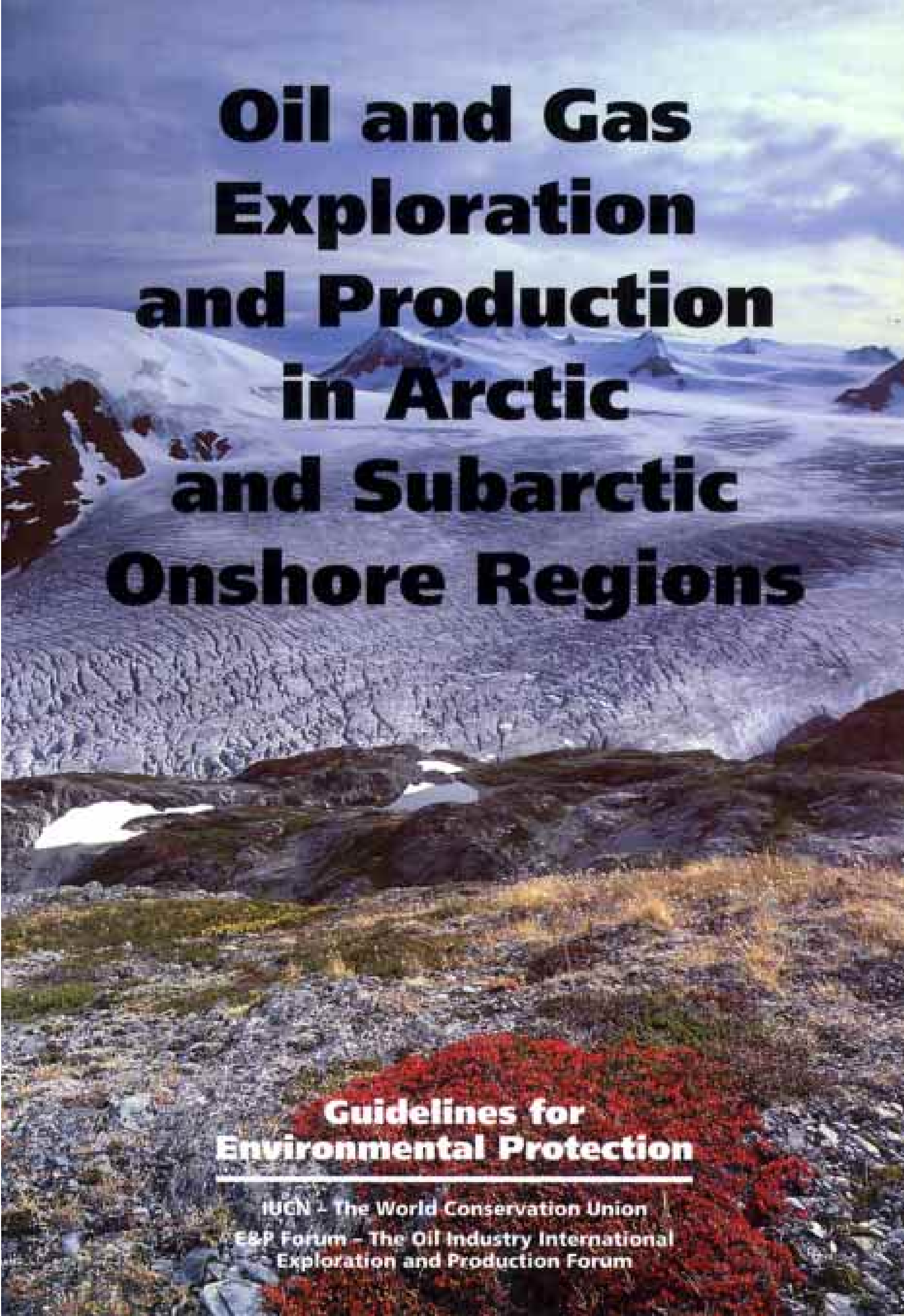

Oil and Gas Exploration and Production in Arctic and Subarctic Onshore Regions

Guidelines for Environmental Protection

IUCN – The World Conservation Union

E&P Forum – The Oil Industry International Exploration and Production Forum

IUCN—The World Conservation Union

Founded in 1948, IUCN—The World Conservation Union—brings together States, government agencies and a diverse range of non-governmental organisations in a unique world partnership: some 720 members in all, spread across 123 countries.

As a Union, IUCN seeks to serve its members—to represent their views on the world stage and to provide them with the concepts, strategies and technical support they need to achieve their goals. Through its six Commissions, IUCN draws together over 5000 expert volunteers in project teams and action groups. A central secretariat coordinates the IUCN Programme and leads initiatives on the conservation and sustainable use of the world's biological diversity and the management of habitats and natural resources, as well as providing a range of services. The Union has helped many countries to prepare National Conservation Strategies, and demonstrates the application of its knowledge through the field projects it supervises. Operations are increasingly decentralised and are carried forward by an expanding network of regional and country offices, located primarily in developing countries.

IUCN seeks above all to work with its members to achieve development that is sustainable and that provides a lasting improvement in the quality of life for people all over the world.

The E&P Forum

The Oil Industry International Exploration and Production Forum (E&P Forum) is an international association of oil companies and petroleum industry organisations formed in 1974. It was established to represent its members' interests at the International Maritime Organisation and other specialist agencies of the United Nations, and to governmental and other international bodies concerned with regulating the exploration and production of oil and gas. While maintaining this activity, the Forum now concerns itself with all aspects of exploration and production operations, with particular emphasis on safety of personnel and protection of the environment.

As of 1992, the Forum has 52 members made up of 38 oil companies and 14 national oil industry associations, operating in 52 different countries.

The work of the Forum covers:

- monitoring the activities of relevant global and regional international inter-governmental organisations;
- developing industry positions on issues;
- advancing the positions on issues under consideration in international organisations, drawing on the collective expertise of its members; and
- disseminating information on good practice through the development of industry guidelines, codes of practice, checklists, etc.

IUCN/E&P Forum Collaboration

IUCN and the E&P Forum have collaborated to produce these Environmental Guidelines for use by industry, authorities and individuals involved with oil and gas exploration and production in Arctic and Subarctic regions. The Guidelines were prepared by a working group of representatives from the Conservation Services Division of IUCN and the E&P Forum. The IUCN team consisted of Jeremy Carew-Reid, Ron Bisset, Paul Driver, David Stone, Claire Santer, Ian Borthwick, Bryan Sage and Tom Beck. The Forum formed a task force for this purpose whose members were: J. C. Quigel (Amoco), Ms E. Ireland (BP Exploration), Ms J. Loporcaro (BP Exploration—Alaska), J. F. Matheson (Conoco), Ms J. M. Bruney (Exxon), J. M. Wren (GECO Prakla), M. Thomassen (Norsk Hydro), W. Robson (Petro-Canada), W. V. de Pijpekamp (Shell Canada), C. Geerling (SIPM), M. T. Stephenson (Texaco), A. Loppinet (Total), and A. D. Read (E&P Forum).

These Guidelines constitute report number 2.55/184 in the list of E&P Forum publications.

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Figure 1, showing the distribution of permafrost in the northern hemisphere, appears in *Arctic and Alpine Environments*, Ives, J. D. and Barry, R. G., 1974, published by Methuen & Co. Ltd.
Figure 2, showing a simplified diagrammatic representation of surface features on tundra underlain by continuous permafrost, is taken from *The Arctic and its Wildlife*, Bryan Sage, 1986, published by Croom Helm Ltd.

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Foreword

The preparation of Environmental Guidelines as a joint venture between one organisation representing conservation interests and another representing industrial interests is a new departure for both IUCN and the E&P Forum. This cooperation is based on an understanding of the close interaction between development activities and the environment, and a belief that conservation is likely to be best served by scientific and technical cooperation.

While these Guidelines relate to hydrocarbon exploration and production in Arctic and Subarctic regions, it must be accepted that certain parts of these regions are so important for landscape, nature conservation or human habitat that economic exploration or production is not feasible. In joining E&P Forum to prepare these Guidelines, IUCN and its members are not departing from this view.

The Guidelines are offered as a practical aid to the avoidance of environmental degradation in those locations where it has been agreed that hydrocarbon exploration and production are appropriate. They are additional to, not a replacement of, the protocols presently available or proposed for the protection of the northern circumpolar environment.

Chapter 1

Introduction

Overview

A considerable portion of the world's oil and gas production in the foreseeable future will come from hydrocarbon deposits in the Arctic and Subarctic regions. Mainly because of the severe climatic conditions and their remoteness from markets, these polar regions are among those least affected by human activities. They are inhabited by various ethnic groups, including indigenous peoples, many of whom depend on the sustainable use of natural resources.

Existing and potential threats to the Arctic and Subarctic environment, not necessarily related to oil and gas exploration and production, are the subject of increasing discussion and concern. These threats include the possibilities of pollution through marine contamination, including oil releases to the environment, the atmospheric deposition of acids, radionuclides and heavy metals, ozone depletion and climate change.

A growing international appreciation of the importance and vulnerability of Arctic and Subarctic ecosystems has led to an increased interest in the ecology of the tundra and taiga. Identification and establishment of additional protected areas and development of new conservation mechanisms for this region are topics of wide and continuing debate. Commercial development faces demands for stringent standards and safeguards for environmental protection. This creates both an opportunity and a responsibility to include the most efficient technologies and practices in any plan for commercial development which will protect the natural qualities of the region.

Cooperation between Canada, Denmark, Finland, Iceland, Norway, Sweden, the former Soviet Union and the United States led to the development of the *Arctic Environmental Protection Strategy*[1]. This calls for management, planning and development activities to provide for the conservation, sustainable use and protection of natural resources for the benefit and enjoyment of present and future generations, especially the needs of indigenous peoples. This strategy is an indication that those countries recognise the importance of Arctic resources and the fact that international action is needed to protect them. The *Arctic Environmental Protection Strategy* applies generally to all onshore exploration and production projects. While its principles should be followed, projects will also be subject to the legislation and standards of the country in which they are situated.

Objectives of the Guidelines

The purpose of these Oil and Gas Guidelines is to establish internationally acceptable goals and guidance on environmental protection during oil and gas exploration and production operations in the onshore Arctic and Subarctic. Requirements and standards for activities in a particular location will be determined for the specific environment by adherence to extant laws and regulations and coordination between the appropriate authorities of the host country and the operating company.

[1] Declaration on the Protection of the Arctic Environment. 1991. Rovaniemi, Finland. Ministry of the Environment, Finland.

In these Guidelines the word 'environment' covers biophysical, social and health factors and their inter-relationships. At appropriate places in the text these aspects are treated individually, but elsewhere 'environment' must be considered in these broad terms.

The main objectives of these Guidelines are:

- protection of Arctic and Subarctic natural resources, ecosystems and their biological diversity, based on informed assessments of the possible impacts of oil and gas exploration and production on the environment;
- recognition and accommodation of the customary rights, cultural heritage, values and practices, and resource utilisation patterns of indigenous peoples, including access to land and other natural resources, exploitation of the 'products' of these resources, and the avoidance of sacred and archaeological sites, whilst harmoniously addressing health, educational, social and economic needs;
- provision of decision-making tools to help achieve a reasonable and effective balance between resource development and environmental protection;
- encouragement of methods that ensure integration of environmental protection into the design, construction and operation of oil exploration and production facilities; and
- encouragement of consultation between operating companies and the host country at all levels throughout exploration and production operations.

Chapter 2

Description of Environment

Arctic and Subarctic Regions

The Arctic regions, broadly defined, are those lying north of the limits of agricultural cultivation. They surround the Arctic Ocean which is divided by a major underwater ridge into two main basins. The Eurasia Basin (connected with the Atlantic Ocean via the Greenland and Norwegian Seas) has a maximum depth of about 5122 m. The Amerasia Basin (connected with the Pacific Ocean via the Chukchi and Bering Seas) exceeds 4000 m in depth near the North Pole. The area of the Arctic Ocean as a whole is approximately 14 million km^2, surrounded by shallow continental shelves with a combined area exceeding 2.5 million km^2. The Arctic Ocean is covered year-round by a more-or-less continuous expanse of pack-ice which, at its annual maximum extent, reaches 10 million km^2. The pack ice varies in thickness over this area.

The large tracts of land comprising the terrestrial Arctic habitats are characterised by being underlain with continuous and discontinuous permafrost. Within this area are three major biomes: **polar desert** (including the Greenland and other ice caps, montane areas of relatively barren rocks, and ice-free but mainly unvegetated lower areas on the more northerly Arctic islands, such as Ellesmere Island and Novaya Zemlya); the **tree-less tundra**; and the zone of **closed coniferous forest**, or **taiga**. In the Canadian and Russian sectors of the Arctic, there is an open canopy zone of intergradation between the tundra and the closed coniferous forest, known as **forest-tundra**.

The 10°C July isotherm is often used to define the boundary between the 'true' Arctic and the Subarctic (as in Koppen's climatic classification of 1900). This definition is ecologically convenient because there is generally a close correlation between this isotherm and the treeline (the northern limit of tree and shrub growth), or the northern limit of the closed boreal forest. The correlation is, of course, not exact and in places the two lines diverge to varying degrees of up to 160 km. This is because detailed patterns of vegetation depend on relief, hydrology, soils, winds and other factors. Patches of woodland are therefore found north of the 10°C isotherm and areas of open ground, especially wetland, occur to its south. Around the 5°C July isotherm, the Arctic has been divided into the low Arctic and the high Arctic. On this basis the latter includes all the Russian Arctic islands, the Canadian Arctic archipelago (except southern Baffin Island) and all of Greenland except the southern region.

Climate

The Arctic climate is characterised by extremely marked seasonal rhythms with prolonged cold, dark winters (8–9 months in some areas) and short, but bright, summers with continuous or near-continuous daylight. In the high Arctic, which is dominated by a persistent high-pressure system, and where the potential warming effect of the Arctic Ocean is largely prevented by ice cover, mean temperatures rise above freezing point for only 2–3 months a year. Mean temperatures of the coldest month range from –5°C to –10°C at the southern margin of the true Arctic, to –30°C or –35°C (or occasionally even lower), on its northern margin. The mean minimum winter temperature at Devon Island in the Canadian high Arctic, for example, is –40.5°C. Yet at other times of the year, for example high summer (July), the temperature may rise to 20–25°C in the tundra regions, even as far as 80°N. Direct warming by solar radiation is

Figure 1. Distribution of Permafrost in the Northern Hemisphere

Source: *Arctic and Alpine Environments*, Ives, J. D. and Barry, R. G., 1974, Methuen & Co. Ltd extremely important ecologically in high-polar regions during summer months. Rock surface temperatures as well as those of the upper part of the soil can reach 30°C at this time. Wind is also an important factor in several respects, for example, affecting the distribution of snow, and causing the chill factor. The latter, rather than ambient air temperatures, is a constant danger (particularly to man): a 40 km/hour wind with an air temperature of –15°C results in an equivalent chill temperature of –37°C.

The above generalisations mask considerable regional and microclimatic variations. The northern regions of Siberia, northern Alaska and Arctic Canada have a typical continental climate, with persistent high pressure, low temperature, light snowfall (the total annual precipitation is around 70–200 mm) and, in terms of absolute humidity, very dry air. In contrast, those areas adjoining the Atlantic and Pacific coasts rarely experience extreme low temperatures, but may receive considerable precipitation in the form of snow, with rain predominating on the exposed coasts of south-west Greenland where up to 1400 mm per annum has been recorded. Islands such as Jan Mayen and the Svalbard Archipelago have an even more maritime climate. Although precipitation decreases towards the North Pole, the concurrent reduction in temperature reduces the ability of the air to hold moisture and the resultant high humidity (84–85 per cent at Devon Island in June and July) minimises evapotranspiration, so that abundant moisture may be available in areas that are classified as polar desert. In the Subarctic zone of wetland, heath and forest, mean monthly temperatures rise above 10°C in the warmest month.

The Arctic has experienced recent climate change. A marked warming took place, for example, between the 1930s and the 1950s, when mean winter temperatures were over 5°C higher than in the early years of the century. A period of cooling followed in the 1960s and 1970s which was most pronounced in those regions which had previously experienced the greatest warming. Similar fluctuations may occur in the future, but their scale and extent are difficult to predict not least because of uncertainty surrounding the global warming issue.

Geomorphology

The structure of the northern circumpolar regions consists of a central deep ocean traversed by a major submarine ridge, surrounded by blocks of continental land, except in the Atlantic section. Many of these land areas have been formed from low-lying ancient crystalline rocks.

A major feature of Arctic lands, and one of considerable ecological importance, is permafrost. This is a layer of permanently frozen subsoil overlain by an 'active layer' of variable thickness that thaws during summer. Permafrost is defined as ground whose temperature has been below 0°C for several years, regardless of the state of any surface moisture that might be present. There are two main types of permafrost: dry permafrost, containing little or no ice, as usually found in areas of rock, gravel or coarse sand; and wet permafrost which generally has a high ice content and is found in fine-grained soils. Continuous permafrost exists at higher latitudes (where it may have existed for thousands of years), its southern limit coinciding, in general, with the –8°C mean annual air temperature isotherm. Further south, discontinuous permafrost extends broadly between the –8°C and the 0°C isotherm. Permafrost underlies approximately 26 per cent (including glaciers) of the Earth's land surface, the majority being in the Northern Hemisphere. Relict permafrost is present in some Subarctic regions because of extreme cold temperatures during the past glacial period (see Figure 1 for further details).

Permafrost generally occurs in the upper 500 m of the Earth's surface but has been found as deep as 1500 m, especially in areas with low air temperature and thin snow cover. The climatic conditions of the Arctic region are basic to the formation and continued existence of permafrost. Its presence depends on low annual temperatures, rather than on temperatures experienced during a particular time period, for example, the summer growing season. Its importance cannot be underestimated; the thermal stability of the polar region depends largely on the volume of this ground ice.

A complex pattern of drainage and vegetation overlies the permafrost. Much of the Arctic terrain undergoes natural thermokarst, a process in which subsidence occurs as a result of melting ground ice. 'Patterned ground' is another product of frost action on polar terrain, unsorted high-centre and low-centre polygons being the most common features. Some of the characteristic surface features that are associated with permafrost are illustrated in Figure 2.

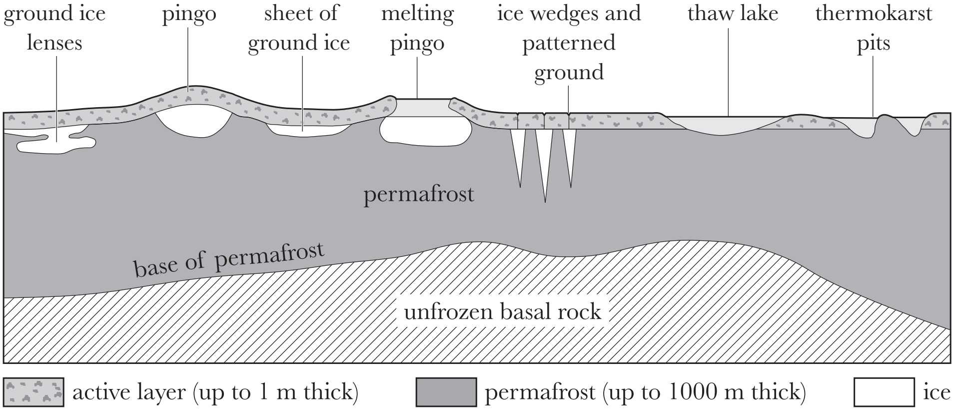
The landscape of the Arctic and Subarctic regions is highly varied, sculpted by the combined factors of wind, ice and precipitation. Prominent features range from vast plains with braided rivers and streams to dissected plateaux with steep escarpments. At ground level the flow of soil over the permafrost, termed cryoplanation, creates raised lines of soil. A related phenomenon is the formation of beaded drainage on slopes.

Hydrology

Lakes, drained lake basins and beaded drainage patterns are characteristic features of Arctic hydrological systems. Arctic lakes, also known as thermokarst or thaw lakes (see Figure 2), are shallow water bodies formed by the melting of the permafrost. Numerous Arctic lakes occur on the coastal plains of northern Siberia, Alaska and Canada and may occupy as much as 90 per cent of the surface area. These lakes have a number of features in common. Many are ultra-oligotrophic and, in general, are characterised by their biological simplicity. Water temperature is low (except in extremely shallow lakes), thermocline formation is rare, and they are subject to severe seasonal variation in insolation. The chemistry of large Arctic lakes is unusual because of the near-absence of annual cycles of nutrients and micro-organisms and the low quantities of dissolved solids.

Due to the extended winter and presence of permafrost at very shallow depths, groundwater is present only in the thawing active layer. Its movement is limited, or even non-existent, because of the slight topographical relief over much of the region. The presence of groundwater is more

Figure 2. Simplified Diagramatic Representation of Surface Features on Tundra Underlain by Continuous Permafrost



Source: The *Arctic and its Wildlife*, Sage, B., 1986, Croom Helm Ltd likely in the Subarctic, although it still depends on the limit of the permafrost zone. Groundwater may be restricted to areas beneath, or near, large bodies of surface water. Many lakes and rivers are shallow and freeze solidly during the long winters. The majority of northern rivers are completely or partially covered by ice for at least six months of the year.

The climate and topographical features of the region create appropriate conditions for wetland formation despite low annual mean precipitation. These wetlands form as a result of the low evaporation rate associated with low temperatures, low plant transpiration, a short growing season, and the lack of drainage due to the underlying permafrost and low gradient. Arctic wetlands are characterised by an absence of the features usually exhibited in more temperate wetland areas. In particular they have:

- no groundwater recharge and discharge;
- no flood storage—limited ground absorption results in most rainfall at high elevations flowing to discharge without interruption;
- no reduction, through spreading, of erosion forces;
- no sediment trapping;
- no nutrient retention or removal; and
- no productive fisheries.

Soil

The formation of soil in the Arctic zone is largely determined by temperature and permafrost regimes. Soils are typically very shallow, low in temperature and deficient in nutrients (primarily available nitrogen and phosphorus). They can be broadly classified as poorly-drained and well-drained. Poorly-drained soils consist of an organic surface mat and a mineral layer overlying the perennially frozen permafrost. They are almost permanently saturated throughout the thaw period and probably occur over 85–90 per cent of the tundra region. Well-drained soils consist of similar layers but the mineral layer usually comprises coarse sand or gravel on steep slopes, ridges and floodplains. These are usually underlain by bedrock or permafrost.

In the polar desert zone of the high Arctic, the soil-forming potential decreases with lack of moisture and suitable vegetation. There is an almost complete absence of vascular plant vegetation and organic materials scarcely enter the soil system. Salt is common at the surface, particularly on areas of hummock ground after long, dry periods. Polar desert soils tend to be neutral or alkaline in composition. Sand dunes are present in some areas.

The active layer above the permafrost is the location of most physical, chemical and biological activity. The thickness of the active layer is highly variable and depends on soil texture and type, water content, exposure, and degree of vegetation cover. In some tundra meadows the depth of this layer ranges from 30–40 cm, compared with 80–100 cm on drier sites. On the Taimyr Peninsula in Siberia, for instance, the depth of the active layer fluctuates from 35–70 cm in loam and 70–90 cm in sand. In those soils with a clearly developed peat structure the depth of seasonal thawing does not exceed 15–35 cm.

In the Subarctic, podzols, peatlands, muskegs and bogs are all characteristic formations of the landscape, with peatlands being the most prominent of these. Areas of boreal forest with high moisture levels are the most suitable for the formation of peatlands. The limited decomposition cycle results in a build-up of organic material over time. In addition, the combination of low temperatures and frequently waterlogged conditions reduces microbial activity in the soil, thus slowing the rate of decay of vegetation. Consequently there is a large accumulation of energy and nutrients in dead organic matter and a scarcity of freely available nutrients.

Vegetation

The vegetation of the Arctic and Subarctic regions is a combination of species that survived the period of maximum glaciation in ice-free zones (termed refugia) and others that migrated northwards in the wake of the receding ice fronts. Newly exposed lands—some of which had only been free of ice for a few thousand years—were soon colonised. The largest and most important refugia in the northern region were the interior of Alaska and Yukon, eastern Siberia and Beringia (an area comprising the Bering Strait and adjacent Siberia and Alaska which was exposed at that time by the lower sea level). The composition and species diversity of plant communities of the present-day Arctic environment reflects both local environmental differences and differences in the processes of recolonisation.

The northernmost regions of the Arctic, the polar deserts, have an impoverished flora of no more than 50 species (excluding lichens, mosses and liverworts). Most of these species are circumpolar in distribution. The total increases further south in the tundra zone which supports 100–250 species of vascular plants, including some ferns.

The polar desert and similar areas found at higher altitudes further south are, for the most part, monotonous expanses of frost-shattered rock, rubble, gravel and fine mineral soil with discontinuous (often under 2%) plant cover. The most characteristic plants are lichens and flowering plants such as Arctic Poppy (*Papaver lapponicum*), Moss Campion (*Silene acaulis*), Saxifrages (*Saxifraga* spp.), *Draba* sp. and scattered grasses and sedges. Other species, including dwarf shrubs and willow-herbs, occur further south.

The vegetation of the low Arctic tundra is best developed in northern Alaska, the Canadian continental Northwest Territories and in northern Siberia. It consists of a nearly continuous (although occasionally thin) vegetation cover, usually 15–35 cm high, dominated by sedges and grasses. In general, the Arctic flora is characterised by a large number of genera, often represented by just a single species. The genera with the largest number of species include *Carex*, *Saxifraga*, *Salix*, *Ranunculus*, *Draba*, *Potentilla*, *Oxytropis*, *Puccinellia*, *Pedicularis* and *Eriophorum*.

Plant communities can be broadly arranged in six main categories:

- **Low shrub tundra**. Generally contiguous with the forest tundra. In areas such as the Mackenzie Delta in Canada and western Alaska it may dominate low, rolling uplands 100–200 km beyond the treeline. The open canopy of low shrubs, 40–60 cm high, is dominated by a combination of *Betula* and *Salix* species. Ground cover includes various combinations of dwarf shrubs (10–20 cm), mostly of heaths, which include *Vaccinium* sp., *Empetrum* sp., *Ledum* sp. and *Cassiope* sp. Grasses, forbs, mosses and lichens are also abundant. This is an important habitat for lemmings and voles, ptarmigan (*Lagopus* sp.), several species of passerines and, where conditions are suitable, colonies of Arctic Ground Squirrel (*Spermophilus undulatus*).
- **Tall shrub tundra**. River banks, sand and gravel bars of many of the larger rivers are frequently covered with *Alnus*, *Betula* and *Salix*, often to a height of 2–5 m. In North America, Moose (*Alces alces*) have extended their range northwards into these areas.
- **Cottongrass tussock/dwarf shrub** communities cover extensive areas of northern Alaska and Siberia, but are much less widespread in the Canadian Northwest Territories. These communities typically occur on rolling topography or soils of intermediate drainage. Various combinations of dwarf shrubs (mostly heath species) occur on the sides of tussocks as well as on moss or soil hummocks. Dwarf shrubs of *Betula* sp. are often associated with *Carex* sp., with numerous forbs and the grass *Arctagrostis* sp. Mosses and lichens (e.g., *Hylocomium*, *Dicranum*, *Aulacomnium* and *Cetraria* species) are common, and *Sphagnum* mosses may be locally abundant where drainage is poor. This community is an important summer range for

Caribou (*Rangifer tarandus*). Lemmings and voles, ptarmigan and various species of passerines are also common.

- **Sub-shrub/heath tundra** communities occur throughout the low Arctic in somewhat drier locations, such as slopes and high-centre polygons. Various heath species are found in low shrub tundra, and scattered plants of *Eriophorum* sp., *Arctagrostis* sp., dwarf *Salix* species and various forbs also occur at most sites. In areas of deeper snow cover and later melt, *Cassiope tetragona* usually predominates.
- **Cushion plant/lichen tundra**. This community is most widespread in the high Arctic but also occurs in the low Arctic on wind-exposed slopes and ridges where *Dryas* is usually a dominant species. Other important species may be *Salix* (dwarf species) and rushes (*Luzula* sp.), along with numerous grasses and sedges. Lichens are also present. Due to the smaller amount of plant cover and production as well as the dry, wind-exposed nature of this habitat there is a reduction in the faunal diversity of this community. A few passerines occur, as do lemmings and voles.
- **Sedge-moss and sedge-grass/moss meadow tundras** dominate on the coastal plains of North America and Siberia, where sedges (e.g., *Carex aquatilis*, *C. rotundata*, *C. membranacea*, *Eriophorum angustifolium* and *E. scheuchzeri*) are the dominant species. The grasses *Arctagrostis*, *Dupontia* and *Arctophila* occur in a gradient from drier sites to standing water. In the shallow waters of some lakes and in most ponds, *Menyanthes*, *Equisetum* and *Arctophila* occur where average water depth is 50–60 cm. *Potentilla palustris* and *Hippuris* sp. occur in water bodies 20–30 cm deep, and species of *Carex* and *Eriophorum* occur in sites with little (10–20 cm) or no standing water. Wet meadows have an almost continuous cover of mosses; species of *Sphagnum*, *Drepanocladus*, *Aulacomnium*, *Calliergon* and *Ditrichum* are commonly recorded. Sedge-moss wet meadows are important habitats for Caribou, waders and waterfowl. Lemmings, other small mammals and ground-nesting birds from this region form an important food resource for many carnivores.

South of the tundra, Subarctic vegetation patterns are largely determined by the distribution of discontinuous permafrost. The number of species is relatively low, and many species are perennial. Areas of dry, fine-grained soil, silt or sand deposits are often dominated by rushes, particularly *Luzula* sp. and *Juncus* sp. The taiga regions of Eurasia and North America are largely covered by coniferous forests. Taiga occurring on well-drained mineral soils will often support an upper layer of coniferous trees, especially species of *Pinus*, *Larix* and *Picea*. The low shrub layers include heath and other shrub species, such as *Vaccinium*, *Arctostaphylos*, *Andromeda* and *Empetrum* species. The ground layer typically consists of mosses. In wetter taiga locations, including those associated with discontinuous permafrost, acid bog communities with *Sphagnum* or *Hypnum* species and *Carex* sedges are common, while *Eriophorum* and *Carex*-dominated communities occur in less acidic conditions. Along river banks and in floodplains, *Salix*, *Populus* and *Betula* species are common.

Birds and Mammals

Birds

Since the end of the last Ice Age a unique avifauna has evolved over the Arctic tundra and polar desert environments. Other species have adapted to the marine environment of the polar seas, but are not considered in these Guidelines. Despite the apparent desolation of the region, the Arctic can support large numbers of birds during the summer months chiefly because of the very high numbers of insects at that time. In winter, conditions are too severe to support many species. Those considered as winter residents include Willow Ptarmigan (*Lagopus lagopus*), Rock Ptarmigan (*Lagopus mutus*), Snowy Owl (*Nyctea scandiaca*), Raven (*Corvus corax*) and Arctic Redpoll (*Carduelis hornemanni*). This contrasts markedly with the Subarctic taiga, where up to 30 species may overwinter (in North America).

The total number of species known to breed in the Arctic is 183, of which 39 are of limited occurrence. Specialised tundra species include Ptarmigan, Gyrfalcon (*Falco rusticolus*), Snowy Owl, Knot (*Calidris canutus*), Sanderling (*Calidris alba*), Ross's Gull (*Rhodostethia rosea*) and Snow Bunting (*Plectrophenax nivalis*).

The most striking characteristic of the Arctic avifauna is the low number of breeding species (less than 2% of the world's bird species). In any one region it is unlikely that more than 50 breeding species can be found. The numbers of individuals are enormous, however, particularly during the post-breeding and migration periods. A striking feature of tundra bird communities is the large number of waders, all of which feed on insects. Passerines are much less numerous but some localities do have breeding bird communities dominated by passerines as, for example, at Sarqaqdalen in north-west Greenland.

Although relatively few birds breed at high latitudes, those that do nevertheless play a key role in the ecosystem, with different species filling the niche of primary consumer, first level carnivore, top carnivore and scavenger. The few avian predators that breed in tundra ecosystems are migratory and, during the breeding season, are particularly dependent upon small mammal populations. Typical examples are the Snowy Owl and the Pomarine Skua (*Stercorarius pomarinus*), both of which may not breed in years when lemming populations are low.

Predation by mammals is probably the primary cause of nesting failure among many Arctic-breeding waterfowl and waders. The Arctic Fox (*Alopex lagopus*) plays an important role in this context. It has been shown that when lemming populations on the Taimyr Peninsula in Arctic Russia are at a low, fox predation on the eggs and young of the Brent Goose (*Branta bernicla*) may increase to the point where virtually no young geese are reared.

Mammals

A total of 48 species of terrestrial mammals occur in the Arctic, a little over 1% of the world total. Species diversity is low and consists primarily of shrews, hares, rodents, wolves, foxes, bears and deer. Included in this total are those from Siberia—Northern Pika (*Ochotona hyperborea*), European Water Vole (*Arvicola terrestris*) and European Mink (*Mustela lutreola*)—and four species from North America—Porcupine (*Erethizon dorsatum*), American Mink (*Mustela vison*), River Otter (*Lutra canadensis*) and Lynx (*Lynx canadensis*). These are primarily species of the taiga and forest-tundra habitats, but they may occasionally venture onto the true tundra. Other mammals of the Subarctic include beaver (*Castor* sp.) and martens (*Martes* sp.). Some species are circumpolar in their distribution, while others, such as the Arctic Hare (*Lepus arcticus*) and the Arctic Lemming (*Dicrostonyx groenlandicus*), are tundra-specific.

One of the most highly specialised of all Arctic mammals is the Musk Ox (*Ovibos moschatus*), which has adapted most successfully to the severe environmental conditions of both the tundra and the polar desert. It is the only ruminant whose distribution is limited to these regions.

Mammalian population cycles are a feature of the Arctic and Subarctic. Important examples are the 3–4 year cycles for several species of lemming in the circumpolar tundra zone, and the approximate 10-year cycle for the Lynx and Snowshoe Hare (*Lepus americanus*) in the North American taiga. There is strong evidence that herbivore population cycles are caused by plant-herbivore interactions, rather than by other factors such as the predator-prey relationship. There can be no doubt that small mammals, particularly certain rodents (voles and lemmings), play a key role in tundra ecosystems, forming a major link between many primary producers and secondary consumers.

An important point in respect of some of the large mammals of the Arctic region concerns their spatial requirements. The most notable example is probably the Caribou which requires very large foraging areas, has specific calving areas (where freedom from disturbance is essential), and which may carry out long-distance migrations between summer areas in the Arctic tundra and wintering areas in the Subarctic taiga. Grizzly Bears (*Ursus arctos*) also require large expanses of wilderness. Research in the Brooks Range of northern Alaska, for example, has shown that the average home ranges for males and females was 702 km^2 and 280 km^2, respectively, during the breeding season.

Environmental Sensitivity

The temperature regime is the dominant factor that controls conditions in the Arctic and Subarctic. It is therefore a major determinant of environmental sensitivity. It has frequently been stated that polar ecosystems are inherently more sensitive than other world ecosystems, but this has to be put into perspective. An important factor in this context is that the slow growth rates of tundra vegetation make this habitat particularly slow to recover following physical damage. Polar deserts are similarly slow to recover from physical perturbations. Another important point is that large concentrations of birds (particularly seabirds and waterfowl) commonly occur in the Arctic at certain times of the year, for example, when ice packs open and following a thaw. On such occasions any large concentration of wildlife would be highly vulnerable to oil spills.

Sensitive aspects of the northern polar environment can be summarised as follows:

- **Air**. The relatively unpolluted air of the Arctic could be vulnerable to pollution build-up in local situations as a result of temperature inversions. Lichens, the base of the tundra food chain, are highly sensitive to air pollution.
- **Water**. The quality of Arctic waters is generally high. Changes in the hydrological regime may initiate permafrost melt. The ecology of bogs can also be altered by disruption of their drainage.
- **Soils**. Disturbance of the insulating active layer can easily lead to problems of thermokarst and erosion.
- **Vegetation**. The sensitivity of the active layer on the tundra has already been stressed. Similarly, the peat layer of Subarctic bogs can also be seriously damaged by compaction. Due to the slow rate of plant growth, scars caused by the passage of vehicles over the tundra after a thaw can take many decades to heal, particularly in the case of moss carpets.
- **Wildlife**. The concentration of seabirds and waterfowl on restricted areas of water during the early stages of the annual thaw render them potentially vulnerable to oil spills, or related disruptions. Due to the very short nesting season any form of persistent disturbance which interrupts the incubation schedule could have serious effects on breeding success. Disturbance of large flocks of geese which concentrate in traditionally-favoured moulting areas may inhibit the build-up of fat reserves necessary for their southward migration. Likewise, Caribou migrate to restricted areas during the breeding season to give birth. Any disturbance at such critical times could lead to increased calf mortality

Indigenous Peoples

The Arctic and Subarctic are inhabited by groups, many of which are based largely on subsistence economies, dependent on renewable resources, in particular plants and animals. The limited range of available, sustainable alternatives to this lifestyle emphasises the importance of maintaining, as far as possible, traditional patterns of resource use associated with indigenous peoples. Since oil and gas exploration and production can be the first major industrial activity in Arctic and Subarctic areas, the potential impact of such developments is considerable.

Chapter 3

Overview of the Oil and Gas Exploration and Production Process

In order to appreciate the potential impacts of oil and gas development upon the environment it is essential to understand the activities involved. This chapter briefly describes the oil and gas exploration and production process for those not familiar with these operations (see Figure 3 for a summary). Environmental protection measures for each stage of this process are discussed in detail in Chapter 6.

Figure 3. Summary of the Exploration and Production Process

ACTIVITY	POTENTIAL REQUIREMENT ON GROUND
Desk study: identifies area with favourable geological conditions	• None
Aerial survey: if favourable landscape features are revealed then	• Low-flying aircraft over study area
Seismic survey: provides detailed information on geology	• Road or helicopter access for personnel and equipment • Base camp facilities
Exploration drilling: verifies the presence or absence of a hydrocarbon reservoir and quantifies the reserves	• Drill stem testing facilities • Access for equipment • Base camp facilities • Storage facilities • Waste disposal facilities
Appraisal: determines if the reservoir is economically feasible to develop	• Large base camp • Additional drill sites • Additional access, storage and waste disposal facilities • Oil storage facilities
Development and production: produces oil and gas from the reservoir through formation pressure, artificial lift, and possibly advanced recovery techniques until economically feasible reserves are depleted	• Semi-permanent base camp • Improved access, storage and waste disposal facilities • Separation/treatment facilities • Increased oil storage • Facilities to export product • Gas production plant, flares • Wellheads, flowlines, gathering stations
Decommisioning and site restoration	• Equipment to plug wells • Equipment to remove installations • Equipment to restore site

Identification of a Potential Hydrocarbon Reserve

In the first stage of the search for hydrocarbon-bearing rock formations, geological maps and satellite data are reviewed to identify major sedimentary basins. Aerial photography may then be used to identify promising landscape formations such as faults or anticlines. More detailed information is assembled using a field geological assessment, followed by one of three main survey methods: magnetic, gravimetric and seismic. Of these, a seismic survey is the most common and can be the first field activity undertaken. Seismic methods are discussed in the following section[2]. Magnetic and gravimetric methods are undertaken using aircraft flying in straight lines and at a fixed altitude. Some countries prohibit low-level flights, however, so that alternative survey means must be identified under such circumstances.

Seismic Methods

Seismic methods on land require the direct input of mechanical energy to the Earth's core at specified points along a survey line. The energy produces acoustic waves that are reflected by changes in the sub-surface geological strata. The reflected seismic waves are, in turn, detected by many sensors (geophones), arranged along several kilometres of the survey line (over several square kilometres in the case of a 3-D survey). Information is then recorded. Prior to surveying the data points and sensor locations, line preparation can involve the removal of some vegetation cover. As recording progresses along the line by the use of successive data points, the sensors are moved from the rear to the front by crews using vehicles or helicopters. Data are then computer-processed to map the underlying strata, and to help define the size and shape of any structure worthy of further investigation.

A variety of methods is available to produce the release of energy, but 90 per cent of surveys use shot hole or Vibroseis techniques. The shot hole method involves the detonation of small explosive charges placed in narrow holes drilled to a depth of 1–30 m. Shot holes are usually placed some 35 m apart in a straight survey line along a specific compass bearing. The detonation produces the required acoustic waves. In the Vibroseis method, a group of three to five heavy vehicles each lower and then vibrate a heavy pad at specific points on the ground. The vibrations create the acoustic waves used for the survey. A series of usually identical sweeps are made at closely-spaced intervals and the results integrated. Vibroseis work is generally confined to roads or other hard surfaces.

Exploratory Drilling

Once a promising geological structure has been identified, the only way to confirm the presence of hydrocarbons, and the thickness and internal pressure of a reservoir, is to drill exploratory boreholes. The location of a drill site is dependent upon the characteristics of the underlying geological formations, although some flexibility in site selection may be possible to achieve environmental protection while still reaching the desired exploration objectives.

At a chosen site, a pad is constructed for drilling equipment and support services. A typical one-hole exploration pad occupies between 5000 and 20,000 m^2. The type of pad construction is dependent on seasonal constraints, with the option of snow and/or ice pads for winter drilling, or a gravel/sand pad to protect the tundra from the heat and weight of the drilling rig during other seasons.

Drilling rigs and support equipment are normally divided into modules to facilitate transport. Depending on access, site location, and module size and weight, drilling rigs can be moved by

[2] For additional information, the International Association of Geophysical Contractors has published detailed and specific Guidelines for geological and seismic operations in their '*Environmental Guidelines for Worldwide Geophysical Operations*' (1993).

land, air or water. Once on-site, the rig and a self-contained support camp are assembled. Typical drilling rig modules include a derrick, drilling mud handling equipment, power generators, cementing equipment, and fuel and water tanks. The support camp is self-contained and generally provides workforce accommodation, canteen facilities, communications, vehicle maintenance and parking areas, a helipad (remote sites), fuel handling and storage areas, and provision for collection, treatment and disposal of wastes. A typical camp might occupy 1000 m^2 and be located up to 500 m up-wind of the drilling rig.

Once drilling begins, drilling fluid or mud is continuously circulated down the drill pipe and back to the surface equipment to balance underground hydrostatic pressure, cool the bit and flush out rock cuttings. The risk of uncontrolled flow from the reservoir to the surface is further reduced by using blow-out preventers, a series of hydraulically actuated devices that can close around the drill string, casing or an open hole to quickly seal off a well. Steel casing is inserted into completed sections of the borehole and cemented into place. The casing provides structural support to maintain the integrity of the borehole and isolates underground formations.

Drilling operations are generally conducted round-the-clock. The time taken to drill a bore hole depends on the depth of the hydrocarbon-bearing formation and the geological conditions encountered and is usually in the order of one or two months. Where such a formation is found, initial well tests—possibly lasting another month—are conducted to establish flow rates and formation pressure. These tests may generate oil, gas and formation water, the disposal of which is discussed in Chapter 6.

After drilling and initial testing, the rig is usually dismantled and moved to the next site. If the exploratory drilling has discovered commercial quantities of hydrocarbons, a wellhead valve assembly may be installed. If the well does not contain commercial quantities of hydrocarbons, the site is abandoned in a safe and stable condition and restored to its original state or agreed after-use. Open rock formations are sealed with cement plugs to prevent upward migration of wellbore fluids. The casing wellhead and the top joint of the casings are cut below the ground level and capped with a cement plug.

Appraisal

The appraisal stage aims to evaluate the size and nature of the reservoir, to determine the number of development wells required, and whether any further seismic work is necessary. Deviated or directional drilling at an angle from a site adjacent to the original discovery borehole may be used to appraise other parts of the reservoir, hence reducing the size of the 'foot print', that is, the land taken for site or road development.

Development and Production

A small reservoir may be developed using one or more of the exploratory or appraisal wells, but a larger reservoir will require the drilling of additional production wells. Multiple production wells are often drilled from one pad to reduce overall infrastructure cost. A central production facility may be used to gather and separate the produced fluids (oil, gas and water). The size and type of the installation will depend on the nature of the reservoir, the volume and nature of produced fluids, and the export option selected. Product transport options may include road, water, pipeline, or an appropriate combination. In remote areas, and for fields producing large quantities of oil and gas, a network of pipelines is usually the most efficient option to transport oil and gas to terminal facilities for distribution. A self-contained base camp will be established to support the production facility.

Routine operations on a producing well include a variety of monitoring, safety and security programmes, maintenance tasks and periodic downhole servicing using a wire line unit or a workover rig to maintain production. The operator will be able to extract only a portion of the oil present using primary recovery, that is using natural pressure and simple pumping techniques. A range of additional recovery methods is available. For example, secondary recovery uses waterflood or gas injection, and tertiary methods employing chemicals, gases or heat may also be used to increase the efficiency of oil production.

Abandonment, Decommissioning and Reclamation

Many exploration wells will be unsuccessful and abandoned after operating for, perhaps, between one and three months. It is, therefore, useful to plan for this from the outset to ensure minimal environmental disruption and to simplify subsequent decommissioning, reclamation and restoration. Decommissioning of longer-term production installations will include removal of buildings and equipment, restoration of the site to its original or agreed after-use, perhaps involving implementation of measures to encourage site revegetation, and continued monitoring of the site for an appropriate period after closure.

Chapter 4

Potential Environmental Impacts

Interactions between Exploration and Production Activities and the Environment

Oil and gas exploration and development can involve power generation, transportation and infrastructure development, together with the consequent influx of people. The intensity of such activity can produce a variety of effects which vary with time and distance from the development site. Effects may sometimes be far removed from the source, for example by contamination of watercourses, or by changes in land-use, caused by access routes. It is important to consider immediate, short-term impacts as well as long-term, indirect and cumulative impacts from separate, but linked operations.

Human Environment

Social Impacts

Likely social and environmental impacts are especially important to all local groups, particularly to indigenous peoples. Oil and gas exploration and production can often induce considerable economic, social and cultural impacts, the extent of which varies according to specific situations. Local people often examine any projected resource exploitation activity in 'their area' in terms of how valued elements of their environment and society may alter. The application of culturally determined values is, in many respects, an intangible phenomenon. These values are difficult to quantify, but overlooking or ignoring them can cause considerable concern amongst local people.

Such concern has inspired many organisations, such as indigenous peoples' groups, environmental organisations and governments, to initiate actions to help local people deal with the consequences of development. Such actions include formulation of local development/management plans, conservation strategies and multinational treaties and agreements. The customary rights and cultural heritage of indigenous peoples, including customary rights of access to land and other natural resources, and to exploit the 'products' of those resources, should be identified and respected throughout all phases of oil and gas operations.

Social impacts can include changes in:

- land-use patterns such as agriculture, fishing, logging, hunting and trapping, as a direct consequence (for example, land-take) or indirectly, by provision of new access routes;
- population levels (for example, from increased in-migration);
- socio-economic systems (employment, income differentials, inflation, *per capita* income, taxation, rent, royalty income);
- socio-cultural systems (social structure, organisation, and cultural practices and beliefs); and
- availability of, and access to, goods and services (housing, medical, educational).

Social effects may be adverse or beneficial, depending upon the structure of the existing community and the nature, size and duration of operations in the region. For example, there may be an increase in employment or the funding of education or regional development programmes. Difficulties may arise, however, if exploration and production strategies are in conflict with existing plans for protection or development of the region. Similarly, the recreational and tourist value of Arctic and Subarctic areas may be decreased by the introduction of oil and gas installations and operations. Alternatively, they may be enhanced by the provision of additional access and emergency facilities.

Visual Impacts

Visual impacts can be caused by poor siting and design of exploration sites, roads and production facilities, and by encroachment of development on wilderness areas. Other visual impacts can arise from excessive land-take, removal of vegetation, and ground preparation for seismic lines and pipelines. Visual intrusion can be caused also by floodlighting and flaring.

Noise Impacts

Noise can arise from helicopters, low-flying aircraft and other vehicle movements, exploration activities, drilling operations and production operations. Noise not only affects humans, but also wildlife—for example, disturbance of migratory bird roosting and nesting areas can result from excessive or poorly coordinated/controlled air traffic.

Natural Environment

Impacts on Air Quality

Atmospheric conditions in Arctic regions may occasionally lead to high local levels of air pollution as a result of temperature inversion. The primary sources of emissions to air are:

- flaring, venting and purging gases, including black smoke emissions;
- combustion processes, such as diesel engines and gas turbines;
- fire protection systems;
- road traffic in summer, causing dust dispersal; and
- fugitive gas losses.

Principal gaseous emissions from oil and gas operations may include carbon dioxide, carbon monoxide, methane, volatile organic carbons, nitrogen oxides and halons. Emissions of sulphur dioxide and hydrogen sulphide can occur and will depend on the sulphur content of natural gas and diesel, particularly when used as a power source. In some cases, flaring and combustion can lead to odour production, and special consideration should be given to the siting of flares and/or the treatment of waste gases.

Ozone-depleting substances have been used in oil and gas operations in fire protection systems, as well as in refrigeration. Emissions occur primarily through fugitive loss, false alarms, system testing and, infrequently, through fires. The industry is taking substantial steps to reduce the use and release of these substances. International protocols will stop the manufacture of halons in 1994 and other CFCs shortly thereafter.

Hydrological Impacts

Groundwater and surface water protection are major priorities in both Arctic and Subarctic regions. Excavation and infill can cause significant alterations to existing watercourses and drainage patterns, which can lead subsequently to marked changes in vegetation and wildlife. Operational activities can also introduce contaminants into the aquatic environment. The principal aqueous waste streams from oil and gas operations are:

- produced water;
- drilling and well treatment fluids;
- process, wash and drainage water; and
- sewage and domestic wastes.

Specific impacts may include:

- alteration of drainage patterns due to topographical changes;
- creation of wetter, pond-dominated landscapes by topographical changes;
- creation of higher, drier landscapes by introduction of fill material into surface water overlying permafrost;
- direct and indirect impacts to water supplies by clearing of vegetation;
- disruptions to surface water movement and changes in quality by vehicle traffic, removal of vegetation and impounding;
- contamination of ground and surface water by drilling fluids and oil during the drilling of wells; and
- contamination of ground and surface water from operational discharges, leakage, site drainage and accidental releases.

The potential to affect water resources should be thoroughly evaluated by the operating company prior to initiating any activities, particularly where water is used by local people, or where fisheries and wildlife populations may be affected.

Impacts on Soil

Ecosystem sensitivity in northern circumpolar regions is directly related to the thermal stability of the permafrost. The extent of any disturbance will depend largely on the soil type and on the amount of ice in the soil. Thermokarsting, pingo formation and patterned ground are all examples of natural dynamic changes associated with permafrost regions. Since these soils have a low resistance to degradation and are vulnerable to changes in temperature, human intervention can dramatically reshape the land. The active layer may have peat at the surface, which provides insulation to the underlying permafrost. Disturbance, compression or removal of the peat layer could decrease the insulating effect, change the heat balance and result in permafrost degradation.

The most significant potential effects of oil and gas development activities on soil include:

- compaction;
- erosion resulting from change of slope angle and pooling of water;
- changes in polygonal structure and drainage patterns; and
- contamination from operational discharges, leakage, site drainage and accidental releases.

Alterations to soil conditions can cause widespread secondary impacts by reducing the capacity of the habitat to support fauna or flora.

Impacts on Vegetation

Loss of vegetative cover is of great concern in Arctic and Subarctic regions. Following disturbance, recovery is slow because of the short growing season and low annual production of nutrients. Nutrients are a limiting factor since the combination of low temperatures and frequent waterlogged conditions reduces microbial activity in the soil. Loss of vegetation affects nutrient cycles, removes the organic litter layer, accelerates the rate of soil loss through erosion and reduces the availability of habitat for wildlife. Significant visual impact also results from the removal of vegetation, until site restoration occurs.

Vegetation can be lost or altered by construction activities for access roads, drilling and production sites, support infrastructure, borrow sites, as well as by contamination from discharges, waste and spills. Wetland, peat, bog, moss and lichen communities are also susceptible to submersion resulting from the use of winter trails.

Disturbance of the plant community can induce change in species composition and its production of energy and nutrients. The severity of any impact depends on the intensity and duration of the disturbance as well as habitat structure. Prolonged changes in vegetation cover can disturb permafrost stability, since evapotranspiration from vegetation at the ground level is one of the significant factors in balancing the heat budget which maintains the permafrost.

Uncontrolled vegetation fires cause significant damage to the environment, and threaten human life and other facilities. The Arctic and Subarctic ecosystem might be significantly altered by a fire through loss of ground cover, habitat destruction, terrain disturbance and siltation of streams.

Impacts on Animals

Animal populations can be affected by changes in vegetation, soil, water and noise. These changes may affect, for example, habitat, food supplies, breeding areas, migration routes, vulnerability to predators or changes in herbivore grazing patterns (with a subsequent effect on predators). The major potential effects of exploration and production activities on wildlife include:

- direct habitat loss and modification (site-specific);
- habitat disturbance;
- displacement (immediate vicinity); and
- blockage of access to habitats (regional effect).

Direct habitat loss results from the 'foot print' on which facilities are constructed. Modification could result from dust deposition, water spray or local ponding. Habitat disturbance could include vegetation or soil removal, erosion and changes in soil structure, sedimentation, and changes in topography or hydrology. Wildlife displacement occurs when animals avoid a site because of its changed nature, because of noise or extraneous light, or for other reasons. Access to habitats can be blocked by the construction of roads and pipelines. Hunting, feeding and general disturbance of wildlife by company and contract employees can occur if not prohibited and strictly controlled. It is important to note that changes in the abundance and distribution of certain wildlife species can have significant impacts on the livelihood of indigenous peoples. Recommendations for the avoidance of adverse impacts on wildlife populations are provided in Chapters 5 and 6.

Impacts on Biological Diversity

The maintenance of biological diversity is of increasing worldwide concern. A number of international governmental and non-governmental agreements exist or have been proposed for protection of Arctic and Subarctic species (see Appendix). Consideration of impacts from oil and gas operations on biodiversity is important in the circumpolar north, where scientific knowledge on threatened or endangered species may not be available, and where an understanding of the implications of species loss is limited.

Important factors to consider, to the extent possible on the basis of existing knowledge, when evaluating the likely effects of development on biodiversity include:

- the status, distribution and vulnerability of individual species;
- the dynamics of ecosystems that support threatened or endangered species;
- the rate of extinction occurring and likely to occur;
- regional differences in extinction rates; and
- minimum sustainable gene pools and population size.

It is important to consider not only those species that are endangered, but also those that have low numbers, those which are important for indigenous groups or those which extensively use habitats for short periods of time. These populations may be significantly affected if disturbed.

Chapter 5

Environmental Management

The Framework

Effective environmental management will help minimise risk and environmental disturbance. An operator's environmental management system is the framework defining the organisational, operational and financial measures required to implement environmental policy and controls. An environmental management system should encompass the following:

- Formulation of an environmental policy.
- Identification and assessment of requirements in relation to policy goals, local and national regulations in the host country and current best practice.
- Planning and organisation to:
  - allocate responsibilities, define roles and job requirements and establish organisational structure;
  - develop a consultation programme;
  - obtain environmental expertise;
  - develop short- and long-term environmental plans;
  - allocate financial resources;
  - establish written procedures and instructions;
  - prepare emergency response procedures; and
  - provide training.
- Execution, covering all stages in a project, requiring attention to the following aspects:
  - Project planning to:
    - prepare an environmental profile;
    - implement a consultation programme;
    - conduct appropriate environmental impact assessments (EIAs);
    - prepare an environmental plan containing detailed guidance on measures to be implemented to prevent or minimise expected adverse impacts and enhance possible beneficial impacts;
    - establish monitoring programmes to check emission levels and, when necessary, measure and verify predictions of the EIAs;
    - set standards and targets and encourage the use of effective technologies for design, operation and maintenance of facilities;
    - formulate a compliance programme to ensure that statutory regulations and the operators' commitments (environmental plans, written procedures, instructions, personnel responsibilities, training programmes, emergency procedures, and monitoring and performance review programmes) are fully established and consistently met;
    - design and select equipment that can perform the required tasks with minimal impact on the environment;
    - incorporate environmental issues in tender procedures and subsequent contracts; and
    - obtain environmental permits.
  - Operations to:
    - minimise waste production and ensure proper waste management;
    - monitor and control emissions and effluents;
    - use 'environmentally benign' chemicals wherever possible; and
    - record, report and follow-up incidents and 'near misses'.

- Post-Operations to:
  - arrange for appropriate abandonment, decommissioning, reclamation and restoration of sites.

■ Control and Verification, achieved by:
- setting standards and targets;
- regular monitoring of environmental performance; and
- periodic review of environmental performance (audit).

■ Feedback/Improvement, achieved by:
- requiring establishment of systematic measurement, reporting and implementation procedures so that performance can be consistently improved.

Key features in implementing this system are shown in Figure 4, illustrating their relation to important activities in the oil and gas exploration and production process.

Figure 4. Environmental Management

ACTIVITY	MANAGEMENT ACTION
Desk study	Establish environmental management system Environmental profile
Seismic survey	Preliminary environmental impact assessment Environmental training Operational procedures*
Exploratory/appraisal drilling	Preliminary environmental impact assessment Environmental training Environmental monitoring Environmental audit Operational procedures*
Development and production	Environmental impact assessment Environmental training Environmental monitoring Environmental audit Waste management Operational procedures*
Decommissioning, reclamation and site restoration	Site assessment Implementation of site restoration plan Environmental monitoring Operational procedures*

* Operational procedures include the establishment and implementation of waste management, emergency preparedness, groundwater protection, and hazardous material handling and disposal programmes.

Environmental Profile

The first stage of project planning—the preparation of an environmental profile—should be conducted prior to the acquisition of an area of land. The profile provides an initial review of an area to describe its environmental, social and cultural sensitivity. The depth of detail will vary depending on requirements, but will usually be limited to a desk-type study. The identification of any particular sensitivity may lead to more detailed study requirements.

The objectives of an environmental profile are to:

- assist planning and control of seismic surveys and exploration drilling activities;
- provide background to consultations with external bodies;
- select sites avoiding areas of high sensitivity;
- schedule activities avoiding sensitive periods;
- modify or select equipment and techniques to minimise adverse impacts; and
- identify specific protection measures.

The environmental profile should provide:

- a review of applicable regulations, land-use patterns and other development proposals likely to affect the area;
- available environmental data, identification of national parks, protected areas, and other environmentally and culturally sensitive areas;
- identification of sensitive issues; and
- an appreciation of existing (arising from local knowledge of impending oil and gas related activities in an area) and potential impacts.

The environmental profile will be the basis for any additional studies.

Consultation

Prior to beginning any exploration activity, an operating company should evaluate information in the Environmental Profile, and undertake a programme of formal (statutory) and informal public consultation, the objectives of which are to:

- create and maintain a mutually beneficial relationship between an operating company, the statutory authorities and the local public by the two-way flow of information and ideas;
- develop a better understanding of local values and traditional ecological knowledge;
- enhance environmental protection by encouraging company consideration of social, cultural, ecological, and public safety issues;
- avoid or reduce conflicts between a company and the communities in which it operates;
- produce a wider range of options for all concerned parties; and
- identify local employment and business opportunities.

These goals can be achieved by:

- initiating early consultation;
- informing and educating the local public of activities and development plans; and
- welcoming public inputs to decisions.

Potential partners for public consultation include government administrators, legislative representatives, local interest groups, communities and indigenous groups likely to be affected by development, local businesses and the media. Consultation should be managed with the greatest possible consideration for the interests and values of local people. It should be recognised that situations will arise in which a local government does not exist, is not effective or does not have priorities consistent with those of the local people. In such situations, the operating company should take steps to ensure that the appropriate level of consultation occurs with local people.

Decommissioning and after-use scenarios should be discussed early in the process, so that local land-use goals can be considered. Such goals may change during the life of a project. The original goal may involve the complete removal of infrastructure, for example, but this may be subsequently modified to leave beneficial facilities in place for future use.

Preliminary Environmental Impact Assessment (EIA)

After an exploration concession has been acquired, a preliminary EIA should be prepared prior to the first phase of any exploration activity which is likely to have more than short-term and reversible impacts on the site and its immediate surroundings. The preliminary EIA builds on the findings of the environmental profile and examines the issues in greater detail. Site-specific surveys and data gathering, for example a cultural resource survey, will be required, particularly where sensitive issues have been identified. The preliminary EIA will further define and quantify sensitive issues and identify additional environmental, social and cultural issues. Recommendations will be made on specific aspects of environmental control and protection. The final document is prepared in consultation with appropriate authorities and organisations, environmental specialists or institutes, indigenous populations and the general public.

A major objective of the preliminary EIA is to determine whether a more detailed EIA is necessary. The structure and format of the preliminary EIA should follow that of the full EIA, as described below.

Cultural Resource Surveys

To ensure recognition and careful consideration of the culture and practices of indigenous peoples, including avoidance of sacred and archaeological sites, appropriate consultation should be initiated and maintained throughout all phases of oil and gas development. In some cases, a cultural resource survey may be appropriate to:

- identify and document cultural resource sites within or near the proposed development area;
- assess the probable impact of the proposed development on cultural resource sites, if any;
- make recommendations for avoidance, or mitigation of impacts;
- satisfy local and national regulations on such matters; and
- evaluate potential environmental factors of cultural importance, such as wildlife, water quality, topographic features and access.

It is likely that local residents will be the most important source of information and full cooperation should be maintained at all stages. Survey results should be made known to the local community, and relevant national or local authorities.

Environmental Impact Assessment (EIA)

An EIA should be prepared for exploration and production activities where the potential for significant environmental impacts has been identified by the environmental profile and/or preliminary EIA. The preliminary and full EIA process should begin during the early stages of pre-project planning, and continue as an iterative process during the project feasibility studies, specification and detailed design. The findings of the EIA can, at each stage, be incorporated into the next phase of the project design. Any changes in project specification must be re-evaluated within the EIA.

An EIA is a comprehensive and detailed examination of a proposed development initiative and the environment in which it is to be constructed and operated. The objectives of an EIA are to:

- identify sensitive components of the existing environment within the project area and its environs;
- assist project design and planning by identifying those aspects of location, construction, operations and decommissioning which may cause adverse environmental, social, health and economic effects;
- recommend measures during construction, commissioning and operations to avoid/ameliorate these effects and/or increase beneficial impacts;
- identify the best practicable environmental option, which requires that the environmental implications of all available development options be evaluated—the chosen option should result in the least environmental damage and be consistent with the prevailing regulations;
- estimate and describe the nature and likelihood of environmentally damaging incidents to provide a basis for contingency plans;
- identify existing and expected environmental regulations that will affect the development and advise on standards, consents and targets;
- identify any environmental issues and concerns which may, in the future, affect the development;
- recommend an environmental management programme for the life of the development, including compliance, monitoring, auditing and contingency planning; and
- provide the basis for support and control documentation and consultation with regulatory and non-regulatory authorities and the public.

The EIA report should include the following:

- description of the nature, quality and dynamics of the existing environment;
- project description, including alternative proposals;
- description of the regulatory regime;
- identification of the significant potential impacts of the development and its alternatives;
- prediction and characterisation of each predicted impact for all alternatives;
- recommended alternative actions or mitigation to minimise adverse impacts and enhance any environmental benefits;
- assessment and evaluation of unavoidable impacts;
- environmental management strategy and plan;
- decommissioning, reclamation and restoration plan; and
- proposed monitoring programme.

Both preliminary and full EIAs should comply with all statutory requirements. The EIA report should be submitted to the appropriate authorities when required. In the event that more than one operator is involved in an area, plans should be coordinated to provide consistency, minimise duplication of effort and consider cumulative impacts. The operator has overall responsibility for ensuring that the environmental management and monitoring plan is implemented, and should liaise with statutory authorities, agencies and the public, which may include indigenous peoples' organisations, other non-governmental organisations and citizens' advisory groups.

Environmental Monitoring

Appropriate environmental monitoring should take place—through a system of routine checks—during all phases of an oil and gas project, to verify the effectiveness of control measures and to identify environmental effects that were not previously predicted. Statutory requirements in the host country may also demand that specific monitoring tasks are undertaken. The objectives of monitoring programmes may vary, depending on the activity and operations in progress, but will include some or all of the following elements to:

- check the overall effectiveness of design and operational procedures in protecting the environment;
- comply with regulations, standards, planning consents, compliance programmes;
- detect sudden or long-term environmental changes;
- measure physical disturbance and subsequent recovery following rehabilitation;
- study impact and recovery following accidents and incidents;
- confirm that environmental protection equipment and procedures are effective; and
- compare actual impacts with those predicted in the EIA.

Environmental performance can be monitored by:
- measuring and recording quantitative source control information (amounts and concentrations of emissions, effluents and wastes against consents and standards; number of spills, permit compliance records);
- measuring and recording environmental quality surrounding a site (ecological/biological, physical and chemical analyses);
- measuring and recording qualitative information (implementation of environmental management measures, local liaison activities, provision of new equipment or process modifications to reduce environmental impact);
- impact monitoring—assessment of the extent and severity of any impacts, demonstration of relationships between observed and predicted impacts (from the EIA), demonstration of relationship between observed impacts and operational activities;
- measuring and assessing re-instatement and recovery success, effectiveness of any mitigation measures; and
- documentation—project reports, records and photographs.

The final and vital element of any monitoring programme is feedback and action. Any indication that conditions are abnormal must be reported, action taken to discover the cause and adequate solutions implemented.

Environmental Audit

Environmental audits provide a systematic, documented, periodic evaluation of environmental, organisational, management and equipment performance. Audit is the fundamental verification tool to ensure that environmental management procedures are being rigorously enforced. Audits are often conducted internally, but periodic reviews involving independent, external auditors may be considered.

Environmental audits should be undertaken on a regular basis. The objectives will depend upon which aspects of operations or activities are being reviewed, but they should include:
- examination of line management systems and procedures, field operations, and monitoring practices and data;
- verification of predictions in the EIA;
- verification of implementation and effectiveness of mitigation recommendations;
- review of incident reporting and remedy schemes;
- identification of current and potential environmental problems;
- recommendation of necessary improvements to management operational practices; and
- formulation of thorough documentation, feedback and implementation procedures.

Environmental Training

The goals of environmental training are to ensure that personnel are able to meet their defined role and job requirements, correctly apply environmental operating procedures and to foster, in each employee, an awareness for environmental, social and cultural concerns. Emphasis should be placed on each individual's responsibility for the environmental performance of both the project and the operating company. To achieve these goals, training should be provided to both employees and contractors, focused on differing environmental issues according to the job responsibilities of the participants.

The following list of topics should be considered for inclusion in a training programme:

- operator's environmental policy, plan and management system;
- annual objectives, goal and target setting;
- awareness of global, national and local environmental issues;
- environmental legislation, liability and compliance;
- contingency and emergency response;
- long-term plans;
- training;
- performance measurement;
- public affairs;
- operator's environmental policy, plan and management system;
- job specific procedures, guidelines and documentation;
- environmental standards, targets, performance criteria;
- local operating conditions, environment and limitations;
- discharge and emission levels, reporting and control;
- waste disposal requirements, reporting and control;
- usage and control of chemicals;
- oil spill and emergency response and reporting; and
- pollution prevention.

Training programmes will need to be tailored to the specific needs and functions of individual employees. Environmental training should be provided and documented for all employees and contractor personnel. Awareness of environmental issues and capabilities to operate effectively cannot be achieved simply through attendance of one training course at the start of employment or operations. Re-inforcement is needed through a combination of refresher courses, regularly scheduled briefings, meetings, newsletters, posters and video presentations.

Figure 5. Waste Disposal—Options For Evaluation

TYPE OF WASTE	METHODS OF DISPOSAL
Domestic waste sludge (biotreater, sewage)	Incineration; burial or land application where authorised
Liquid	Biological, chemical, or mechanical treatment
Process water, wash water	Biological treatment; incineration (if oil content high); chemical treatment; injection; reclamation; discharge to watercourse if properly treated and authorised
Site drainage; contaminated rainwater/snowmelt	Biological treatment; chemical treatment; injection; reclamation
Gases	Scrubber unit; smokeless flare; injection
Produced water	Injection (waterflood or downhole disposal); water flooding; treatment and discharge
Medical	Incineration; removal from site and appropriate disposal, or return to vendor
Filters	Incineration; biological treatment; landfill
Oil-contaminated soils	Incineration; biological treatment, removal off-site for stabilisation and burial
Water-based muds/cuttings	Recycle muds; injection; solidification; stabilisation and/or washing for use as road fill or burial, land application
Oil-based muds/cuttings	Recycle muds; injection; solidification; chemical stabilisation; thermal and/or biological treatment with subsequent burial, land application or off-site disposal
Spent treatment fluids	Re-injection, reclamation, neutralisation/discharge of water-based material; reclamation; re-injection or incineration of oil-based material
Unused drilling chemicals and hazardous materials	Return to vendor or use at alternative site; chemical neutralisation, solidification, and off-site disposal
Waste lubricants	Reclamation; fuel; incineration
Domestic refuse	Recycling, incineration; land fill at approved sites; composting; grinding; injection
Industrial refuse (organic)	Reclamation; incineration; burial
Industrial waste (inorganic—batteries, drums, etc.)	Recycling, reclamation; off-site disposal
Squeeze/fracturing fluids	Reclamation; injection
Tank and plant sludges	Reclamation for increased recovery (refinery); re-injection; incineration; solidification; stabilisation and burial

NOTE: Burial and land application is acceptable at approved locations where statutory authority or permits are issued. Where no statutory authority exists the practice is only acceptable with full, documented assessment and under strict control and monitoring programmes.

Chapter 6

Environmental Protection

Environmental Protection Measures for the Main Phases of Exploration and Production Activities

Exploration Surveys

Onshore seismic surveys in the Arctic and Subarctic are generally conducted in winter when there is sufficient snow cover to minimise damage to the underlying tundra and taiga. The environmental profile and preliminary EIA will provide information concerning any particular sensitivities within the seismic survey area, as well as the most suitable timing for the operation. All necessary permits to conduct the survey will have been obtained from the appropriate authorities well before the scheduled start date. In addition, plans should be made before the survey starts to:

- inform local authorities and inhabitants;
- specify routes for aircraft (either fixed wing or helicopters) to avoid sensitive areas and maintain a minimum operating height so that wildlife is not disturbed;
- ensure all aspects of the preliminary EIA have been addressed and a compliance programme issued to the head of the survey group;
- ensure personnel are trained in environmental operating procedures;
- avoid unnecessary clearing of vegetation; and
- avoid the use of track vehicles on exposed tundra or taiga, and preferably use vehicles that offer very low ground pressure, such as buggies.

Frequently, in remote areas, base camps have to be established to support exploration operations. Sites must be selected with care and be subject to a preliminary EIA; the Site Selection Guidelines detailed in the following section should also be followed.

Preparing a seismic line in the Arctic involves taking a straight route across the tundra and marking it with shot points and geophone stations at regular intervals. When areas of difficult access are encountered, such as steep banks of frozen streams, limited and carefully controlled use of mechanical equipment may be allowed to move snow and to reduce the gradient, provided local regulations permit this and permission has been received. It is necessary to ensure that there is a sufficient thickness of snow and ice on the slope to protect the stream bank during vehicle crossings. Likewise, a sufficient thickness of snow cover should be in place on hills and other sensitive areas before allowing vehicular access. If possible, snow should not be cleared from ice except for landing strips on lakes, since clearing it will cause the ice to freeze deeper.

The operator and head of the survey group are responsible for ensuring that the tundra is not damaged, and that only snow and ice are used as fill-in construction materials. Where accidental damage occurs, it is the responsibility of the party chief to record the location and to report the incident so that restoration can be conducted as necessary during the summer months.

In the Subarctic, where substantial vegetation may exist, preparing the survey line generally involves cutting trees to allow access for equipment as well as for the establishment of the base camp or for helipads. In all cases, clearing of vegetation should be kept to a minimum, consistent with aircraft safety requirements. The following environmental protection measures should be followed:

- limit access routes for vehicles, where practicable, to one-and-a-half vehicle widths, with occasional passing spaces;
- prohibit cutting or damage to rare and endangered species of trees and shrubs (identified in the EIA);
- leave larger trees standing by deviating the line or access route;
- deviate the line a short distance from any public roads to reduce visual impact and deter public access;
- cut leaning trees if they represent a safety hazard, and trim limbs to speed decay;
- hand-cut trees near water bodies to avoid damage to river banks;
- minimise removal of vegetation near water bodies to reduce surface run-off into the water;
- restrict ground contact when using mechanical equipment for clearing, so that the root stock of shrubs and grasses is left in place;
- on level ground, scatter trimmed branches;
- construct barriers on slopes to act as sediment traps and reduce erosion; and
- remove cut timber from routes of natural drainage.

During shot hole surveys, the depth of the hole and the amount of explosive should be reduced when the seismic line approaches streams or lakes in order to minimise impact on aquatic life. Shot holes should be backfilled with cuttings after the charge has been loaded to avoid blow-outs during detonation and to reduce the chance of later erosion.

Shot hole seismic survey techniques are preferable to Vibroseis, wherever practical, since this avoids extensive vegetation clearance, grading, and damage to tundra and taiga. If Vibroseis is deemed necessary, however, and receives the required authorisation, precautions must be taken to limit removal of vegetation to a minimum and to avoid damage to the surface layer. Additional precautions are necessary to minimise spillage of vibrator hydraulic oil in the event of equipment malfunction.

The recording operation is usually performed within a few days of the line being marked out, and generally results in very little disturbance. The crew at the back end of the line must ensure that no equipment is left on site as recording progresses, and that all non-permanent survey markers are recovered. Any waste generated by the recording personnel should be carried back to the camp for disposal. Further details of environmental protection measures for support operations and base camps are provided later in this Chapter ('Environmental Protection Measures for Exploration and Production Support Operations').

Little rehabilitation is usually required after seismic activities, except perhaps to tidy and remove all debris from survey lines and camps, repair any surface damage and restore and rehabilitate where shot holes have blown to the surface. Abandonment should follow the procedures discussed later in this Chapter ('Decommissioning and Reclamation').

Drilling

Site Selection

Selection of the surface drilling site is largely governed by the location of the potential hydrocarbon trap. The drilling site can often be positioned within a certain radius of the target location. Under special circumstances, for example if no drilling location is found which is outside a sensitive area, then directional (even horizontal) drilling can be carried out, thereby minimising disturbance in environmentally sensitive areas.

Within the constraints necessary to achieve the bottom target, selection of the drill site should be guided by the following pointers:

- avoid local communities;
- select site to minimise impact on fauna and flora;
- avoid areas with tourist interests;
- avoid protected and conservation areas;
- avoid locations with cultural or social importance;
- take into account topography, natural drainage and site run-off;
- choose the location as close as possible to established access routes, since frequently it is the opening up of access that leads to most environmental and social/cultural impact;
- minimise size of land take for drilling sites and base camps; and
- recognise that small and elongated shapes allow invasion by native species to occur more rapidly after decommissioning.

More specific considerations for support operations are provided in a later section, 'Environmental Protection Measures for the Main Phases of Exploration and Production Support Operations'.

Site Clearance

Clearing of a site will be required for a variety of purposes: roads, borrow sites, pipeline corridors, and for exploration and production sites. Recommended practices include the following:

- preserving the surface organic layer, particularly in areas with thaw-sensitive or erodible soils;
- salvaging displaced soils for use in site reclamation and restoration activities;
- notifying local people who use the natural resources of the site prior to operations;
- limiting work to the winter season if possible;
- inspecting any areas cleared in the summer to ensure fire prevention;
- clearing only to minimum width or area required;
- marking all areas to be cleared to minimise disturbance and for control purposes;
- cutting trees close to ground level, leaving stumps and roots in the ground to maintain soil cohesion;
- removing any obstructions to natural drainage caused by clearing and disposal; and
- maintaining natural topography, hydrology and stream flow to the maximum extent possible.

Spoil disposal procedures should be designed to minimise the area disturbed, maintain existing drainage and enhance the potential for reclamation. In general, the disposal of spoil materials should be conducted so that the cumulative thermal effect, due to the change at the surface and to changes in the active layer, has no degrading effect on the permafrost. Burning may be conducted if permitted by local authorities but, if possible, should not take place near a watercourse and should be restricted to the winter season. Monitoring programmes should be established to ensure that objectives are met.

Terrain Stabilisation

Two main options are available: a winter-only, temporary ice pad or an all-season structure. Winter operations using an ice pad location will cause the least surface impact and are recommended for exploration if drilling activities can be completed before the spring break-up.

Construction of an ice pad consists of packing snow and/or flooding the area with water to form an ice base, which can then support and distribute the weight of the drilling equipment. Insulation material combined with an impermeable liner should be placed below all tanks and equipment to reduce transfer of heat to the ice pad, and to contain any spilt fuel, chemicals or drilling fluid.

An all-season drill site requires an elevated pad thick enough to distribute the weight of the equipment and avoid heat transfer to the permafrost. Construction materials can include sand, gravel or rock combined with geotextiles, insulation material, matting and an impermeable liner. The use of clusters of wells on a single pad can significantly reduce adverse environmental impacts and costs by limiting unnecessary road and pad construction.

Drilling Operations

On-site company supervision of drilling activities and clear delegation of authority for environmental management are key elements for ensuring adherence to the environmental plan and compliance programme.

The following general operational considerations should be met:

- all fuel, chemical and mud mixing/treatment and power generation areas should be sealed in order to contain any spillages and facilitate clean up—good housekeeping is essential;
- closed mud systems and tanks are preferred, with a water separation/recycling package included in the mud handling facilities—if mud pits are used, however, they should be lined;
- the selection of drilling fluids should consider environmental aspects, including disposal—water based, non-saline muds are generally preferred from an environmental perspective, but the safety implications of their use should always be considered;
- protect watercourses and groundwater tables by proper design of site drainage systems—a fully sealed site is frequently the preferred option;
- ensure reservoir and wellbore fluids are isolated down-hole;
- insertion of casing through permafrost and groundwater zones with cement designed to set before freezing and to have a low heat of hydration;
- any portion of an annular space within a permafrost zone not protected by cement should be filled with a liquid treated to minimise corrosion and to have a freezing point below the minimum permafrost temperature to prevent internal freeze-back;
- ensure frozen gas hydrates are properly dealt with to minimise risk of flow-out by lightening hydrostatic pressure of drilling mud;
- well test fluids should be incinerated, re-injected or contained and disposed of correctly off-site; and
- personnel should be trained and aware of environmental operating procedures.

More specific considerations for treatment and handling of waste and hazardous materials are provided in 'Environmental Protection Measures for the Main Phases of Exploration and Production Support Operations'.

Blow-out prevention plans are designed to prevent an uncontrolled flow of reservoir formation or wellbore fluids from reaching the surface. Such plans should cover:

- procedures and equipment requirements to maintain hydrostatic pressure in the wellbore;
- characteristics, quantities and uses of drilling fluid and related equipment;
- training requirements for rig personnel; and
- contingency plans for a relief well if the original rig is disabled or destroyed by a blow-out.

Well Abandonment

A well should be abandoned in a stable and safe condition. For a dry hole, this includes sealing the well to the ground surface with cement plugs. The following actions should be considered:

- isolation of any known hydrocarbon zones to prevent fluid migration in or out of these zones;
- isolation of the open hole from the cased hole;
- plugging of all annulus spaces that are open to formations and that extend to the surface;
- placement of a surface plug below the ground surface in the smallest casing string that extends to the surface;
- removal of all equipment and debris;

- re-instatement of all removed soils;
- infill, stabilisation and restoration of mud pits;
- excavation and/or appropriate treatment and disposal of waste muds and cuttings; and
- breaking up the site surface to restore topography and drainage characteristics compatible with the surrounding natural contours.

During abandonment, the well cellar should be demolished and removed, pad material removed, and mud and borrow sites filled. The site should be restored as close as practically possible to its original condition, consistent with local requirements. Further information is provided in the section dealing specifically with 'Decommissioning and Reclamation'.

Production Facilities and Operations

Planning and Design for Development

During the design phase of a production facility, as in all other phases, efforts should focus on prevention and minimisation of adverse environmental effects rather than on their mitigation. Major issues to be addressed will have been identified in the EIA process, and the design phase will have incorporated mechanisms to avoid or mitigate environmental degradation. Production is a long-term activity and although many of the same criteria applied to the exploration and drilling phases are still relevant, the long-term view must be considered.

Additional site clearing and preparation will be required for production sites, centralised petroleum processing facilities, accommodation, additional access and pipelines. In design, consideration should be given to the difference in the size of areas required for centralising all facilities when compared with those required for individual wells. Facilities should have provisions for spill minimisation and sumps for site drains. Produced water treatment and gas flaring operations should be at the same site as the oil dehydration/desalting operations.

Clearance corridors for flowlines and pipelines should be minimised, and planned in parallel with access routes. Satellite stations and cluster well sites should be considered in order to minimise the number of flowlines.

Some additional measures include the use of directional or horizontal drilling, sequential use of wells or converting existing wells to secondary recovery. These measures reduce surface disturbances by reducing the physical size of production facilities, resulting in a smaller land take, more efficient use of materials and increased flexibility in the siting of facilities.

Production Operations

In the production phase, project personnel and construction contractors are replaced by permanent operations staff and service contractors. All personnel should be aware of and trained to meet the requirements of the environmental management scheme in place. During this phase, decisions must be made and reviewed on a regular basis concerning the maintenance, inspection and testing of production equipment to ensure safety of personnel, protection of the environment and efficiency of operations. Monitoring and regular audits are key mechanisms. In addition, contingency plans should be periodically reviewed and upgraded as required. Attention should also be given to environmental awareness and prevention, rather than clean-up alone.

Well maintenance activities (such as acidising, fracturing and solvent stimulation) should involve collection of spent treatment fluids in steel tanks, not open pits. These fluids should either be injected, reclaimed, chemically neutralised and combined with produced fluids, incinerated or disposed in other acceptable ways.

Provision should be made to prevent the accidental escape of produced fluids onto soil or into waterways by ensuring correct, contained site drainage, particularly during flowline maintenance. Chemical application should be centralised whenever possible, allowing the use of bulk storage tanks and reducing the number of drums on-site. Cluster wells and satellite stations are ideal places for such centralisation.

Decommissioning and Reclamation

Site decommissioning and reclamation is an important part of environmental management. The main purpose of reclamation is to rehabilitate a site to a condition that meets certain objectives. Discussions with appropriate authorities and/or local communities should have been held during the consultation phase to determine a preferred and feasible after-use. Such discussions should occur periodically through the life of the project to check that circumstances have not resulted in a change of opinion regarding the preferred after-use. Once final agreement has been reached a reclamation plan should be prepared. A number of reclamation options are available and are discussed below.

Reclamation Options

Options for reclamation include:

- rehabilitation to pre-development condition;
- partial rehabilitation;
- rehabilitation to an acceptable alternative condition; and
- no action.

In general reclamation should restore the site to its condition prior to oil and gas exploration or production. In some cases, however, no rehabilitation or partial rehabilitation may be more appropriate. For example, gravel mine sites in Alaska cannot be restored to their former condition but, if properly managed, could provide valuable habitat for a variety of species. In cases where operations have taken place in the vicinity of existing human settlements, there may be a local wish to retain roads or other useful infrastructure. Partial restoration would then involve the removal of all equipment and contaminants, but not the agreed infrastructure. The environmental consequences of retaining roads and therefore access into the area, however, need to be taken into consideration before such partial rehabilitation can be approved.

The selection of a particular option should include consideration of:

- the requirements of local authorities and local people;
- existing flora and fauna;
- nature and extent of any contamination;
- feasibility of revegetation options;
- time required for completion; and
- cost.

Implementation of reclamation options should take account of the following topics related to rehabilitation.

Physical Aspects of Reclamation

Protection of the underlying permafrost is critical. Long-term development and production facilities in the Arctic require a stable foundation to prevent subsidence and maintain thermal integrity of the permafrost. Operations in Canada and Alaska have used gravel extensively for this purpose, while in parts of Russia, only sand is readily available—but this can be structurally strengthened by various means.

Upon decommissioning, the removal of the substrate used in pad and road construction can present a number of stability and structural problems. If a pad is removed without providing suitable cover to the underlying substrate, thermal erosion can occur. Roadways and pads become an integral part of the permafrost system, with permafrost penetrating into the pad. Rehabilitation options should evaluate whether fill removal threatens local or regional drainage patterns, and whether the area of coverage is significant enough to require removal. If the fill material is to be removed, the rehabilitation technique employed should ensure that an appropriate level of artificial insulation is maintained, on-site, until vegetative cover is re-established.

Biological Methods of Reclamation

A number of reclamation methods for disturbed sites is available. Minimal treatment can consist of restoring soil layers to appropriate relative positions and allowing natural floral communities to develop from existing seed banks or other vegetative fragments in the soil. This method is best suited to communities with a good seed bank and low floristic diversity.

Reseeding is more complex, but more likely to be successful. Unfortunately, this method is often complicated by scarcity of local seed. Experiments in Alaska, Canada, Norway and Russia have shown that seeding with native grass species can be successful. Although it may give a temporary unnatural green appearance, it does appear to prevent significant permafrost thawing. Turfing can be highly effective since it uses the original vegetation to restore the disturbed area, but this assumes availability of sufficient quantities of turf. Another option, direct planting, is labour-intensive, but on a small scale can increase the representation of particular species. At no stage, however, should non-native species be introduced.

During any attempt to enhance vegetation cover on a site that has been barren or near barren for any length of time, the following issues will have to be evaluated on a site-specific, case by case basis:

- length of the growing season;
- seed availability and mix;
- percentage plant cover required over an established time period;
- desired species and habitat diversity;
- fertilization requirements (surface organic matter, mulches, commercial fertilizers);
- moisture availability and manipulation (snow fences, irrigation channels); and
- overall compatibility of the site with the surrounding region.

Post-project monitoring is required to assess whether or not rehabilitation has been successful. Advice is given in the following sections on rehabilitation in relation to the main phases of oil and gas development.

Seismic Activities

The potential effects of seismic surveying should be minimal and should have been mitigated through careful planning, monitoring and waste management. As previously mentioned (see 'Exploration Surveys'), practical, expeditious steps should be taken at the end of the survey to restore any damage created by the crew that has not been attended to during the normal course of the operation. Monitoring should be carried out to ensure that restoration and reclamation is successful.

Exploration Drilling and Production Activities

Rehabilitation of the environment following oil and gas exploration and production activities may take longer than the time needed for areas affected by seismic activities. Gravel, sand, timber, geotextiles or some combination of these is used in site preparation as fill, to insulate permafrost from facilities. Vegetation directly affected by cover or impoundments, or indirectly affected by dust and vehicle traffic, may require rehabilitation and the site analysis should include:

- consideration of ecological and social needs/objectives;
- identification of key habitats and species;
- evaluation of the carrying capacity and species diversity of the site;
- an assessment of ecosystem processes; and
- evaluation of proposed treatment and techniques.

Rehabilitation can include the following methods:

- slope contouring and grading;
- replacement of soil and surface organic layer;
- revegetation through seeding or natural recolonisation;
- maintenance of thermal stability and protection of permafrost;
- maintaining or restoring drainage patterns and hydrology; and
- preventing erosion and riverbank slumping.

Site Decommissioning and Demolition

At the time of closure, prior to commencing any decommissioning or demolition, a planned programme of site clearance should be formulated. All cement, steel or wood installations not being left for others should be removed to at least 1m below ground level, except in special circumstances, or as required by legislation. All pits, cellars, and holes will be cleared and filled to ground level, and any oil or otherwise contaminated soil must be removed and properly disposed. Wells will be plugged and abandoned in a stable and safe condition, in accordance with appropriate industry standards and local regulations.

Roads, well or facility sites designated for decommissioning will have all paving and man-made structures removed to a sufficient depth to allow soil replacement and revegetation. The surface will be contoured for drainage and control of erosion, and restored topographically to that of the surrounding landscape.

Environmental impacts can arise directly from the demolition and decontamination work, including waste disposal, noise and disturbance, and off-site vehicle movements, potentially damaging surface vegetation. Most adverse impacts can be mitigated by conducting activities during the winter when the active layer is frozen (and surface disturbance is minimal) and when migratory species are absent.

Potential Contamination

A study should be conducted to determine potential sites of contamination. Oil and chemical contaminants are present in:

- waste disposal areas;
- drums;
- some containment ponds;
- storage tanks;
- pipelines and flowlines; and
- chemical storage areas.

Experienced operational personnel are essential in identifying potential areas of contamination.

The proposed treatment of contaminants can be classified as follows:

- materials to remain on-site;
- moderately contaminated materials for standard disposal; and

- heavily contaminated materials for specialist waste disposal.

Areas where soil or substrate is suspected of being contaminated may require sampling and analysis to determine the level and extent of contamination, and therefore its health and environmental risk, including:

- human hazard from toxic and potentially carcinogenic chemicals through skin contact, ingestion and/or inhalation;
- hazards to flora and fauna from chemicals (chlorides, heavy metals, nutrient depletion by leaching or chelation, extreme pH and hydrocarbons, etc.);
- contamination of water bodies (tarry wastes, oils and condensates, etc.);
- explosive hazard from volatile emissions (petroleum product vapours, methane, etc.);
- physical hazard from infilled unstable ground (landfill, deep foundations, deep storage tanks, surface and deep mining, etc.); and
- mobility, persistence and bio-availability of contaminants.

Environmental Protection Measures for the Human Environment

Social and Cultural Aspects

During the consultation and EIA phases, a full evaluation of social, cultural and economic impacts will have been completed. Areas of particular concern to local authorities, communities and individuals will have been identified, and the operating company must ensure that the predicted adverse effects resulting from their activities are avoided, minimised or mitigated. In particular, the following protection measures should be considered:

- avoid disturbance of existing land and resource use patterns, and rights of access;
- control access to and exploitation of the local resource base by all categories of workers, including contractors;
- control immigration and local migration;
- initiate actions to assist local peoples with the consequences of development;
- avoid conflicts with local or regional development and protection plans and conservation strategies;
- where desirable or required, isolate non-local work force within defined boundaries and access routes; and
- make infrastructure available to local communities where possible and required (housing, medical, educational).

Economic Aspects

Rapid and undesirable changes to local socio-economic systems can arise from development. The EIA Report will have identified possible significant adverse and beneficial socio-economic impacts with accompanying mitigation measures. It is important to implement these measures to manage such changes as increasing income differentials and inflation. Specialist advice may be needed to ensure that the mitigation measures achieve their objectives.

Personnel recruitment and training programmes can be implemented depending on the desires of the local people to participate in such activities. It may be a requirement of the exploration licence that local labour is employed.

The workforce should be organised in order to minimise any conflicts between different groups of local peoples and to protect the culture of the local workforce. Working practices, and the structure, timing and nature of the non-local workforce and its accommodation must also be considered. Planning and training should encourage avoidance of potential problems that may be associated with socio-economic or cultural changes.

Workforce Aspects

In all operations, starting with surveys and extending through decommissioning and after use, the prohibition on hunting, disturbing and feeding wildlife by company and contract employees should be strictly enforced. Controls should apply to leisure and off-duty periods as well as working periods. The non-local company workforce should keep within the defined boundary of the site, to the agreed access routes and, when necessary, be segregated from local communities.

Environmental Protection Measures for Exploration and Production Support Operations

Transportation and Infrastructure

Environmental protection during the construction and maintenance of logistic and transportation facilities can be implemented through a variety of measures. The following sections provide a range of specific recommendations for vehicles, roads, pipelines, base camps and other aspects of oil field infrastructure.

Transportation

Transportation in Arctic and Subarctic regions should, wherever possible, make use of existing infrastructure such as roads, helipads, airstrips or boat/barge facilities. Issues to consider when evaluating transportation options include:

- length of time a transportation option is required during construction and operation phases;
- potential significant environmental impacts due to the option and route under consideration (for example, impeding wildlife movements and altering surface drainage, aircraft noise, use of waterways); and
- potential of option to alter surface conditions, topography and affect hydrology.

The use of helicopters for the transportation of men and equipment will usually be preferable from an environmental perspective to road building. However, the hazards incurred through flight operations must also be considered. Where aircraft and helicopters are used, routes must be selected and specified to avoid sensitive areas so that wildlife is not disturbed. In such sensitive areas a reasonable minimum operating height should be established.

Vehicles

Most potential adverse effects of vehicles (including mobile camps) can be avoided. Specific measures include:

- ensure vehicles keep to 'all-year' or snow/ice roads;
- check vehicles for oil or fuel leaks;
- report and collect spillages for appropriate disposal;
- avoid breaking through snow cover, or if vehicles break through, note location of areas for restoration of damaged zones;
- avoid excessive compaction of underlying ground surface, especially tundra; and
- avoid sharp turns with tracked vehicles.

For all vehicle uses, the effects of crossing streams and rivers should be evaluated and mitigated where possible. Potential environmental impacts can be reduced with the following measures:

- minimise number of crossings;
- avoid activities during sensitive ecological periods, such as fish spawning and migration times;
- avoid crossings in areas where banks and bottoms are unstable;
- construct crossings perpendicular to the stream course and at a single location;
- restrict travel over main channels;
- set access roads back from streams except at crossings;

- minimise duration of in-stream activity and changes in water quality, flow and level, or in the shape of the channel or bank;
- take extra care when traversing steep slopes to minimise additional erosion; and
- use temporary bridges.

Where ice travel is required, the following guidelines are recommended:
- use ice bridges in cases of numerous crossings of fish wintering areas;
- construct ice bridges to prevent full-depth freezing of the waterbody;
- construct bridges high enough to permit free passage of ice and water;
- install culverts in compacted snow; and
- remove or breach all bridges and snow fills at stream crossings prior to spring breakup.

When refuelling vehicles for any type of operation, potential adverse environmental effects can be reduced by implementing the following measures:
- refuel vehicles under constant supervision and with care to ensure that no spills occur;
- equip vehicles with absorbent materials, drip trays, shovels and disposal bags;
- restrict refuelling to specific areas within floodplains; and
- fuel and oil supplies should be properly sealed, labelled and stored with secondary containment.

Roads

If the construction of new roads is necessary, the following environmental protection measures should be implemented:
- proper route selection to avoid environmentally, socially and culturally sensitive areas;
- ensure right of way agreements are negotiated in advance;
- minimise interference with erosion control;
- minimise introduction of sediment into watercourses;
- minimise interference with natural drainage patterns;
- leave the surface organic layer in place during construction;
- keep cuts and grading to a minimum;
- leave as many stumps and roots in the ground as possible to maintain soil cohesion and to facilitate regrowth; and
- adequately contour fill sections to minimise erosion.

Permanent roads should be surfaced with gravel or a suitable substrate material to protect the permafrost from thawing with subsequent differential settlement. In some situations it may be appropriate to water the roads to minimise dust. Brine water should not be used for this purpose. Equipment or vehicles should not be operated overland (except in an emergency), if the ground surface cannot fully support the equipment or vehicles without rutting. Use of ice roads in Arctic and some Subarctic regions during winter can reduce surface impact, but winter roads should not be used in summer unless they have been upgraded. Seasonal limitations for using ice roads should be clearly stipulated and traffic should cease before the spring melt.

Airstrips and Waterways

Airstrips should be located adjacent to base camps, taking into account safety considerations and the need to minimise the clearing of vegetation. During the design phase, an estimate should be made of the likely duration of use for the airstrip, natural obstacles and other safety considerations, potential noise effects on people and wildlife, and of the potential of proposed flight routes to interfere with waterfowl migrations, other sensitive wildlife features or native subsistence use of wildlife resources.

If waterways are to be used during the operation (for example, by barges, boats or air-cushioned vehicles) it is necessary to evaluate the availability of navigable routes, the seasons when such routes are available, any obstacles or hazards that could be present, and to assess any environmental issues arising prior to route selection and initialisation.

Borrow Sites

Borrow sites are often required as a source of soil, sand or gravel, for a variety of construction, maintenance and decommissioning activities. Some principal environmental protection measures for these sites include:

- careful site selection to avoid environmentally, socially and culturally sensitive areas;
- selecting acceptable excavation methods and conducting excavation to minimise loss and disruption of vegetation and wildlife habitat, potential terrain degradation through erosion and thawing, and alteration of drainage patterns;
- using existing borrow sites and associated roads, trails and cutlines in preference to developing new sites;
- constructing berms to minimise drainage disruption, and to form a buffer between waterways and the borrow site;
- marking the borrow development area, stockpile area and limits of clearing, to prevent over-extension of the borrow site;
- salvaging and properly storing soils for use in site reclamation; and
- confining all vehicle maintenance to a particular site in the pit, and ensuring compliance with 'Guidelines on Vehicles' (see above).

Construction

In general, construction of facilities, roads, camps and pipelines should be kept to the minimum necessary for operations. Structures in the Arctic and northern Subarctic are generally enclosed within modules for protection from extreme climatic effects.

General environmental protection recommendations include:

- selecting a site to avoid environmentally, socially and culturally sensitive areas;
- minimising the surface area without compromising safety;
- avoiding alteration of drainage patterns and hydrology;
- maintaining the thermal integrity of permafrost;
- maintaining existing vegetation cover as much as possible;
- incorporating abandonment in the planning and design phase; and
- considering the need for future expansion.

All construction operations should be carefully timed to minimise potential adverse impacts on vegetation and wildlife. Often this means conducting operations during the winter when the active layer of permafrost is frozen, thus allowing travel whilst minimising the risk of surface damage. In addition, much wildlife is absent during winter, thereby significantly reducing the opportunity of disturbance. Assessments must be made, however, to identify the sensitivity of remaining species.

Base Camps

Temporary base camps are required for seismic exploration and exploratory drilling. Winter seismic camps in the Arctic consist of several 'trains' of sled-mounted trailers, which are often moved daily to keep pace with the progress of the recording operation. At other times of the year, and in forested areas, the camp is moved less frequently. If the base camp is temporary—for the winter season alone—an ice pad should be considered in preference to a base of gravel or sand, as the former quickly disappears in the spring thaw. Care must be taken to remove all equipment and debris before the thaw sets in. Appropriate provision must be made for the collection, treatment and disposal of all waste.

In contrast with temporary camps, greater consideration must be given to the planning of long-term sites, particularly with regard to location, size and construction. Location should be close to the expected operation in order to reduce the need for access roads. If the most convenient location is environmentally sensitive, however, a more distant location should be considered. The base camp is generally built elsewhere, transported and assembled on-site.

The following environmental protection measures apply to both temporary and permanent base camp operations:

- select site to minimise impact on wildlife and local communities (see 'Site Selection');
- minimise land take;
- preserve ground vegetation where possible and conserve organic surface layer for restoration purposes (see 'Site Clearance');
- take into account local topography, natural drainage and run-off;
- select and construct site with abandonment in mind, particularly related to length of time used;
- ensure proper and adequate waste disposal considerations (see 'Waste Management');
- ensure fuel and chemical storage is isolated by impermeable bunding or drip trays;
- at abandonment, remove equipment, structures and debris, and restore site to its natural condition; and
- manage activities of workforce on- and off-duty to avoid environmental/social disturbance.

Water Supply

Strict environmental protection measures will be necessary in the abstraction, transport, use and discharge of drinking water. These measures include:

- maintenance of an environmentally acceptable base flow or level in water courses;
- minimisation of the effects of water withdrawal on the overall hydrology, for example, existing drainage patterns, and on the overall ecosystem including fish populations and habitats;
- preventing fish from entering the pipes; and
- routine discharge monitoring.

Pipelines

Clearance of vegetation for pipelines should be minimised whenever possible. The use of ice roads for construction in northern regions can reduce direct surface and indirect impacts on wildlife and habitats. For pipelines, as with access roads, a right-of-way agreement may be required.

Specific protection measures should include:

- selecting routes and siting of facilities to avoid environmentally, socially or culturally sensitive areas;
- constructing the minimum number of pipelines using common corridors for transportation, power transmission and communications;
- avoiding interruption of the flow of surface water or the movement of wildlife;
- installing sufficient bridges or culverts along roads to maintain existing drainage patterns;
- burying or raising pipelines to minimise interference with wildlife and maintain the thermal integrity of permafrost;
- avoiding damage to plant and animal resources;
- reconstructing, repairing or restoring structures, property or wildlife habitat along the right-of-way;
- prohibiting the use of equipment or vehicles overland where the ground surface is subject to rutting;

- avoiding operation of vehicles and equipment in waterbodies;
- ensuring that emissions from equipment, installations and incineration meet applicable air quality standards;
- ensuring the proper disposal of hydrotest water;
- ensuring proper restoration and aftercare measures are applied, and monitor subsequent success; and
- monitoring the physical stability of the pipeline support.

Maintenance

Once in operation, oil and gas facilities and the associated infrastructure require a variety of occasional maintenance activities. These include maintenance of roads and access, buildings, facilities and structures, pipelines, vehicles and aircraft, and various maintenance operations to the wells. Potential environmental impacts should be considered during the preliminary and full EIA.

Specific protection measures should include:

- disposal of spent treatment fluids from well maintenance (for example, acidising, fracturing, solvent stimulation chemicals);
- disposal of produced fluids during process equipment and flowline maintenance;
- dust control;
- avoidance of drainage interference;
- erosion control; and
- safe waste handling and disposal.

Hazardous Materials

Various hazardous materials are used or generated in the course of oil and gas operations. To ensure adequate protection of the environment, hazardous materials should be used only by personnel who are trained and qualified in the handling of such materials, and only in accordance with manufacturers' instructions and appropriate host country regulations. Operating companies should initiate and maintain controlled monitoring regimes for chemicals and additive use and discharge, and ensure compliance with existing statutory requirements. Under the environmental management system, specific procedures should be developed to ensure correct practice and disposal of hazardous materials.

Specific environmental protection measures should ensure that:

- transportation of dangerous or hazardous goods follow all appropriate regulations;
- all vehicles carry the materials necessary to clean up small leaks and spills (shovels, bags and absorbent materials);
- a contingency plan is established to prescribe measures for preventing spillage and to describe procedures to be followed in the event of a spill;
- all fuels are stored in bunded tanks, adequately protected from vehicle collision, rust and corrosion, and appropriately marked;
- all chemicals and hazardous materials are to be stored in secure locations which will not be liable to flooding;
- secondary containment, of appropriate volume, is to be installed;
- adequate waste disposal methods are applied, such as chemical neutralisation, incineration (where permitted), or waste may be returned to the supplier; and
- personnel are fully trained in use and disposal of hazardous materials.

Waste Management

Waste Handling

Waste management and minimisation should be a priority. Full evaluation of waste streams, treatment technologies and the potential environmental impacts of waste should be conducted during the EIA process and in the design phase. Proper consideration will result in more advanced designs, more efficient operations and improved environmental protection. Consideration should also be given to recycling/re-use, particularly of more hazardous substances. Guidance in methods and options for treatment of exploration and production wastes are summarised in Figure 5. Statutory permits are, however, required for many of the options cited.

The correct disposal option for a particular kind of waste will be dependent on both the chemical and physical properties of the waste, on the site-specific environmental conditions, and on the statutory regulations, permits and emission standards in force. When there are no statutory controls, including classification and reporting requirements for chemical and additive usage, operating companies should develop and maintain their own control regimes.

Arctic and Subarctic areas pose special challenges to implementing cost-effective, prudent disposal practices. Waste treatment facilities are generally not readily available in these areas, so operating companies must use processes that can be readily designed and implemented in the field, such as incineration or disposal of wastes off-site at approved facilities. In the absence of waste handling facilities, a major concern should be the prevention of risk to human health and the impairment of the environment. Improper waste disposal in remote areas can pose significant long-term impacts to the environment requiring costly corrective action. Assessment of disposal options must ensure protection of permafrost, vegetation, groundwater and wildlife.

Effluents and Emissions

When effluents have been treated and there is a residue, for example oil, sludge or other solids, then they should be disposed of properly, as described below in the section on 'Production and Associated Wastes'. No effluent should be directly discharged into the environment without a full assessment and proper treatment. This can range from simple settling to complex chemical flocculation. Effluents should meet standards designed to limit negative impact on the environment. Treatment and disposal options include, but are not restricted to:

- sewage effluents can be treated using mobile biological treatment systems or permeable pits (outside of flooded areas);
- wash water and process water can be treated biologically or chemically to prevent introduction of bacterial or pathogenic organisms into the environment;
- grey water can be filtered and discharged to the land surface; and
- site drainage should include separators or interceptors to remove oily waste before discharge.

Drilling Wastes

Drilling operations will produce effluents from run-off, wash water, process water, excess drilling fluids and drill cuttings, and fluids associated with well treatments. The principal wastes from drilling operations are, however, spent drilling muds and cuttings. It is important that waste management considerations are integrated into the selection of drilling fluids and components. A wide variety of chemicals and additives are used in drilling and production operations, and the combinations vary greatly, depending on the activity being undertaken. Prior to initiating operations, attention should be paid to the proposed make up of drilling fluid. In addition, proposed use of chemicals in the production process should be carefully examined to assess the potential effects of waste or accidental discharges. Considerations should include chemical composition, concentration, flow rate, acute toxicity, bio-accumulation and degradation potential, and ecological and other chronic effects.

Waste disposal facilities will generally not be available, and drilling mud disposal must be managed on-site. The methods for disposal should be based on a careful assessment of the mud formulation and environmental conditions in disposal areas. Where water-based muds are employed, additives containing oil, heavy metals which are in a form that could be taken up by organisms, or other bio-accumulating, persistent and acutely toxic substances should be controlled and avoided where possible. This is of particular importance if cuttings with adhered mud were to be disposed on land or to be used for unpaved road maintenance. Salt content is the principle concern for disposal techniques involving land application, since low concentrations can alter soil structure, kill vegetation, and hinder restoration. If land application techniques are considered, both the properties of the waste itself and environmental conditions at the proposed disposal site should be carefully examined to determine acceptability.

From both an environmental and cost perspective, water-based muds are normally the preferred option for drilling. Sometimes, however, drilling or geological conditions dictate the use of oil-based muds. If the latter are used, precautions should be taken to prevent spills. Steel tanks or other provisions for mud and cuttings collection that prevent uncontrolled surface or sub-surface contact should be in place. Oil- and water-based muds with high salt content present a greater concern for disposal. Disposal options include re-injection, washing and treatment, and removal off-site for solidification and burial. For all disposal options, some pre-treatment of mud or cuttings may be necessary; chemical, mechanical, thermal or biological processes may be appropriate for this purpose.

Mud pits, if used, should be lined with an impermeable layer and built with sufficient capacity to hold the spent muds, cuttings and any run-off water. The mud pit can be constructed either by raising a bund (which also prevents the entry of run-off water from the well site and adjacent areas), or by digging a pit in the permafrost. Construction should be assessed on a site-by-site basis to determine the best method of lining the pit to prevent fluid seepage. Monitoring should be undertaken to ensure that any seepage is detected and that appropriate corrective action is taken if necessary. Water that accumulates in the pit as a result of snow melt in the spring should be removed to reduce the hydraulic head in the pit. Spent muds can often be reconditioned and recycled. Downhole injection and stabilised burial at approved sites are potential alternatives.

Leak minimisation should be incorporated into facility design and maintenance procedures, for example:

- provision of oil sumps for all drains to prevent contamination of rainwater drainage;
- use of drip pans as needed; and
- separation of drainage systems, for example, rainwater from contaminated zones.

Production and Associated Wastes

Well tests conducted during exploration/appraisal drilling can generate oil, gas and water. Any gas produced during testing can be flared or, in an emergency, vented to the atmosphere. When present, produced oil can be stored in tanks and subsequently used or incinerated on-site, flared, re-injected or sold. Leak minimisation, containment bunds or drip pans should be incorporated into the design phase of permanent operations facilities.

Injection is a method of handling waste streams that require special attention. Injection can range from re-injection of produced water into formations for pressure maintenance or enhanced recovery purposes, to grinding and injection of drill cuttings into a permeable zone. The former would be classified as a 're-use' or recycling alternative, while the latter is more readily defined as a waste disposal method. In any case, injection requires attention and safeguards given to the prevention of contamination of usable aquifers or breaches to the surface through proper design, construction, operation, maintenance and monitoring of injection facilities. These items should be covered in the overall waste management plans.

Produced water is the principal waste arising from the production of oil and gas. It contains variable quantities of hydrocarbons and inorganic salts, and may also contain metals and other constituents from the formation and well treatment operations. Produced water can be treated to remove oil and solids and re-injected for secondary recovery operations or for disposal purposes.

All produced water effluents should be treated to reduce oil content to a level that will not cause environmental damage. The final composition of produced water and the dilution potential of the receiving body will determine whether its discharge or re-injection will be appropriate. Re-injection may be the only viable disposal option in some cases, as long as permafrost and ground water protection is assured. Well treatment fluids need special care: heavy brines and acids can be filtered and recycled, spent acids and workover fluids will need to be chemically neutralised prior to disposal off-site at approved or appropriate locations.

Organic wastes such as paper, wood, oily rags, non-metallic oil filters, absorbent pads, kitchen wastes and other flammable materials can be disposed of on-site using a low-emission incinerator. Inorganic industrial wastes, including discarded wires, scrap metals, paint cans and plastics should be recycled or disposed at approved or appropriate locations. Where re-use is not possible, waste drums should be sent off-site as scrap or for proper disposal.

Certain production chemicals, such as descalers (acids or converters), biocides and fungicides, require special disposal techniques, including chemical neutralisation or incineration. Unused chemicals and hazardous materials should be returned to the supplier.

Wastes from tanks, gas facilities and vessel bottoms, as well as oil-contaminated soils should be evaluated for oil, salt and heavy metal content to determine disposal options. As with drilling fluids both the character of the specific waste and the environment at the potential disposal site should be examined carefully. Other options include reclamation, re-injection, incineration, solidification and stabilisation.

Where authority is granted for waste burial, particular care must be taken to contain the wastes to avoid seepage and loss especially in permafrost areas and those prone to flooding. In areas where permafrost is near the surface, burial in the upper layer of soil can result in exposure of the permafrost to heat transfer, resulting in melting, free water flow and subsidence. Where permafrost is deeper it can be affected by seepage of waste material through the soil.

Emissions to Air

Proper design considerations and correct engineering should minimise gas emissions and flaring through appropriate control methods. Black smoke, which results from gas flares, may occur occasionally during high pressure operations. Facilities should, in any case, operate to minimise such events. When the volume of gas produced is significantly larger than field operational requirements, an assessment should be made whether there are any local markets for the gas. If none are available, gas re-injection should be evaluated as an alternative to flaring or venting.

Operations should be monitored to ensure statutory compliance, to meet the operators' standards and to ensure that the environment is not adversely affected. The limits for ozone-depleting gases (CFCs, HCFs and halons) established by the Montreal Protocol, and subsequent amendments, will ban the production of these materials in the future. Some of these materials will be approved for essential uses, such as the use of halons in fire suppressants and extinguishers in enclosed facilities. Operators must, however, evaluate alternative designs, operational methods, materials and approaches, such as inert gas blankets and sprinklers.

Figure 6 provides a summary of environmental protection measures for important phases and activities in the development process for an oil/gas field.

Contingency Planning and Emergency Response Management

Potential Emergencies

Even with the implementation of correct procedures and personnel training, accidents can occur. All operators should be prepared to deal with crises that threaten people, the environment or property. Potential emergencies include:

- spillage of fuel, oil, gas, chemicals or hazardous materials;
- oil or gas well blow-out;
- natural disasters (earthquakes, for example);
- explosions; and
- fires (vegetation and facility).

All emergency response activities should be directed to saving life, protecting the environment and minimising property damage.

Contingency Planning

Emergencies can best be managed by appropriate contingency planning and response; preparedness is based on conducting the following actions:

- identifying and recognising significant health, safety, environmental and security risks;
- planning and implementing actions to manage risks;
- reviewing and testing preparedness and effectiveness on a regular basis; and
- training personnel in response requirements.

For example, the section of the drilling plan which addresses blow-out risk ('Drilling Operations') should address contingency planning for drilling operations.

Careful contingency planning should help establish an emergency response system, including the following:

- identification of primary objectives;
- establishment of steps to be taken;
- establishment of reporting, communications and security procedures;
- training of response personnel;
- provision and maintenance of necessary equipment, including housing, food, water, sanitary facilities, fuel and decontamination facilities;
- identification and implementation of a notification and evacuation plan for on-site personnel, local residents, transients and other operators;
- documentation of all actions; and
- normalisation of operations.

Contingency planning should facilitate the rapid mobilisation and effective use of manpower and equipment necessary to carry out and support emergency response operations. Exercises and training should be conducted regularly to ensure preparedness. Environmental risk assessment and appropriate planning activities should be coordinated with updated strategic and operational goals. Communications should be maintained with appropriate authorities, local communities, media, business units, neighbouring operators, contractors, employees and families. By providing a structure and allowing flexibility, such a system can be adapted to any type of incident or operating environment.

Oil Spill Response

Site design should incorporate adequate interception systems to minimise damage from minor incidents and fugitive sources. Although the risk of major oil spills from properly managed operations is low, maintaining effective containment and clean-up measures are essential.

All activities, including seismic studies and exploration drilling, and sites such as camps, pipelines and transportation routes, should have adequate contingency plans in place to deal with spills, not only of oil but also fuel, chemicals and hazardous materials. Plans should be based upon the risk, location, volume and type of potential spill. The type of spill response equipment, manpower and organisation required to effectively respond to incidents, both large and small, should be included in the plan, together with the identification and protection of vulnerable and sensitive areas.

The plan should clearly identify the actions necessary in the event of a spill: the communications network, the organisation structure and the individual responsibilities of key emergency personnel, together with the procedures for reporting to the relevant authorities. The plan should deal with disposal of recovered material, contaminated waste and debris generated by the spill, and the transportation and housing of support personnel brought in for clean-up activities. The plan must be exercised and reviewed periodically to ensure its adequacy, and personnel trained to be competent in fulfilling their expected roles and responsibilities.

Oil spills can enter streams and rivers, although the presence of surface water is limited seasonally in the Arctic. The presence of groundwater should be a main concern in relation to spills in the Subarctic. In northern regions, even if appropriate technology is available, oil spill counter measures may be complicated by extremely cold temperatures, the presence of ice, long periods of darkness, intense storms and lack of support facilities. The movement, velocity and stability of the ice can also be a factor, as can water temperature, current strength and wind speed.

For an oil spill emergency, both on land and in freshwater, typical response activities should include the following, as determined by the specific incident characteristics:

- incident briefing and appropriate prompt notifications to relevant bodies;
- detailed site assessment, including identification and characterisation of sensitive areas;
- source control or stabilisation, including mechanical containment, recovery and storage, care in use of dispersants, *in-situ* burning and nearshore containment and recovery;
- shoreline protection (booming, trapping and collection) and shoreline clean-up (debris removal, washing, flushing and rehabilitation);
- wildlife deterrence and rehabilitation;
- solid waste handling and disposal; and
- demobilisation and site restoration.

Equipment resources that should be available for oil spill response might include: landing craft, barges, tugs, fishing vessels, dredges, igniters, lightering vessels and pumps, tenders, helicopters, fixed-wing aircraft, booms, stationary skimmers, advancing skimmers, sorbents, earth-moving equipment, pressure washers, vacuum trucks and waste storage containers. If chemical dispersants are used, it is important to choose those that are effective, have low toxicity, that do not have a tendency to bio-accumulate and that are biodegradable. Prior approval for their use in such

Figure 6. Summary of Environmental Protection Measures

<table>
<tr><td>GENERAL</td><td>
■ Awareness and avoidance of protected areas
■ Assessment of general and site-specific environmental sensitivities
■ Minimisation of land take for facilities and camps
■ Avoidance of thermokarst:
● maintaining the protective vegetation cover;
● insulating all temporary or permanent structures by means of ice, snow, sand or gravel pads;
● minimising emission of effluents
■ Preservation of surface hydrology and topography
■ Avoidance of vehicle use on exposed tundra, especially during the summer
■ Consideration of site decommissioning, reclamation and restoration in the early planning and design stages
■ Seal and bund chemical and fuel storage
■ Maintain adequate oil spill contingency
</td></tr>
<tr><td>ACCESS AND INFRASTRUCTURE</td><td>
■ Minimisation of 'foot print'
■ Minimise adverse environmental impacts of:
● temporary operations by:
- conducting winter operations, limiting activities outside gravel or sand pads during the summer;
- use of ice/snow pads, roads and bridges particularly in permafrost;
- use of helicopters within safety limits instead of ground transport;
- limiting clearance of vegetation
● permanent features by:
- limiting clearance of vegetation;
- siting to minimise impacts on indigenous peoples, water resources, wildlife, vegetation and landscape;
- concentrating roads and pipelines in single corridors
</td></tr>
<tr><td>DRILLING</td><td>
■ Cluster drilling to reduce 'foot print'
■ Avoid use of mud pits. Where necessary, ensure impermeable liners are used
</td></tr>
</table>

Figure 6. Summary of Environmental Protection Measures (continued)	
DEVELOPMENT AND PRODUCTION	■ Use of winter roads for construction and other one-time operations ■ Minimisation of emissions to air ■ Operation to minimise impacts on indigenous peoples, water resources, wildlife, vegetation and landscape
WASTE MANAGEMENT	■ Evaluation and minimisation of waste streams at planning stage of project to ensure minimal adverse impact on environment ■ Evaluation of environmental costs and benefits for a variety of options
DECOMMISSIONING AND RECLAMATION	■ Definition of objectives of future land-use at the early planning stage ■ Clean-up of any contamination ■ Proper abandonment of wells and sites ■ Proper disposal of all wastes ■ Restoration of site to its original condition, encourage natural re-vegetation ■ Severance, blockage or removal of access roads if appropriate

emergencies should be obtained where there is such a statutory requirement. Manpower resources should be identified in the contingency plan.

Detailed Incident Assessment

A detailed incident assessment and reporting process should be implemented. The process should review, analyse and document the situation, including conditions, progress and prognosis, and should focus on the following:

- status and safety of personnel;
- status of facility and source;
- site assessment;
- weather conditions (light, air and water temperatures, wind speed and direction, and tides, if appropriate);
- potential impact zone, including habitat and ecosystem types, sensitive areas and wildlife concentrations;
- identification of sensitive areas for indigenous peoples;
- nature, status and effectiveness of response efforts and additional potential responses;
- response priorities;

- equipment and manpower requirements;
- logistics and support requirements; and
- public affairs considerations.

All appropriate authorities should be informed of the location of the environmental hazard, status of response and planned operations. The continued consideration of health and safety concerns throughout the response operations should be ensured. Environmental concerns should be prioritised to determine the most efficient procedures. Examples of priority considerations include:

- source control versus containment or recovery operations;
- protection of unaffected resources versus placement of equipment in the spill zone; and
- evaluation of differential sensitivities of regions and species.

Glossary of Terms

abandon (a well)	To cease work on a well and seal it with cement plugs.
active layer	The top layer of the ground, above the permafrost table, that thaws each summer and refreezes each winter.
aftercare	A management programme which follows decommissioning and restoration of a site to ensure full restoration to a predetermined after-use.
annular space	The space surrounding a cylindrical object within a cylinder; the space around a pipe in a wellbore, the outer wall of which may be the wall of either the borehole or the casing, sometimes termed the annulus.
appraisal well	A well drilled after a hydrocarbon discovery to delineate the extent of a reservoir, and to test its productivity and properties.
Arctic	Within the context of these Guidelines, Arctic is used as a generic term which encompasses both geographical and ecological zones.
bentonite	A naturally occurring clay which is often a major constituent of drilling muds.
berm	A raised, narrow ridge.
blow-out	The uncontrolled flow of gas, oil or other well fluids into the atmosphere which occurs when formation pressure exceeds the pressure applied to it by the column of drilling fluid.
boreal forest	The circumpolar forest of high latitudes composed primarily of coniferous trees such as spruce, but also including large tracts of deciduous trees such as aspen, birch and willow.
borehole	See wellbore.
borrow site	Area from where material required in development has been taken, e.g., soil, gravel or sand source.
casing	Steel tube which is cemented into an oil well to prevent the collapse of the well, the flow of fluids between formations, possible contamination of groundwater, and to protect permafrost layers.
chelation	A naturally occurring mechanism in soils which involves a reaction between a metallic ion and an organic molecule. The process removes heavy metal ions that are in solution from where they may be directly toxic to plants or may interfere with the uptake of essential nutrients.
crude oil	Oil produced from a reservoir after any associated gas and/or water has been removed, often simply referred to as 'crude'.
cuttings	The fragments of rock dislodged by the drill bit and brought to the surface in the drilling mud.
development well	Well drilled in a formation for the purpose of producing oil and gas. Also called a production well.
deviated or directional drilling	Controlled progressive deviation of a well away from the vertical to reach different parts of a reservoir from a single drilling site.
drilling muds	Specialised fluid made up of a mixture of clays, water (and sometimes oil) and chemicals, which is pumped down a well during drilling operations to lubricate the system, remove cuttings and control pressure.
drilling rig	The complete machinery and structures needed for drilling a well (the most visible component being the mast or derrick).
dry hole	A well drilled without finding gas or oil in commercial quantities.
effluents	Liquid waste materials discharged from the operations.

exploration	The search for reservoirs of oil and gas, which includes aerial and geophysical surveys, geological studies, core testing and drilling of wells.
exploration drilling	Drilling carried out to determine whether hydrocarbons are present in a particular area or geological structure, or to learn more about subsurface structures.
extraction	The process of separating one material from another.
field	Geographical area in which a number of oil or gas wells produce from a continuous reservoir.
flaring	Controlled disposal of surplus combustible vapours by igniting them in the atmosphere.
flowline	The surface pipe through which oil travels from the well to processing equipment or to storage.
foot print	Area of land-take for an oil operation.
forb	Any herbaceous plant that is not a grass.
formation	A bed or deposit composed throughout of substantially the same type of rock; a lithological unit; each different formation is given a name.
geomorphology	The science that deals with the land features of the Earth's surface.
geophones	Detectors used in seismic surveys to pick up acoustic waves reflected from sub-surface strata.
grey water	Waste water from washing operations in a mobile/temporary camp (for example, from showers, laundry, kitchen, handbasins, etc.).
hummock	A rounded knoll or ridge, sometimes composed of ice.
hydrocarbon	Naturally occurring organic compound containing hydrogen and carbon. May be gaseous, solid or liquid, and includes natural gas, bitumens and petroleum.
hydrotest	Water, to which anti-corrosion compounds, oxygen scavengers and biocides have been added; used in the commissioning of pipelines.
indigenous	Having originated in, or being native to, a particular region or environment.
injection well	A well used to inject gas or water into an oil/gas reservoir rock to maintain reservoir pressure during the secondary recovery process. Also, a well used to inject treated wastes into selected formations for disposal.
isotherm	A line on a map of the Earth's surface connecting points having the same temperature at a given time, or the same mean temperature for a given period.
muskeg	Undrained boggy land characterised by *Sphagnum* moss vegetation.
oil field	A productive oil or gas formation comprising one or more reservoirs, usually related to the same geological features.
oligotrophic	Nutrient deficient waters with low primary productivity.
patterned ground	A feature produced by repeated thawing and freezing actions. Under these conditions, surface material is often graded into linear strips or polygons in which separation occurs between coarse and fine materials.
perforate	To pierce the casing wall and cement to provide holes through which formation fluids may enter, or to provide holes in the casing so that materials may be introduced into the annulus between the casing and the wall of the borehole.
permafrost	A layer of permanently frozen subsoil, including the accumulation of ice masses in the soil caused by alternating processes of dehydration of the soil and hydration of ice crystals. Consists of frozen mineral soil, organic soil or rock.
pingo	Large, ice-cored, dome-shaped hills prominent in Arctic areas.
podzol	Soil profile formed at an advanced stage of leaching. Upper soil layers become acidic.
polygon	An arrangement of surface materials (such as soil) forming part of a uniform pattern, often caused by alternative freeing and thawing of the crust. Polygons may range from 0.23 m to over 100 m in diameter.

primary recovery	The first stage of oil production, in which natural reservoir pressure is used to recover oil.
produced water	Water, originating from the natural oil reservoir, that is separated from the oil and gas in the production facility.
production	That phase of the petroleum industry that deals with bringing the well fluids to the surface and separating them, and with storing, gauging, and otherwise preparing the product for the pipeline.
prospect	A geological feature which has the potential of containing oil and gas that merits further exploration work.
pump station	One of the installations built at intervals along an oil pipeline to contain storage tanks, pumps and other equipment to route and maintain the flow of oil.
reclamation	The activities undertaken to restore a site to a predetermined land-use.
recoverable reserves	That proportion of the oil/gas in a reservoir that can be removed using currently available techniques.
recovery	The total volume of hydrocarbons that has been or is anticipated to be produced from a well or field.
reservoir rock	Porous and permeable rock, such as sandstone, limestone, or dolomite, containing petroleum within the small spaces in the rock.
rotary drilling	Drilling in which the entire drill string and bit are rotated, as opposed to turbine drilling where just the drill bit is rotated by a downhole turbine.
secondary recovery	Recovery of oil or gas from a reservoir by artificially maintaining or enhancing the reservoir pressure by injecting gas, water or other substances into the reservoir rock.
shot hole	A borehole in which an explosive is placed for blasting in use as the energy source for seismic survey.
shot hole blow-out	The ejection of water, mud and/or rocks and cuttings from a shot hole as a result of the shot explosion.
strata	Distinct, usually parallel beds of rock.
Subarctic	Areas with discontinuous permafrost, including taiga or boreal zones.
taiga	Ecological zone south of polar regions in Subarctic areas, characterised by discontinuous permafrost and boreal forest.
tertiary recovery	Recovery of oil or gas from a reservoir over and above that which can be obtained by primary and secondary recovery—generally involves sophisticated techniques such as heating the reservoir to reduce the viscosity of the oil.
thermocline	Temperature gradient in a thermally stratified body of water such as a lake.
thermokarst	The process in which subsidence of the terrain occurs as a result of melting ground ice.
tundra	Ecological zone in polar regions characterised by continuous permafrost and an absence of tree growth. Types include wet, tussock, mesic and shrub.
Vibroseis	A seismic survey technique which uses a large vehicle fitted with vibrating plates to produce shock waves.
waterflood	Injection of water to enhance the recovery of oil from a reservoir.
water injection	A process whereby treated water is pumped into the reservoir rock to maintain the reservoir pressure.
wellbore	The hole made by drilling or boring; it may be open, or a portion may be cased.
well cellar	Foundation which may be constructed around a well head, generally a shallow (less than 1 m) excavation with concrete for structural support.
workover	A process by which a completed production well is subsequently re-entered and any necessary cleaning, repair and maintenance work done.

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1 A list of Guidelines and Study Reports relating to industrial activities in Arctic and Subarctic areas can be obtained from E&P Forum, 25–28 Old Burlington Street, London WMX 1LB, UK.

Appendix

International Agreements

The following conventions and agreements may include provisions relevant to oil and gas operations in Arctic and Subarctic onshore regions. Note that this is not a comprehensive list and does not include conventions covering such subject areas as: maritime and shipping regulations, road traffic, vehicle noise, nuclear testing, animal health and welfare, whaling, sealing, fishing, conservation of fish stocks, exploration and exploitation of the deep seabed, exploration and exploitation of outer space and atomic energy. The listing of bilateral agreements does not include those relating to the management, regulation and use of the waters of specific river basins, fisheries agreements, sealing agreements and provisions for the recognition of frontiers between countries.

This annex should therefore be taken as a guide to the international regulatory provisions which might prevail.

Multilateral Conventions concerning Canada, Denmark, Finland, Iceland, Norway, the former Soviet Union, Sweden and the United States

Convention for the Protection of Birds Useful to Agriculture. 1902.

International Convention for the Protection of Birds. 1950.

International Plant Protection Convention. 1951. Amended 1979, 1983.

Convention for the Establishment of the European and Mediterranean Plant Protection Organisation. 1951. Amended 1962, 1966, 1968.

Statutes of the International Centre for the Study of the Preservation and Restoration of Cultural Property. 1956. Amended 1963, 1969.

European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR). 1957. Amended 1975.

European Agreement on the Restriction of the Use of certain Detergents in Washing and Cleaning Products. 1968. Amended 1983.

European Convention on the Protection of the Archaeological Heritage. 1969.

International Convention on Civil Liability for Oil Pollution Damage. 1969. Amended 1976, 1984.

International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage. 1971. Amended 1976, 1984.

Convention on Wetlands of International Importance especially as Waterfowl Habitat. 1971. Amended 1982, 1987.

Convention concerning the Protection of the World Cultural and Natural Heritage. 1972.

Agreement on conservation of Polar Bears. 1973.

Convention on International Trade in Endangered Species of Wild Fauna and Flora. 1973. Amended 1979, 1983.

Convention for the Prevention of Marine Pollution from Land-based Sources. 1974. Amended 1986.

Agreement on an international energy program. 1974. Amended 1976.

Nordic Environmental Protection Convention. 1974.

North American Plant Protection Agreement. 1976.

Convention on Long-Range Transboundary Air Pollution. 1979.

Convention on the Conservation of Migratory Species of Wild Animals. 1979. Amended 1985, 1988.

Convention on the Conservation of European Wildlife and Natural Habitats. 1979. Amended 1987, 1991.

Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Long-Term Financing of Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP). 1984.

Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at least 30%. 1985.

Protocol on Substances that Deplete the Ozone Layer. 1987.

Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution concerning the Control of Emissions of Nitrogen Oxides or their Transboundary Fluxes. 1988.

Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. 1989.

Agreement on transboundary cooperation with a view to preventing or limiting harmful effects for human beings, property or the environment in the event of accidents. 1989.

Amendment to the Montreal Protocol on Substances that deplete the Ozone Layer. 1990.

International Convention on Oil Pollution Preparedness, Response and Cooperation. 1990.

Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes. 1991.

Convention on Environmental Impact Assessment in a Transboundary Context. 1991.

Convention on the Protection and Use of Transboundary Watercourses and International Lakes. 1992

Convention on Biological Diversity. 1992.

Convention on Transboundary Effects of Industrial Accidents. 1992.

Bilateral Conventions concerning Canada, Finland, Iceland, Norway, Sweden, the former Soviet Union and the United States

Convention between the Republic of Finland and the Russian Socialist Federal Soviet Republic concerning the Maintenance of River Channels and the Regulation of Fishing on Watercourses forming part of the Frontier between Finland and Russia. 1922.

Agreement between Canada and the United States of America concerning a sewage disposal system. 1966.

Exchange of notes between the Government of Canada and the Government of the United States of America for mutual cooperation between the two countries in the detection and suppression of forest fires within a buffer zone along the boundary separating the Yukon Territory and the State of Alaska. 1971.

Agreement between the United States of America and the Union of Soviet Socialist Republics for cooperation in the field of environmental protection. 1972.

Memorandum of Implementation of the Agreement between the United States of America and the Union of Soviet Socialist Republics on cooperation in the field of environmental protection. 1972.

Agreement between the United States of America and the Union of Soviet Socialist Republics on cooperation in the field of energy. 1974.

Agreement effected by exchange of notes on contingency plans for spills of oil and other noxious substances. 1974. Amended 1977, 1982, 1986.

Convention between the United States of America and the Union of Soviet Socialist Republics concerning the Conservation of Migratory Birds and their Environment. 1976.

Interim Canada-Denmark Marine Pollution Contingency Plan. 1977.

Protocol on Canadian/Soviet Consultations on the Development of a Programme of Scientific and Technical Cooperation in the Arctic and the North. 1984.

Agreement between the Government of Finland and the Government of the USSR on cooperation in the field of environment protection. 1985.

Agreement between the Government of Canada and the Government of the United States of America on the conservation of the Porcupine Caribou Herd. 1987.

Further information can be obtained from the IUCN Environmental Law Information Service, Environmental Law Centre, Adenauerallee 214, D-5300 BONN 1, Germany.

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