Perspective on oil spills

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Perspective on oil spills

Oil has been affecting the environment for centuries. In the last few decades, with the massive increase in tanker size and greater offshore exploration, oil spills have become a more controversial point of interest.

This briefing paper, prepared as an information service by Shell Canada, looks at a broad range of oil spill considerations — from their source and effect on the environment, to society's ability to deal with them effectively.

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Protecting the Environment

The Oil Spill Phenomenon

Oil is an essential part of industrialized society. Alternative energy sources are being developed, but petroleum will be needed for many years for essential services such as transportation and for products such as plastics and fertilizers.

This dependence on oil carries with it the reality of oil spills as a continued threat to the environment.

Although spills occur on land and in rivers and oceans, more emphasis has been placed on those in water. They spread more rapidly on water and cause the most apparent environmental damage.

Oil spills are created from both natural and man-made sources — surface drainage, natural seeps, tanker accidents and urban and industrial wastes.

Nature's sources of oil pollution have been known for centuries. When English explorer George Vancouver was sailing off the Californian coast in 1793, he noticed a dark-coloured smudge on the surface of the water. He had found oil coming from one of nature's oil wells. He noted in his log: "As far as the eye can see the sea is covered with a sticky smelly substance".

Geologists describe these natural oil spills as seeps. They have been leaking oil and gas into the environment for millions of years.

Man-made Spills

Man-created oil spills have received increasing attention because of the volumes of petroleum involved. Spills from offshore exploration and major tanker accidents, such as the Torrey Canyon disaster off the coast of England in 1967, the Arrow in Chedabucto Bay, Nova Scotia, in 1970, and the Amoco Cadiz incident off the French coast in 1978, have left their mark.

This should be kept in perspective because Nature has ways of cleansing itself. Thousands of tonnes of oil were lost in the Atlantic Ocean from ships sunk in the Second World War, but there is no evidence the environment suffered any lasting damage.

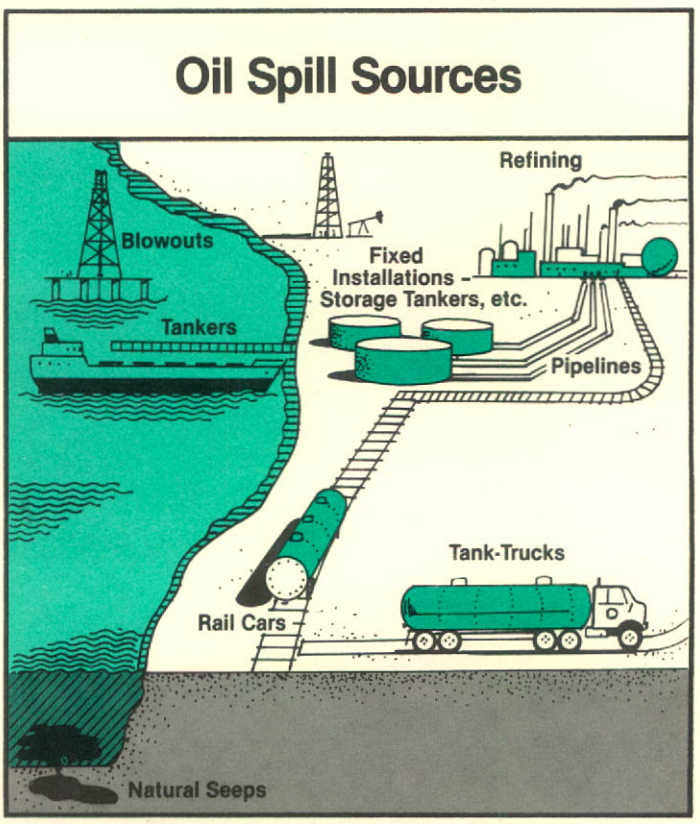
The vast majority of oil spills in Canada occur on land. Tanker accidents account for less than two per cent of all reported oil spills. Pipeline incidents account for the largest proportion of land spills (31.6 per cent of all oil spills reported to Environment Canada from 1974 to 1976).

Supertankers

The increase in oil shipping movements and the advent of the supertanker (160,000 tonnes or more) has brought a higher profile to oil spills. Supertankers are the biggest self-propelled vehicles ever built by man.

These enormous vessels (up to 400 metres long or the length of four football fields) have created considerably greater carrying capacity. While the length, breadth and depth of a 200,000-tonne supertanker is only about twice that of a 20,000-tonne tanker, it carries more than 10 times as much oil.

On-land risks are also involved in transporting oil from the field to the consumer. As many as 10 to 15 transfers may be required in six different transportation modes — including those from tankers, pipelines, trains and tank trucks as well as from temporary storage in a variety of facilities. Accidents may occur during each of these transportation and storage steps, and the number of spills at points of transfer from one type of transportation to another is high. For these reasons, the petroleum industry and government work together to minimize risks wherever possible.



Behaviour of a Spill

There are several factors which affect the behaviour of an oil spill — mainly the type of oil, the water and the climatic conditions.

For a spill in water, the oil first spreads into a slick. Certain crude and heavy fuel oils may tend to solidify rapidly and form "tar" lumps.

Oil spilled in water or on land undergoes a progressive series of changes in physical and chemical properties called "weathering".

Major processes include: evaporation, dissolution, oxidation, emulsification and microbial degradation. In effect, weathering is the loss of certain components of the oil through a series of natural processes which continue indefinitely while oil remains in the environment.

The lighter and more volatile components of the spilled oil are lost most rapidly. Light crude oils and fuel oils weather at a much faster rate than heavy crudes or heavy fuel oils which contain a smaller proportion of light fractions.

In evaporation, certain fractions of the oil are lost to the surrounding atmosphere. The lighter hydrocarbons evaporate more rapidly than heavier components of the oil. Evaporation rate is significantly influenced by air and water temperature, water turbulence, wind and the spreading rate of the slick.

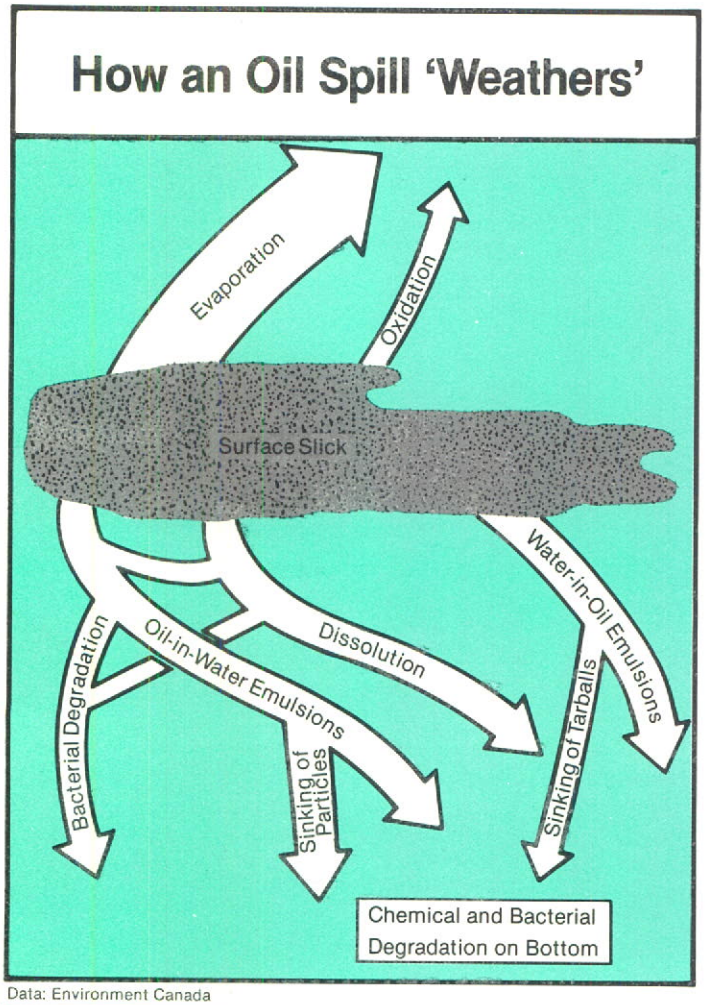
Slicks produced by gasoline, kerosene and lighter fuel oils almost disappear after 24 hours, whereas the slicks produced by heavy bunker oils and crude oil persist longer.

Throughout the process of dissolution, some components of the oil are lost to the large volume of water surrounding the slick. Dissolution starts immediately after an oil spill and, unlike evaporation, is a long-term process continuing throughout the total weathering process.

The chemical combination of hydrocarbons with oxygen is called oxidation, another process which contributes to the weathering of oil. Since this reaction occurs at the surface, oil will oxidize more rapidly when it is spread into a thin film. Oxidation is slow in relation to other weathering processes, because only a limited amount of oxygen is capable of penetrating the oil slick.

Emulsification is the process by which one liquid is dispersed into another in the form of small droplets. In the case of oil, the resulting emulsion can be either oil-in-water or water-in-oil. Water-in-oil emulsions can be formed when water is mixed with a relatively viscous oil by wave action. This is called "chocolate mousse" — a viscous emulsion which is difficult to handle and dispose of. Chemicals are being developed which could prevent this mousse forming or help break it up after formation.

Biodegradation is an oxidizing process. Almost all the micro-organisms involved require dissolved or atmospheric oxygen in order to metabolize oil. Many species of marine bacteria, fungi and yeasts oxidize petroleum hydrocarbons through the use of these compounds as food energy sources. Hydrocarbons consumed by micro-organisms can be almost completely metabolized to lower carbon number compounds, built up into additional cell mass and tissue through normal growth processes, or completely metabolized to carbon dioxide and water.



Data: Environment Canada

Effect on the Environment

Research continues in the petroleum industry, government agencies and in academies throughout the world on the effects of oil on the environment.

Most land spills involve small quantities of oil and have less impact on physical and biological resources than spills in water. Land spills normally penetrate only a few centimetres and are either cleaned up immediately or left to degrade through natural processes. However, when large quantities of oil are spilled on land there is a threat of contaminating ground and surface waters and clean-up programs are generally initiated as early as possible.

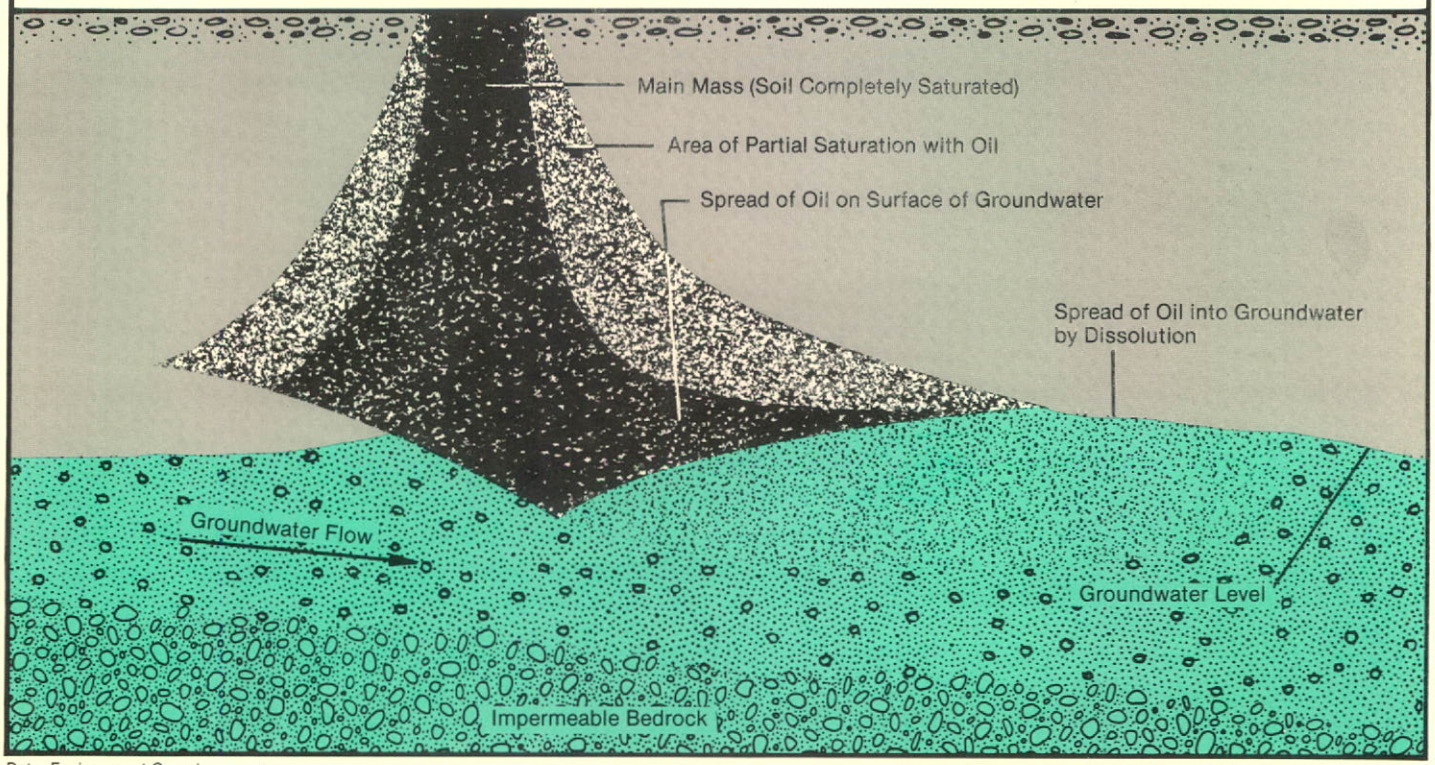
Spilled oil tends to move along pipeline trenches, foundation fills and utility ducts. Oil which penetrates into the sub-soil will move downward under the influence of gravity. Where the amount of oil spilled is small or the water table is low, the mobile oil will dissipate during its descent and will leave behind a trail of relatively immobile oil in a roughly vertical column. Subsequent rainfall, percolating through the soil, may cause further downward movement of minor amounts in this residual oil. This presents less risk of significant pollution than if the main body of the oil reaches the water table.

Migration of the oil will continue until it is completely absorbed by the soil, stopped by an impermeable layer or reaches the ground water. This oil can eventually re-appear in springs and in such cases may contaminate surface waters.

Spills in Water

Experiments have been carried out into the effects of spilled oil in marine and inland waters. In some tests marine organisms such as shrimps, oysters, minnows and other marine animals have been exposed to refined and crude oils. When placed in clean flowing seawater again, the shellfish purged themselves of oil within two to three weeks after being contaminated. The fish and certain shellfish proved they also can

Movement of Oil in Porous Subsoil in Contact with Groundwater



Data: Environment Canada

metabolize much of the oil injested. The oil is changed chemically by bodily processes and the fish then excrete the metabolized substances.

These findings suggest it is highly unlikely oil would represent a threat to human life from being passed up the food chain.

Damage to marine vegetation from oil spills has been found to be minimal. Plants such as salt marsh grass have been shown to withstand all but the most concentrated applications of oil.

Because of the rapid transformation of oil in the sea, an oil spill does not in most cases cause significant damage on the open ocean, even on a temporary basis. The oil dilutes rapidly in seawater to harmless proportions and the most toxic parts of it evaporate quickly. Significant environmental damage is caused when certain conditions exist.

1. Large amounts of oil were spilled in a confined area — particularly in the vulnerable inter-tidal zone, making the ratio of oil to water extremely high.

2. Although smaller amounts of oil were spilled, the oil involved was a refined oil, which is more toxic to marine life than crude oil.

3. Whether crude or refined oil, it was pounded into the shoreline sediment by the action of wind and waves.

When these conditions exist, the oil will remain concentrated and therefore likely to suffocate species. Fish will be unable to swim away to uncontaminated water and will be poisoned. Shellfish on the inlet bottom will be smothered by the oil undiluted by the natural flow of seawater. Finally, the oil will remain as a surface film long enough to impregnate the feathers of aquatic birds.

In contrast to spills of refined oil and oil that has reached the shoreline, and their possible lethal effects, the less toxic crude oil from the Torrey Canyon spread over a much larger area on both sides of the English Channel. This enabled rapid dilution and flushing by fresh seawater. Other than the death of seabirds caught in the initial slick, there was little biological damage directly attributable to the oil itself. Whatever damage did result was attributed more to the improper use of dispersants due to a lack of knowledge of their effect. Newer dispersants available today are much less toxic to marine organisms.

Studies have been undertaken into the effects on marine life of chronic exposure to natural oil seeps on the ocean floor. The results showed no effect or abnormality on the growth rate or reproductivity of the organisms, nor any increase in concentration of hydrocarbons by transfer up the food chain.

Effect on Wildlife

Oil causes immediate and serious external harm to birds by destroying the waterproofing and insulation provided by their plumage. More serious are the harmful internal effects as the birds ingest oil in attempting to remove it from their feathers. Their insides become inflamed and they are unable to take food or water.

Fish are not affected by oil pollution as much as seabirds or bottom-dwelling organisms. They live and thrive in many offshore areas where oil is produced and appear to have an ability to sense an approaching oil slick and swim away.

Coastlines and the Arctic

On rocky coasts, oil may be deposited in the upper part of the tidal zone. But most of it will be removed by surf action. In the splash zone, the oil will be gradually removed by weathering. The process of natural cleansing is slower with sandy beaches because the oil tends to become buried in the sediments. In bays, estuaries and marshes, where fine sediments occur, natural cleansing by wave action is slower and buried oil may remain for long periods.

The effects of oil spills in Arctic conditions have been closely studied by the petroleum industry and government, particularly in recent years, as petroleum exploration moves more and more into frontier areas.

In the Arctic the greatest difficulty from a blow-out during drilling is oil being trapped under the ice. By the time the well is reached for capping, large amounts of oil could have spilled into the environment and would be difficult to track.

Spills in cold, deep Arctic waters, as found off Canada's east coast, also present major difficulties. Oil from a blow-out at such depths would become widely dispersed and emulsified with sea water, making it difficult to clean up by skimming and other methods. The low temperatures of these waters are also thought to lessen the effectiveness of chemical dispersants.

Planning the Clean-up

Human error has been claimed to be responsible for about 80 per cent of all oil spills, with equipment failure or malfunction largely contributing to the remaining 20 per cent. This underlines the fact that even with near-perfect technology, spills from human error and negligence will continue to threaten the environment.

As a result, intensive training programs aimed at reducing human error and improving equipment and methods are major objectives of the petroleum industry and government agencies.

Through the combined efforts of industry and government, procedures have been developed for co-ordinated and integrated response to oil spills. These contingency plans may be developed for a specific industry or encompass entire provinces or coastal areas. For example, in Canada/United States boundary water areas, an international contingency plan provides for joint response to pollution incidents through an organization which includes federal, provincial, state and regional agencies.

The National Emergency Equipment Locator System (NEELS) was developed by the government in Canada. NEELS provides a readily accessible up-to-date computerized inventory of all the spill clean-up equipment held by participants, including the oil industry, in Canada and some United States border states.

Where several oil companies are doing business in the same area, co-operatives are often formed for the purpose of pooling equipment and training personnel to combat oil spills. The co-operative, rather than one oil company, purchases and maintains containment clean-up and disposal equipment and sponsors training programs. Including co-operatives and low-risk area oil spill packages, more than 150 units are ready for immediate use in Canada.

A first priority is the immediate reporting of the spill by the primary response agency to the appropriate federal or provincial authority. By law, all oil spills in Canada, irrespective of the size and apparent seriousness, must be reported to the proper authorities.

Containment and Recovery

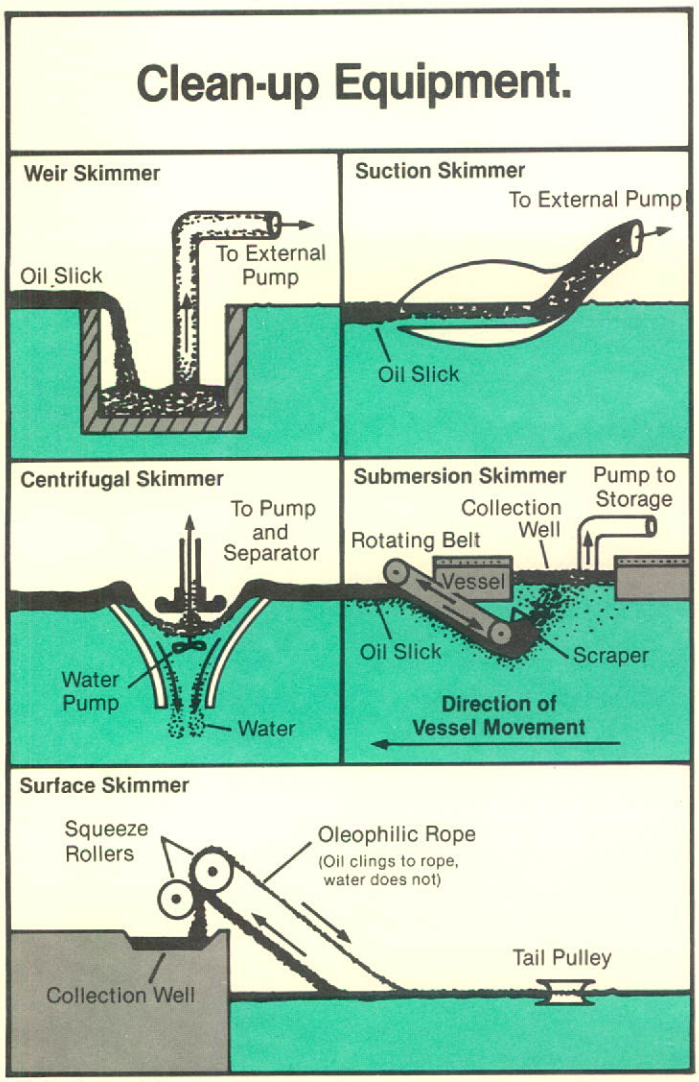
In general, the heavier the oil, the more difficult it is to clean up.

Many different methods are used to prevent the spread of oil slicks. These include floating booms, sorbent barriers, air or bubble barriers and chemical barriers.

Collecting agents have also been developed. Sprayed on waters surrounding a spill, these chemical agents push or "herd" the oil into thicker but smaller pools, making it easier to contain and recover.

Recovery of oil from the water surface is carried out by a variety of methods — skimmers, sorbents which recover oil through absorption or adsorption, and by manual means. After oil has been recovered the separation and disposal takes place. Separation is accomplished by pouring the oil and water mix into large portable tanks or drums, then allowing the water to settle before removing it from the bottom.

Disposal methods can vary from re-refining oil not



Data: Environment Canada

contaminated by significant amounts of water or debris, to incineration at selected sites and oil refineries.

Land disposal methods take advantage of natural biodegrading processes, especially when the amount of oil is small and contains a high proportion of debris. This either involves the spreading of recovered material over the surface of land or burial of it at approved sites.

Treatment of Oil Spill

There are an assortment of chemical agents which can be added to oil to facilitate its removal from water. But the use of chemicals in oil spill clean-up programs is not only officially discouraged in most cases, but in many instances is prohibited. It may only be considered after all other means fail. Generally, chemicals are only used in oil spill clean-up when the potential damage to biological and physical resources could be greater if they were not used. Common treatments for spills include dispersants, sinking agents, herding or surface active agents, gelling agents, wicking and biological agents.

Burning is another way of disposing of oil in water. However, while many hydrocarbons are flammable, burning is often difficult. The fire must be kept hot enough to support combustion continually and must be supplied with sufficient oxygen. It is virtually impossible to ignite a thin layer of oil in water because it is cooled by the water.

As in water, oil on the shore is difficult to ignite. Incineration of the collected oil in rotary kilns or burners is the most satisfactory method.

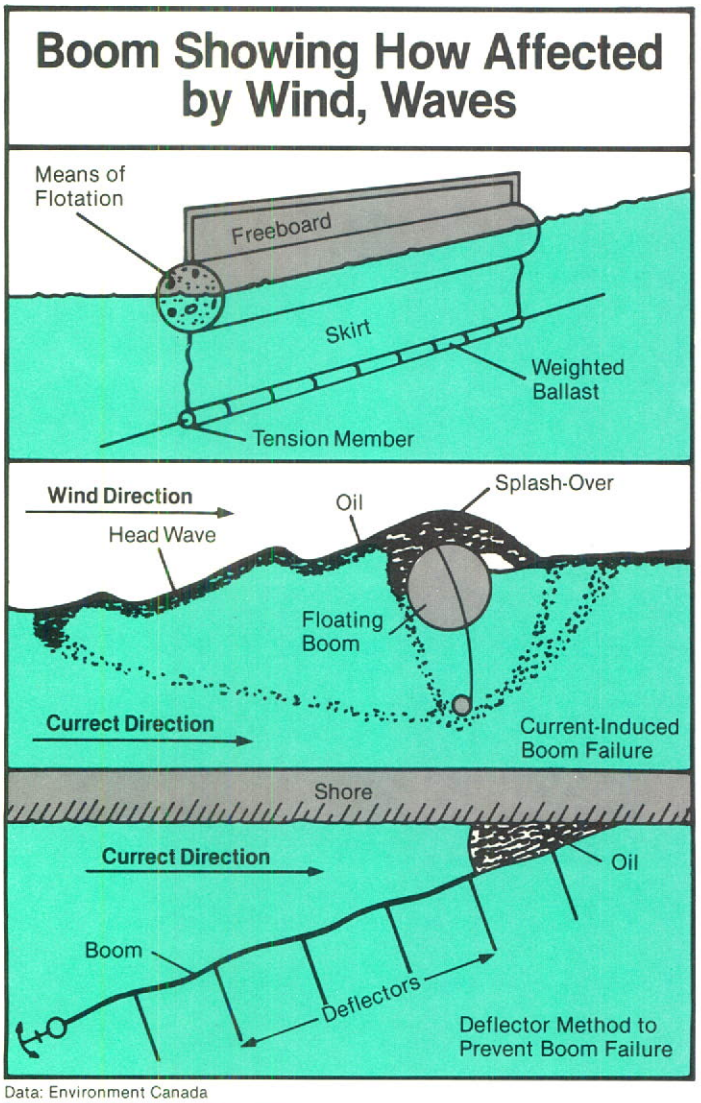
Clean-up of shoreline areas is considerably more difficult and time-consuming than containment and recovery operations on water. The physical removal of oil from some types of shoreline may result in ecological or physical damage far greater than would have occurred if oil removal was left to natural processes. The decision to initiate clean-up and restoration activities on oil-contaminated shore areas is based on careful evaluation of socio-economic, aesthetic and ecological factors. Shoreline restoration methods can involve chemical and hydraulic dispersion, steam cleaning, sand blasting and manual labour.

Land Spills

A variety of methods are used to recover oil spilled on land. Oil lying near the surface can be removed with pumps or other equipment, or removed with the soil it has contaminated. Where oil is threatening groundwater supplies, one clean-up strategy is to flush it out of the soil by circulating water through the contaminated soil layers. Another is to let it move to underground wells and then pump it to the surface.

When the oil is some distance from groundwater supplies which are not used for domestic or agricultural purposes, the favoured approach is to leave the oil in the ground. This oil will eventually slowly biodegrade as a result of microbial activity.

Oil spill emergency procedures and co-operatives are in place in Canada's Arctic region. But more research is being carried out on how spills affect this type of environment as the need increases for more and more offshore and Arctic exploration.



Data: Environment Canada

Major Spills in Canada and World

	Date	Volume Spilled 1000 tonnes	Total Cost $ million
Canada:			
Arrow (Chedabucto Bay, Nova Scotia)	1970	16	3.9
Imperial Sarnia (St. Lawrence River)	1974	0.5	2.2
Nepco 140 (St. Lawrence River)	1976	1	12
Kurdistan (Gulf of St. Lawrence)	1979	7.9	6
World			
Torrey Canyon (English Channel)	1967	115	10
Mitsubishi Refinery (Japanese Inland Sea)	1974	45	200
Amoco Cadiz (off Britanny Coast, France)	1978	230	2,120
Ixtoc 1 (Gulf of Mexico)	1979	600	450
Burmah Agate (Gulf of Mexico)	1979	1.5	16.8

As a step towards gaining greater knowledge, government has added to some of its own programs by joining with the petroleum industry in Canada and overseas governments. The petroleum industry and the Canadian government are working with the industry and governments in Norway and the United States to carry out a series of experiments over the next few years. Crude oil is to be released under controlled conditions in Canadian Arctic waters to test the effect of oil spills and clean-up chemicals on the fragile environment.

Oiled Birds

If birds are affected by an oil spill, those captured should be brought promptly to a reception centre for care and cleaning only by trained and qualified people. Home care of birds is not advised as it poses unnecessary risks for both volunteer and birds.

Where large numbers of birds are involved in a spill, it may be advisable to destroy those birds that are least likely to survive. This can be done by a veterinarian with an overdose of barbiturate or other suitable drug.

Care of wild birds depends on minimizing stress and providing facilities and feeding diets which are as close as possible to what they are accustomed. Birds are cleaned either in detergent, warm soapy water or light solvent oil, followed by detergent. Rough handling of feathers will destroy the arrangement of feather elements needed for waterproofing. Birds must be dried with forced hot air indoors, regardless of weather, to prevent chilling.

Cleaned birds under ideal conditions can be set free within 72 hours of cleaning, but most must be held longer. A bird's readiness for survival in the wild can be judged by the waterproof qualities of plumage, body temperature, behaviour and physical capability. In the case of seabirds, tolerance of swimming in and drinking salt water is vital. Before being able to regain waterproof plumage, birds need an active program of swimming.

Canada's Largest Spill — A Case Study

At 9:30 a.m. local time, on February 4, 1970, the Liberian tanker, Arrow, struck Cerberus Rock in Chedabucto Bay in Nova Scotia. The Arrow was carrying 16,000 tonnes of bunker oil which it had picked up in Venezuela and was delivering to a paper plant in the Strait of Canso.

Early salvage attempts resulted in the ship breaking in two. A massive miles-long oil slick began to take shape as the Arrow's cargo seeped into the surrounding bay.

A task force was formed of the Science Council of Canada, the Defence Research Board and the Maritime Command Headquarters of the Canadian Armed Forces.

Attempts were made to pump the oil remaining in the submerged Arrow's tanks into an oil barge. At the end of the operation, about one-third of the ship's cargo had been recovered, one-third was trapped in the bay and one-third driven out to sea.

To protect the upper reaches of Lennox Passage and Canso Tickle it was decided to dam these passages with rock fill before ice blocking the passage melted.

Commercial booms of many types were tested or used to confine the oil slick. None were found satisfactory in the strong currents or rough seas and high winds. Alternative booms were created from oil drums, chain link fencing and conifer boughs which proved more successful.

Alternative sources of water or suitable filters were developed for the four fish processing plants in the area, so that they would not be shut down because of oil entering water lines.

To deal with cleaning fishing gear — including nets worth $25,000 each, floats and lobster pots — a "laundromat" using steam jets, a diesel oil and emulsifier mix and a hot water wash was developed.

Methods used to deal with the oil varied from peat moss and mechanical surface skimming devices, to steam cleaning, bulldozers and manual labour.

After the $3.9 million Arrow clean-up operation, contamination of the local ecology had not been serious. The lobstering season opened on schedule and the catch was normal. Herring catch was above normal.

It was estimated about 7,000 birds died because of oiling, but wildlife authorities gave assurances that no serious long-term effects on any particular species would result.

Who Pays the Bill

Cleaning-up operations and settling claims from oil spills can be a costly business — particularly with spills on marine and inland waters. Damage claims can run many times the clean-up costs.

Clean-up costs of the largest oil spill in history, the IXTOC I in the Gulf of Mexico, which was capped early in 1980, were about $150 million. Compensation and damage claims and lawsuits pending total well over $300 million and are expected to increase.

The Torrey Canyon incident focused attention on the question of compensation for pollution damage and brought home to governments and to the tanker and oil industries the need for compensation schemes.

The companies entered into two voluntary agreements:

— The Tanker Owner's Voluntary Agreement Concerning Liability For Oil Pollution (Tovalop)

— A Contract Regarding an Interim Supplement to Tanker Liability For Oil Pollution (Cristal)

Tovalop came into operation in October, 1969, by which time more than half the world's tonnage had been enrolled. Cristal followed in April, 1971. These two voluntary schemes have functioned smoothly ever since and have already paid out large sums that would not otherwise have been available to settle pollution claims.

Legal schemes that achieve the same effect as Tovalop and Cristal respectively, have now been agreed by international convention through the machinery of the Intergovernmental Maritime Consultative Organization (IMCO) and ratified by many governments.

Since Tovalop's introduction, the scheme has become so widespread that virtually every tanker in the world trade today is covered. Oil companies transporting some 90 to 95 per cent of the total crude and fuel oil moved by sea worldwide are now contracted to Cristal.

A specialized United Nations agency, IMCO is the international governmental forum which debates and drafts conventions on maritime matters of all kinds. IMCO conventions do not themselves constitute maritime law, but member states of IMCO — now numbering more than 100 — base their own regulations on them. Once a nation has ratified a convention it then becomes international law. This results in consistent standards being required throughout the international shipping industry.

At the International Legal Conference on Marine Pollution Damage held in Brussels in 1969, governments represented signed the International Convention on Civil Liability for Oil Pollution Damage (CLC). CLC places legal liability on tanker owners, whereas under Tovalop they undertake liability voluntarily.

Eventually, governments agreed the cargo-owning community as a whole should supplement the money available from tanker owners. In 1971, a subsequent

Compensation for Oil Spills

Canada

Maritime Pollution Claims Fund (MPCF)

Funded by the oil industry through levies placed by government. Covers situations where pollution costs cannot be collected from polluters or where polluters cannot be identified.

International

The Tanker Owner's Voluntary Agreement Concerning Liability for Oil Pollution (Tovalop)

Covers virtually every tanker in world trade.

A Contract Regarding an Interim Supplement to Tanker Liability for Oil Pollution (Cristal)

For Cristal to apply the tanker involved must be entered in Tovalop.

International Convention on Civil Liability for Oil Pollution Damage (CLC)

For CLC to apply, the pollution damage must occur on the territory (including the territorial sea) of a state contracted to CLC.

International Convention on the Establishment of an International Fund for Oil Pollution Damage (IFC)

For IFC to apply, the pollution damage must have occurred in a state contracted to both CLC and IFC.

conference in Brussels adopted the International Convention on the Establishment of an International Fund for Oil Pollution Damage (IFC). This set up a fund contributed to by oil companies importing crude oil and fuel oil by sea.

Canadian Claims Fund

In Canada, the Maritime Pollution Claims Fund (MPCF) has been established, funded by the oil industry through levies placed by government on the movement of petroleum products in Canadian waters. The fund, amounting currently to more than $55 million, covers situations where pollution costs cannot be collected from the polluters or where the polluters cannot be identified.

Normally, with marine spills (and land spills in certain provinces) in Canada, the transporter and/or the owner of the oil is liable for clean-up and legal costs. Funds from schemes like the MPCF become available only when the appropriate industry fund or provincial and federal judicial process has been exhausted.

Where possible, Canada has allied itself to international compensation programs. Certain waterways such as the Great Lakes and the St. Lawrence River have now been recognized as "seas" under these international agreements. The Canadian government has not at present ratified CLC or IFC, but the Federal Department of Transport is actively pursuing this.

In any event, a claimant would be able to pursue a claim through conventional legal channels.

In Summary

- Concern over oil spills has increased in the last few decades, particularly since the advent of the supertanker and expanded offshore exploration.
- Greater government and oil industry research has been undertaken and must continue on how oil spills affect the environment.
- At the same time, the industry and governments have co-operated extensively to provide contingency plans in the event of an oil spill.
- Prevention is the key to minimizing environmental damage from oil spills.
- Efforts continue around the world to develop adequate clean-up and compensation funds to deal with major oil spill damage.

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