lignosulfonate, one of the main water-based drill mud additives; barite has reduced the amounts of mercury and cadmium. At the same time, environmental regulations under which the companies operate have been strengthened in most areas.

Environmental performance has improved particularly in terms of the oils used to free pipe while drilling, and the reduced toxicity of mineral oils in some drilling muds. Early drilling frequently used diesel oil in drilling fluid, but its use was stopped because it was so toxic.

Mineral oils replaced diesel, but at first these too proved toxic. However, the highly refined mineral oils used now are virtually free of harmful contaminants; however, they have other objectionable environmental effects, and their use is highly regulated.

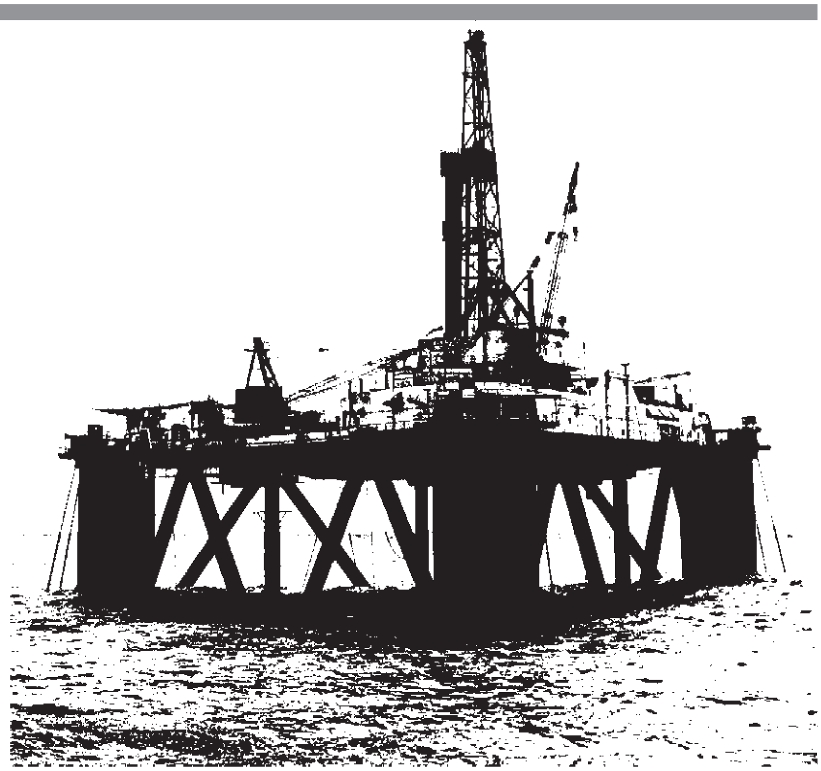
Improved methods of separating oil from drill cuttings discharged from rigs have further reduced emissions entering the marine environment.

SUPPORT VESSELS

Drill rigs are tended by support vessels, which bring in supplies and equipment, including pipe, drill muds, fuel, chemicals and supplies. Vessels usually steam regularly from nearby ports. Helicopters make regular trips out to the rigs.

An exploratory drilling operation usually employs one or more drill rigs, a rig tender, and supply vessels. Occasionally, two or more drilling vessels may be used simultaneously depending on the exploration plan.

Drill rigs for exploratory drilling are leased for each project, usually from large international drilling companies such as Rowan, Zapata, and Sedco.



a semi-submersible drilling rig at an offshore well

HOW CAN OFFSHORE OIL AND GAS EXPLORATION AFFECT THE ENVIRONMENT?

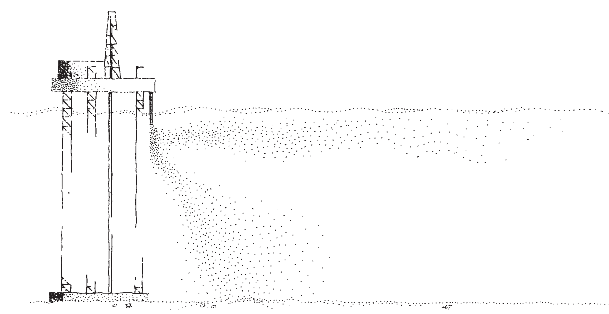
Our complex human actions, like exploring for offshore oil and gas, can have many and varied environmental effects. Here we look at how exploration affects the sea environment in local, immediate ways; a companion paper, *Global Environmental Implications of New Hydrocarbon Developments*, reviews the broader aspects of our uses of hydrocarbons.

Seismic Surveys

The loud sounds from the air guns used in seismic surveys can have a range of effects on living creatures, depending on how close they are. Sound can travel a long way through water.

Sound pressure from the air gun can kill or injure fish with swim bladders, and damage the hearing of marine mammals and other animals, if either are within a few metres of it. Fish eggs and larvae can be killed or mortally damaged in a radius of 1.5 to 6.5 m from the seismic source; less than one percent of the eggs and larvae are usually affected in a given survey area. Sea birds tend to be unharmed; to be hurt they would have to be actually underwater and very close to the air gun when it went off. Small crustaceans like krill, found in zooplankton, are usually unaffected.

Further away, more than a few metres from the source, seismic surveys can disturb fish and marine mammals. The noise may affect how they feed or migrate, or their distribution in the ocean. Fish catches are known to drop for some time after seismic work has occurred.



release of drill cuttings from an offshore rig

Marine mammals can hear sounds from seismic surveys at great distances, but it is not known how much the sounds influence their behaviour. Mammals and other higher animals often develop a tolerance to unnatural sounds. Some kinds of whales, for example, seem to be comfortable in noisy harbours and sea lanes; other species, like certain dolphins, like to ride the bow waves of ships.

However, the question remains whether seismic sound might cause a species to leave an area critical to its survival, whether for food or for protection. In that case, seismic surveying might well cause greater damage over the long run, than through any immediate affects.

The class environmental assessment of seismic exploration on the Scotian Shelf (1998), concluded that the predicted impacts on invertebrates, fish and marine mammals were negligible to minor. There exists the potential for conflicts between seismic operations certain fishing gear types. These conflicts, however, can usually be avoided by careful scheduling.

Drilling Discharges

Drilling an exploratory well releases different materials into the sea's environment. What and how much is released depends on the characteristics of the particular well, like how deep it is, and what kind of rocks it penetrates. In shallow wells and the upper portions of deep wells, the main discharge is water-based drilling mud and rock cuttings.

Under Canadian regulations, companies can dump water-based mud into the ocean, as it is comparatively non-toxic. Usually the mud is dumped in single large discharges (bulk discharge) of typically 500 cubic metres. A single well may lead to 6000 m^3 of cuttings and mud discharge. Mud is dumped when it is no longer suitable for drilling.

Drill cuttings are small pieces of rock generated by the crushing action of the drill bit. Typically they are about the consistency of sand or finer, such as silt and clay. Additional material can slough off the drill hole wall, commonly referred to as "washout".

All rock removed from a well is deposited on the seabed. For an average well, this is equivalent to a column 5000 m deep, with a diameter of 90 cm at the surface, to about 20 cm at the bottom. The volume of rock can range from 300 to 1200 m^3, and the volume of mud and cuttings combined

continued on next page

Environmental Effects (from page 5)

can reach 3200 m^3 from each exploratory well, although the amount is usually lower. The cuttings are continuously dumped during the drilling process.

Some drilling fluids also enter the environment along with the rock cuttings. *Solids control equipment* on board the rig separates cuttings from fluids, usually with 90% efficiency for water-based mud and 75% for oil-based mud. However, some fluids still adhere to the rock.

Many drill rigs have a large diameter pipe or caisson reaching below the water surface. The cuttings are discharged into the caisson, allowing for the washing of cuttings and further recovery of oil, if oil-based muds are in use.

Currently under Canadian regulations, no oil-based mud can be dumped over the side, and consequently oil-based muds are shipped to land for disposal, or reinjected into the well. C*uttings* drilled with oil-based muds used to be dumped at sea as long as the level of mineral oil in the cuttings and the drill fluid was less than 15% of the dry weight. However, the CNSOPB now limits the oil content in cuttings to 1% by weight, which virtually eliminates the releases of oil-based mud and cuttings in the offshore. The 1% tolerance allows for small amounts of oil taken into water-based muds in unusual circumstances, for example, to free a stuck drill pipe.

Formation water

Salt water trapped within rock formations containing hydrocarbons often reaches the surface along with the hydrocarbons during production tests on exploratory rigs. This water, known as formation, or ‘produced’ water if from an operating well, contains nutrients and occasionally dissolved metals, and may have low concentrations of radioactive material from rock formations. The amount of formation water released during exploration tests is small; it dilutes rapidly in the volume of ocean water around the well.

Other drilling rig discharges

With few exceptions, all wastes from operations on offshore drilling rigs must be returned to shore for disposal. However, many incidental discharges may occur and are allowed under current regulations.

Such incidental wastes include muds and associated chemicals released along with drill cuttings; fluids such as salt solutions, polymers and various additives used to prevent damage to the well bore while the well is being prepared for production; as well as deck drainage, domestic sewage and wastewater from crew facilities.

Deck wash may contain small quantities of oil from the well and from lubricants of various kinds (e.g. greases, hydraulic fluids, and incidental fuels) used on the drilling rig. Before it goes overboard, it is run through a process to remove oily hydrocarbons.

Other minor wastes produced by offshore drilling operations include:

- desalination water (from the freshwater drinking system),
- blow-out preventer fluid (if the blowout preventer is activated),
- wastes from on-board laboratories;
- bilge and ballast water;
- mud, cuttings and cement at the sea floor released when drill is removed from the sea floor;
- uncontaminated seawater such as cooling water;
- water used to clean out boilers;
- excess cement slurry from equipment wash down;
- filter materials such as diatomaceous earth;
- waste from painting, such as sandblast sand, paint chips and paint spray;
- accidental discharges of materials such as cement and drill muds;
- strainer and filter backwash water for procedures using water; and
- test fluids from the wells during drilling.

Accidental Spills

Accidental spills can happen, especially during transfers to and from supply vessels. Many different materials and supplies could spill, such as diesel during connection or disconnection of fuel lines, or spills from containers being lifted from vessel to vessel.

However, the most serious form of accidental spill is a blow-out, where an uncontrolled release of hydrocarbons may occur for hours, weeks or even months, until the well can be controlled. The chance of a blow-out is greater in an exploration than a production well, though still very rare.

Approximately 1% of exploratory wells world wide have had blow-outs; the resulting releases are normally quite small. In over 22,000 wells of all kinds drilled in US coastal waters from 1971 to 1993, only five blow-outs occurred and the total discharge was 170 m^3.

Two blow-outs have occurred off Eastern Canada; one at the West Venture N-91 site, the other while drilling the Uniacke G-72 well north of Sable Island in 1984. The latter released natural gas and 240 m^3 of condensate, and was controlled in nine days.

Natural gas and condensate, a light oil similar to gasoline, are the hydrocarbons most likely to be found on the Canadian portion of Georges Bank. Both rapidly disperse or evaporate, and do not tend to stay in the marine environment as long as do the heavier crude oils. However, while it lasts, condensate is quite toxic.

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Exploratory Techniques (from page 2)

deeper water. They use anchor systems and thrusters to maintain their position while drilling.

Assessing Hydrocarbon Reserves

From the findings of seismic surveys and exploratory wells, oil companies assess

Drilling Basics (from pg. 3)

Environmental Effects (from facing page)

Marine Impacts (from previous page)

The farther the discharge moves, however, the more dilute and less harmful it becomes. Studies examining the effects of exploratory drilling on the U.S. portion of Georges Bank found that small amounts of some drilling muds (in particular the weighting agent barite) had been transported as much as 60 km from the well site.

Sea scallops are particularly sensitive to fine particles and mineral oil from drilling muds. Other filter feeding organisms which filter water to extract microscopic algae for food, may also be exposed and may be sensitive to levels of suspended drill muds. Levels of suspended drill mud in the vicinity of a drill rig and along the trajectory followed by the drill fines during storms may be high enough on a continuous basis to affect scallops.

Tainting

Tainting is an off-taste or flavour in a food and a potential concern in offshore exploration and development. Many studies have investigated tainting of commercial fish in the vicinity of offshore exploration and production activities.

There have been no reported cases where tainting from offshore exploration was detected in commercial fish catches. However, suspended drilling muds might be able to taint scallops, most probably in the immediate vicinity of the drilling platform.

Abandonment

Exploratory wells are sealed at the seabed, leaving nothing to be snagged by fishing gear. Over 150 wells have been drilled on the Scotian Shelf without impact on later fishing.

Other impacts

Lights of drill rigs and other marine vessels attract birds and possibly other wildlife. Noise levels on and near drill rigs are comparable to those of large ships and tankers. Noise sources include engines, helicopters, supply vessels, and routine equipment operation related to pipe handling.

FURTHER READING

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Exploring for Offshore Oil and Gas

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GLOSSARY

Flocculate — Fine particles such as clays clump together forming larger particles when placed in seawater. The particles are attracted because they have tiny electrical charges on their surfaces.

Kick — A condition in a well where gas or oil from the rock formations overcomes pressure control and enters the well bore.

Mineral oil — A type of clear, often colourless oil used as a lubricant in drilling muds; in purified form used for human and animal medicinal purposes.

Production test —If an exploratory well strikes a suitable rock formation containing hydrocarbons, a production test may be carried out, using a controlled release of hydrocarbons to test the volume and quality. Excess hydrocarbon is burned or "flared" off the rig.

Semi-submersible — A mobile drilling platform that floats and is held on location by anchors and/or thrusters.

Synthetic based muds — Drilling muds that have synthetic oils in place of mineral oil. Synthetics mainly include chemicals such as esters, ethers, and polyalpha-olephins, but other types can include other various chemical forms of olefins, as well as acetals and paraffin.

Trace metals — metals occurring in minute amounts in water or sediment. Elevated levels of some trace metals can be harmful to marine life.