Det Energipolitiske Udvalg
EPU alm. del - Bilag 89
Offentligt

MILJØMINISTERIET

Miljøstyrelsen

ORIGINAL

Kemikalier
J.nr.
Ref. jaaha
Den 8. december 2008

Assessment of Arctic Oil and Gas Activities 2007

Vedlagt følger:
Arctic Oil and Gas 2007

Vedlagte rapport "Arctic Oil and Gas 2007" er en forkortet og populariseret udgave af den videnskabelige rapport "Assessment 2007: Oil and Gas Activities in the Arctic – Effects and Potential Effects", som en lang række eksperter fra landene under Arktisk Råd står bag. Arktisk Råd er sammensat af Danmark/Grønland/Færøerne, Sverige, Norge, Finland, Island, Rusland, Canada og USA samt en række oprindelige folkeslag.

Rapporten giver en holistisk sammenfatning af de påvirkninger, som nuværende olie og gas aktiviteter i Arktis har på miljø, sundhed og sociale og økonomiske forhold. Desuden giver rapporten en beskrivelse af den sandsynlige udvikling af fremtidige olie og gas aktiviteter i det arktiske område, og potentielle afledte effekter heraf vurderes.

Den videnskabelige og den populærvidenskabelige rapport er resultatet af et ministerrådsmøde i Arktisk Råd i 2002, som anmodede rådets arbejdsgrupper om at udarbejde en vurdering af olie og gas aktiviteter i Arktis. AMAP (Arctic Monitoring and Assessment Programme), den ene af rådets seks arbejdsgrupper, har koordineret dette arbejde. Det er også AMAP, der udgiver rapporterne. Det danske bidrag til arbejdet er finansieret af Miljøstyrelsen via programmet Miljøstøtte til Arktis – DANCEA.

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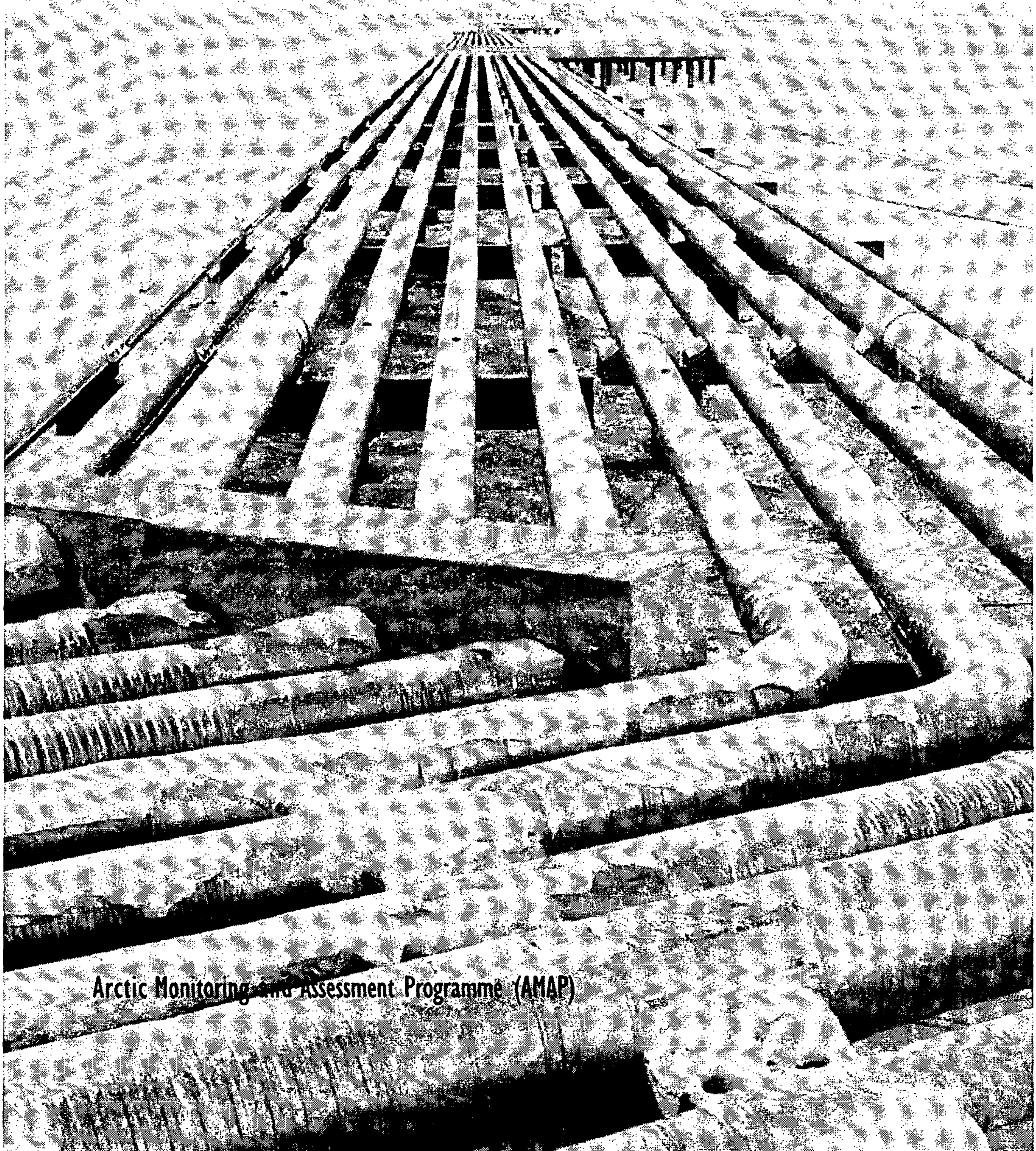
Yderligere eksemplarer af "Arctic Oil and Gas 2007" kan – så længe lager haves – fås ved henvendelse til Miljøstyrelsen eller købes via AMAP sekretariatet. Rapporten kan også - sammen med de hidtil udgivne kapitler af den videnskabelige rapport – hentes i PDF format på AMAPs hjemmeside: www.amap.no/oga/.

Med venlig hilsen
Jacob Hald

Arctic Oil and Gas 2007



Arctic Monitoring and Assessment Programme (AMAP)

Arctic Oil and Gas 2007

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AMAP
Arctic Monitoring and Assessment Programme
Oslo 2007

AMAP
Arctic Monitoring and Assessment Programme

Arctic Oil and Gas 2007
ISBN 978-82-7971-048-6

Published by
Arctic Monitoring and Assessment Programme (AMAP), P.O. Box 8100 Dep., N-0032 Oslo, Norway (www.amap.no)

Ordering
AMAP Secretariat, P.O. Box 8100 Dep. N-0032 Oslo, Norway
This report is also published as electronic documents, available from the AMAP website at www.amap.no

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China, France, Germany, Italy, Netherlands, Poland, Spain, United Kingdom.

Advisory Committee on Protection of the Sea (ACOPS), Arctic Circumpolar Route (ACR), Association of World Reindeer Herders (AWRH), Circumpolar Conservation Union (CCU), European Environment Agency (EEA), International Arctic Science Committee (IASC), International Arctic Social Sciences Association (IASSA), International Atomic Energy Agency (IAEA), International Council for the Exploration of the Sea (ICES), International Federation of Red Cross and Red Crescent Societies (IFFCRCS), International Union for Circumpolar Health (IUCH), International Union for the Conservation of Nature (IUCN), International Union of Radioecology (IUR), International Work Group for Indigenous Affairs (IWGIA), Nordic Council of Ministers (NCM), Nordic Council of Parliamentarians (NCP), Nordic Environment Finance Corporation (NEFCO), North Atlantic Marine Mammal Commission (NAMMCO), Northern Forum (NF), OECD Nuclear Energy Agency (OECD/NEA), OSPAR Commission (OSPAR), Standing Committee of Arctic Parliamentarians (SCAP), United Nations Development Programme (UNDP), United Nations Economic Commission for Europe (UN ECE), United Nations Environment Programme (UNEP), University of the Arctic (UArctic), World Health Organization (WHO), World Meteorological Organization (WMO), World Wide Fund for Nature (WWF).

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Cover design:
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Printing and binding:
Narayana Press, Gylling, DK-8300 Odder, Denmark (www.narayanapress.dk).

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Preface

This assessment of oil and gas activities in the Arctic is prepared in response to a request from the Ministers of the Arctic Council. The Ministers called for engagement of all Arctic Council Working Groups in this process, and requested that the Arctic Monitoring and Assessment Programme (AMAP) take responsibility for coordinating the work.

The objective of the 2007 'Assessment of Oil and Gas Activities in the Arctic' is to present an holistic assessment of the environmental, social and economic, and human health impacts of current oil and gas activities in the Arctic, and to evaluate the likely course of development of Arctic oil and gas activities and their potential impacts in the near future.

The assessment updates information contained in the AMAP 1997/98 assessment reports, including several aspects not covered in the earlier assessments regarding impacts of oil and gas activities, aiming to offer a balanced and reliable document to decision makers in support of sound future management of oil and gas activities in the Arctic. The assessment also includes recommendations to the Ministers for their consideration.

This 'State of the Arctic Environment Report' is intended to be readable and readily comprehensible, and does not contain extensive background data or references to the scientific literature. The complete scientific documentation, including sources for all figures reproduced in this report, is contained in a related report, '*Assessment 2007: Oil and Gas Activities in the Arctic - Effects and Potential Effects*', which is fully referenced. For readers interested in the scientific background to the information presented in this report, we recommend that you refer to the scientific report. This report is the fifth 'State of the Arctic Environment Report' that has been prepared by AMAP in accordance with its mandate.

A large number of experts from the Arctic countries (Canada, Denmark/Greenland/Faroe Islands, Finland, Iceland, Norway, Russia, Sweden, and the United States), together with experts from indigenous peoples' organizations, from other organizations, and from other countries have participated in the preparation of this assessment. AMAP would like to express its appreciation to all of these experts, who have contributed their time, effort, and data for the preparation of this assessment. AMAP would also like to thank IHS Incorporated for contributing information that was vital to the preparation of this assessment. A list of the main contributors is included in the acknowledgements on the previous page of this report. The list is based on identified individual contributors to the scientific assessment, and is not comprehensive. Specifically, it does not adequately reflect the contribution of the many national institutes, laboratories and organizations, and their staff, which have been involved in the various countries. Apologies, and no lesser thanks, are given to any individuals unintentionally omitted from the list.

Special thanks are due to the lead authors responsible for the preparation of the scientific assessments that provide the basis for this report, and also to the author of this report, Henry Huntington. The author worked in close cooperation with the scientific experts and the AMAP Secretariat to accomplish the difficult task of distilling the essential messages from a wealth of complex scientific information, and communicating this in an easily understandable way.

The support of the Arctic countries is essential for the production of assessments such as this, with much of the information presented being based on ongoing activities within the Arctic countries. The countries also provide the necessary support for most of the experts involved in the preparation of the assessments. In particular, AMAP would like to express its appreciation to Norway and the United States for undertaking the lead role in supporting the Assessment of Oil and Gas Activities in the Arctic. Special thanks are also offered to the Nordic Council of Ministers for their financial support to the AMAP parts of the work on this assessment, and to sponsors of other bilateral and multilateral projects that have delivered data for use in this assessment. Finances from the Nordic Council of Ministers and some countries also support the participation of indigenous peoples' organizations in the work.

The AMAP Working Group is pleased to present this State of the Arctic Environment Report, the fourth in the series, for the consideration by governments of the Arctic countries. This report is prepared in English, which constitutes the official version.

Oslo, November 2007

OGA Executive Summary and Recommendations

The Arctic Council's assessment of oil and gas activities in the Arctic is prepared in response to a request from Ministers of the eight Arctic countries. The Ministers called for engagement of all Arctic Council Working Groups in this process, and requested that the Arctic Monitoring and Assessment Programme (AMAP) take responsibility for coordinating the work. [1]

This Executive Summary is in three parts. Part A presents the main findings of the assessment and related recommendations. Part B is structured in the same manner as Part A and provides additional information for those interested in examining the basis for the conclusions and recommendations that are presented in Part A. Part C presents information on 'gaps in knowledge' and recommendations aimed at filling these gaps.

PART A: Conclusions and Recommendations [2]

Arctic Petroleum Hydrocarbon Resources and Oil and Gas Activities

The importance of oil and gas development to the economy of the Arctic means that, with the possible exception of climate change, this activity will pose the most significant challenges to balancing resource development, socio-cultural effects, and environmental protection in the Arctic in the next few decades.

Extensive oil and gas activity has occurred in the Arctic, with much oil and gas produced and much remaining that could be produced. More activity is expected in the next two decades, however projections farther into the future become increasingly speculative since the pace of activity is affected by a number of factors including economic conditions, societal considerations, regulatory processes, and technological advances. Global climate change may introduce additional factors that need to be taken into account.

Activities in the early decades of Arctic oil and gas exploration and development typically had larger impacts than corresponding activities today. Reduced impacts today are the result of improved technology, stricter regulations, and a better understanding of environmental effects of human activity in the region. Technological advances are likely to continue to change the way oil and gas activities are conducted. Even so, the presence of oil and gas activities both onshore and offshore is substantial in many parts of the Arctic.

The history of oil and gas activities, including recent events, indicates that risks cannot be eliminated. Tanker spills, pipeline leaks, and other accidents are likely to occur, even under the most stringent control systems. Transportation of oil and gas entails risk to areas beyond production regions. Pollution cannot be reduced to zero, although adherence to strict regulations and sound engineering practice can greatly reduce emissions, discharges, and the risk of accidents. Physical impacts and disturbance are likewise inevitable wherever industry operations occur; their effects can, however, be minimized. Increased activity may extend these impacts and effects into additional areas of the Arctic.

It is therefore recommended that:

- *Oil and gas activities and their consequences for the environment and humans should be given increased priority in the future work of the Arctic Council, focussing in particular on:*
  - *research, assessment and guidelines to support prevention of oil spills and reducing physical disturbances and pollution;*
  - *research, assessment and guidelines leading to improved management of social and economic effects on local communities; and*
  - *research, assessment, and guidelines in relation to the interactions between oil and gas activities and climate change.* [3]

  Specific recommendations in this respect are included under the heading 'Managing Oil and Gas Activities', below.
- *Arctic oil and gas activities should be conducted in accordance with the precautionary approach as reflected in Principle 15 of the Rio Declaration as well as in Article 3, paragraph 3 of the UN Framework Convention on Climate Change; and with the polluter pays principle as reflected in Principle 16 of the Rio Declaration.*
- *Recognizing the trans-boundary context of pollution hazards associated with certain oil and gas activities, the Arctic Council should support improvements in bilateral (and multilateral) cooperation among the Arctic countries to institute or improve coordination of preparedness and response measures across the circumpolar region, in particular cooperation in the Barents, Chukchi and Bering Seas.*

[1] Ministers representing the eight Arctic States, convening in Reykjavik, Iceland, for the Fourth Ministerial meeting of the Arctic Council. Request AMAP, in cooperation with the other relevant Arctic Council working groups, to continue work to deliver the assessments of oil and gas in the Arctic ... and propose effective measures in this regard. (Ministerial Declaration, Reykjavik 2004).

[2] Some Arctic governments are already implementing some or all of the activities described in the recommendations in this document.

[3] A focus on climate change should address both climate change effects on oil and gas activities in the Arctic and the influence of development of Arctic oil and gas resources on climate change, given the special, and sometimes local, sensitivity of the Arctic climate to emissions of methane, nitrous oxides, formation of tropospheric ozone and other pollutants and agents affecting climate change in the Arctic.

Social and Economic Effects

Oil and gas activities provide a significant contribution to the regional and national economies of the countries that currently produce oil and gas from their Arctic territories.

Effects on individuals, communities, and governments can be both positive and negative. Detriments and benefits are unlikely to reach everyone in the same way. Some people will receive greater benefits and others will experience greater negative effects. The development and construction lifecycle phases of oil and gas activity typically have the largest social and economic effects, but they are also the most rapid and transient.

Oil and gas are non-renewable resources and, as such, are finite resources that will eventually be exhausted; however the benefits resulting from oil and gas development may be sustainable if properly managed. Setting aside part of the revenue from oil and gas production, for example in long-term support or investment funds, or through provisions of land claims settlements can provide means of securing benefits for communities over the longer term, including when oil and gas activity declines or ceases.

Society in general has a responsibility to manage the positive and negative effects that oil and gas activities have on people. Involvement of local people in all stages of the decision-making process, and planning for the longer-term are key elements in this process. In some parts of the Arctic, the political influence of local and indigenous peoples is a driving force in modern oil and gas industry supervision.

It is therefore recommended that:

- *Prior to opening new geographical areas for oil and gas exploration and development, or constructing new infrastructure for transporting oil and gas, local residents including indigenous communities should be consulted to ensure that their interests are considered, negative effects are minimized and advantage is taken of opportunities afforded by the activity, especially during the early, intensive phases of development and construction.*
- *Consideration should be given to securing lasting benefits from oil and gas activities for Arctic residents, for example through the establishment of infrastructure and health-care facilities, so that northern economies and people benefit over the longer-term and so that infrastructure and services are maintained in the period after the activity has declined or ceased.*

Effects on the Environment and Ecosystems

The Arctic surface environment is one of the most easily impacted on Earth. On land, physical disturbance has the largest effect. In marine environments, oil spills are the largest threat.

In some areas, the tundra has been damaged by tundra travel and construction of infrastructure related to oil and gas exploration and development. Direct physical impacts and disturbances from oil and gas activities contribute to habitat fragmentation. New technology and methods have significantly reduced damage caused by operations, but the impacts may be cumulative.

This assessment confirms AMAP's previous findings that petroleum hydrocarbon concentrations are generally low in the Arctic environment. Furthermore, this assessment indicates that the majority of petroleum hydrocarbons in the Arctic environment come from natural sources. From human activity, oil spills are the largest contributor of petroleum hydrocarbons in the Arctic environment, followed by industrial activity. The oil and gas industry is responsible for some spills but other sources such as shipping, fishing fleet operations, and spills at local storage depots also account for much of the oil spilled. With the exception of spills, oil and gas activities are, at present, relatively modest contributors to overall petroleum hydrocarbon levels found in the Arctic. Although human inputs comprise a small proportion of the total petroleum hydrocarbons in the Arctic environment, they can create substantial local pollution.

If oil and gas activities in the Arctic reach levels projected by some countries, these activities may contribute an increasingly significant proportion of the input of petroleum hydrocarbons to the Arctic during the next few decades.

Oil spills and other pollution arising from oil and gas activities can damage ecosystems, but the extent of the impact depends on many factors. Seabirds and some marine mammals are particularly sensitive if oil fouls the feathers or fur they depend on for insulation, frequently resulting in death. Animals living under cold Arctic conditions are particularly vulnerable in this respect. Seasonal aggregations of some animals such as seabirds, marine mammals, and spawning fish make them particularly vulnerable to a spill at those times and places. Leads, polynyas, and the marginal ice zones are particularly important habitats where such aggregations occur.

Arctic plants and animals may be exposed to a large number of compounds released by oil and gas activities in a number of ways. In general, Arctic plants and animals may be expected to exhibit effects from petroleum hydrocarbon exposure similar to those shown by plants and animals elsewhere in the world. For most of the Arctic, with the exception of local spill situations, petroleum hydrocarbon levels are below known thresholds for effects. Aquatic animals may be sensitive to exposures to crude and refined oils and to numerous pure petroleum hydrocarbons, with larval stages of fish among the most sensitive. Experience from the Exxon Valdez oil spill has shown that such effects can persist for decades. To date, no major oil spills have occurred in the Arctic seas.

Human health can suffer from pollution and disturbance. Exposure to petroleum hydrocarbons at levels high enough to cause adverse health effects is rare outside of occupational situations or accidental releases such as spills. Spills can also lead to changes in the quality, quantity or availability of traditional foods. Oil and gas revenues can also improve health care and overall well-being. Demonstrating a connection between petroleum hydrocarbons and human health in the Arctic is complex at best. Many factors contribute to overall health.

It is therefore recommended that:

- *Measures should be adopted to enforce stringent controls on activities in sensitive areas, especially during periods when vulnerable species are present, and in particular on activities that involve a risk of impacts from spills. Governments need to play an active role in this.*

- *Where relevant, consideration should be given to staged opening of areas for oil and gas exploration and development or application of seasonal restriction on activities to minimize effects on ecosystems.*
- *Consideration should be given to the need for additional protected areas and areas that are closed for oil and gas activities, to ensure protection of vulnerable species and habit; the need for such areas should also be considered in areas already designated as appropriate for oil and gas development.*
- *Improved mapping of vulnerable species, populations, and habitats in the Arctic should be carried out, also taking into account seasonal, annual and longer-term changes, in order to facilitate oil spill contingency planning.*

Managing Arctic Oil and Gas Development

Economic benefits have accrued in those regions where oil and gas activities have occurred, but with some negative social and environmental effects as well. The benefits tend to be widespread (geographically and across society), whereas the negative effects tend to be more local.

It is difficult, however, to balance tangible (economic) benefits against risks of damage to the environment or ecosystems that, until a major spill occurs, remain essentially 'potential' or 'hypothetical'.

The regulatory process in most Arctic countries is modern and responsive. However, in many cases it is also complex, involving many agencies and jurisdictions. The continued improvement of regulatory systems, including the use of adaptive management, is necessary to ensure adequate control and enforcement as conditions and technology change, and as new areas are explored and developed.

When oil and gas activities cease, the final steps in environmental protection are appropriate decommissioning and remediation. Because these activities take place after revenues from production have ended, it may be necessary to establish the respective responsibilities of government and industry in regard to such activities. One option is for industry to contribute to a government-managed fund, to be used for decommissioning and remediation.

Offering incentives to operators to clean-up old sites in areas of their current operations may represent a cost-efficient way to facilitate remediation in some remote areas.

The environmental and negative social effects of oil and gas activities in the Arctic can only be minimized if existing regulations are effectively implemented and new regulations addressing current weaknesses are developed. Enforcing regulations requires commitment by governments, which can be aided by strong public pressure and industry cooperation.

In the United States (Alaska) and Canada, land claim settlements and agreements have given, and continue to give indigenous people a role in environmental assessment, permitting, and regulation of oil and gas activities.

Planning can help reduce risks and impacts. Preparation of environmental impact assessments and risk assessments prior to new development is a standard and required procedure; strategic environmental assessments that have a more holistic approach are becoming increasingly common. There is, however, scope for making these types of assessment more relevant and useful.

Responding to major oil spills remains a major challenge in remote, icy environments. This is especially true for spills in waters where ice is present. Many areas along Arctic coasts that are vulnerable to spills from oil and gas activities, especially transportation, do not have spill response equipment stationed nearby. Most oil combating equipment that is currently stored in Arctic depots was designed for use in non-ice-covered waters and may be inadequate for combating spills under typical Arctic conditions. Research on oil spill response technology and techniques has progressed in recent years, resulting in new technology and techniques with improved potential, however, these have yet to be fully-tested. For these reasons, spill prevention should be the first priority for all petroleum activities.

Experiences with leakages from older pipelines underline the necessity to use the highest engineering and environmental standards, including right-of-way selection, inspection and maintenance, monitoring, and environmental studies.

Tanker transport of oil in the Arctic seas, especially from Norwegian and Russian fields, has increased and is likely to increase further.

Differences exist in the laws, regulations, and regulatory regimes and their implementation among oil and gas producing countries in the Arctic. Some countries have enacted and enforced laws and regulations providing a robust regulatory regime for oil and gas activities. However, further measures may be warranted in areas with vulnerable ecosystems and low accessibility.

It is therefore recommended that:

Laws and regulations

- *Laws and regulations in all Arctic countries and their regional and local subdivisions should be enacted, periodically reviewed and evaluated and where necessary strengthened and rigorously enforced, in order to minimize any negative effects and maximize any positive effects of oil and gas activity on the environment and society.*
- *The requirement to use best industry and international standards should be addressed in laws and regulations. Management systems and regulations should be clear and flexible, and reviewed regularly to ensure that they are effective, adequate, consistently applied, and accommodate changes in technology in a timely manner.*
- *Monitoring of compliance and implementation of regulations should be improved in the Arctic countries, and appropriate authorities across the Arctic should be encouraged to adhere to and to enforce compliance with regulations.*
- *An assessment of the oil and gas industry's degree of compliance with applicable domestic regulations and monitoring programmes should be undertaken.*
- *Guidelines for oil and gas activities in the marine environment, and the legal framework for planning and controlling oil spill response operations in the Arctic, should be improved where necessary to reduce risks and minimize environmental disturbances.*
- *Oil and gas companies should be responsible for the costs associated with risk reduction, spill response, remediation and decommissioning activities, and be prepared to share in the costs for studies and*

for monitoring of effects on the environment and on society associated with oil and gas development

- *Environmental impact assessments, strategic environmental assessments, and risk assessments should continue to be rigorously applied and streamlined to increase their relevance and usefulness for all stakeholders.*
- *The ways in which local and indigenous knowledge has been and can be used in project planning, environmental assessment and monitoring, and regulatory decision-making should be evaluated to determine how best to involve such knowledge and its holders.*

Technology and practices [4]

- *Oil and gas industry should adopt the best available Arctic technology and practices currently available in all phases of oil and gas activity when undertaking such activities in the Arctic.*
- *Oil and gas industry should take action to reduce the physical impacts and disturbances associated with oil and gas activities, including, where appropriate: using 'road-less' development techniques to reduce physical impacts of roads; conducting as much activity as possible in winter months to avoid effects on tundra, permafrost, streams, and water bodies.*
- *Where appropriate, real-time monitoring should be used to minimize disturbances and impacts on wildlife, and scientifically-based best practices used to avoid adverse effects on marine mammals during seismic operations.*
- *Tanker operations in Arctic waters should employ the strictest measures for spill prevention and response, including improved communication, training, and cargo handling techniques and the use of ice-strengthened and double-hulled vessels. International coordination of oil transport information should be improved. International standards and national legislation for ships engaged in oil transportation in seas with potential for ice problems should be reviewed for adequacy and strengthened as appropriate.*
- *All pipeline projects should use the best available Arctic engineering and environmental standards, including right-of-way selection, inspection using state-of-the-art leak and corrosion detection systems, monitoring and environmental studies. Arctic design, engineering, construction and monitoring standards, and response capabilities, should be strictly adhered to and, if necessary, improved. Existing pipelines should be properly maintained and, if necessary, replaced.*

Spill prevention and response

- *Consideration should be given to whether Arctic areas should be opened for oil and gas activities or transportation where the methods of dealing with a spill or other major accident are lacking.*
- *Actions should be evaluated and applied to reduce risks of marine and terrestrial oil spills, especially aiming to prevent the occurrence of marine spills in the presence of sea ice.*
- *Emergency preparedness should be of the highest levels, including continued review of contingency plans, training of crews to operate and maintain equipment, and conducting regular (and unscheduled) response drills. Cooperation and emergency communications between operators and local, regional, national and international authorities on routes and schedules of transport and response capabilities need to be established and maintained.*
- *Oil spill response capabilities should be maintained and, where necessary, strengthened. Spill response technology should be further developed, especially technology or techniques for dealing with spills in water where ice is present. More (modern) combating equipment should be deployed in the Arctic, and distributed more widely to enable a rapid and effective response to the challenges associated with an acute spill in the Arctic environment.*
- *Countries should evaluate current funding levels to ensure full support for oil spill prevention, preparedness and response measures, including enforcement of these measures.*

Remediation

- *Oil and gas industry should be encouraged to continue their efforts to reduce emissions and discharges to the environment, including as appropriate: consideration of 'zero discharge' policies for harmful substances; reducing the amounts of produced water discharged to surface waters or the terrestrial environment; improved treatment of wastes prior to discharge; use of materials and chemicals that are less harmful to the environment; employment of closed-loop drilling practices for waste management; reducing the use of sumps and ensuring safe disposal of spent muds and cuttings; and discontinuation of flaring of associated solution-gas except in emergencies or for safety reasons.*
- *The benefits and costs of decommissioning and removing abandoned oil and gas facilities and remediation of affected areas should be evaluated on a case-by-case basis. Action is required to remediate sites that are polluted or severely contaminated in order to significantly reduce or prevent threats to the environment and the health of affected local populations.*
- *Where not already defined, countries should ensure that the respective responsibilities of government and industry for undertaking appropriate actions for decommissioning and remediation of all sites and infrastructure associated with ongoing and new oil and gas activities are clearly defined, and that measures are implemented to ensure that these obligations are met.*
- *Where necessary, a mechanism should be put in place for the clean-up of sites still seriously polluted as a result of past oil and gas activities where the operators of the sites can no longer be identified.*
- *Facilities for handling wastes from the oil and gas industry, including port reception facilities for transportation and ancillary vessels, should be extended to reduce environmental pollution, including pollution resulting from illegal discharges.*

[4] Different definitions of Best Available Technology (BAT) and Best Available Practices (BAP) exist. In the context of this assessment, these terms are used to imply the most advanced technology and practices currently available that are appropriate to Arctic operations.

PART B: Supplementary Information

Arctic Petroleum Hydrocarbon Resources and Oil and Gas Activities

1. Oil and gas are among the most valuable non-renewable resources in the Arctic today. The Arctic is known to contain large petroleum hydrocarbon reserves, and is believed to contain (undiscovered) resources that constitute a significant part of the World's remaining resource base.
2. Unique characteristics of the Arctic mean that development of oil and gas activities within the region faces a number challenges or considerations that do not apply in other parts of the World.
3. Since the 1970s, Arctic regions of the United States (Alaska), Canada, Norway and, in particular, Russia have been producing large volumes of both oil and (with the exception of Alaska) gas. With over 75% of known Arctic oil and over 90% of known Arctic gas resources and vast estimated undiscovered oil and gas resources, Russia will continue to be the dominant Arctic producer of oil and gas. In some Arctic areas, activities have peaked and in others they are increasing or are changing phase from exploration to development or from production decline to shut down. Exploiting Arctic oil and gas resources is difficult and expensive, as is transporting the products to markets; much of the region currently lacks the necessary infrastructure to transport oil and gas to the major markets.
4. With rising global demand, and the desire for stable and secure supplies, oil and gas activity in the region is expected to increase. Plans for new pipelines and for evaluation and development in new areas are underway. A major discovery could transform the prospects for oil and gas development in offshore areas around Greenland and the Faroese Shelf. These areas, together with offshore areas in northern Norway, northern Russia, the United States (Alaska) and Canada, are of particular interest to both government and industry. During the next two decades, the construction of new infrastructure for development and particularly transportation will likely extend into wilderness areas. The depletion of existing reserves worldwide may also lead to greater interest in unconventional resources such as heavy oil, coal-bed methane, and potentially vast methane hydrate deposits that exist both onshore and offshore in the Arctic. The many factors involved in development decisions, and their complex interactions, make it difficult to project future activity levels with confidence.

Selected key characteristics of the Arctic relevant to oil and gas activities and their effects

Characteristic	*Relevance*
Physical environment	
Cold	Difficult work conditions, especially in winter Slow weathering of oil compounds
Light/dark regime	Difficult work conditions in winter Extreme seasonality of biological production
Permafrost	Surface easily disturbed, with long-lasting effects and slow recovery of surface vegetation
Sea ice	Difficult access; difficult to respond to oil spills
Biological environment	
Seasonal aggregations of animals	Major impacts possible even from localized oil spills or other disturbance
Migration	Effects in the Arctic impact other parts of the world Effects elsewhere impact the Arctic
Intact habitats	Landscapes and wide-ranging species susceptible to major developments and to incremental growth
Short, simple food chains	Disruption to key species (lichen, polar cod) can have major impacts to many other species
Human environment	
Remote, largely roadless	Difficult to reach, especially in response to disaster Expensive to develop, transport oil and gas Major impacts possible from new roads Improved access
Few people	Major demographic changes possible from industrial activities Limited human resources to support industry; many workers required from elsewhere
Many indigenous peoples	Already changing cultures susceptible to further impacts on society, environment Indigenous rights and interests, including land ownership Business and employment opportunities Access to services (health care facilities, schools)

5. Climate change is expected to increase access to Arctic resources. Tanker shipment is increasing rapidly in Arctic waters. Initial plans for possible north-east and north-west trans-Arctic shipping lanes are under development due to expected decreases in sea-ice cover. Permafrost melting, however, may reduce access for development on land and will present new challenges with respect to infrastructure and pipeline construction.

6. Oil and gas activities include several 'lifecycle stages'. In some oil and gas regions, several phases may be taking place at the same time.

7. Early prospecting and resource delineation were conducted using methods that have unacceptable levels of environmental impact under modern standards. Improved technology and practices have reduced, and in some cases eliminated, the 'footprint' of oil exploration and extraction activities in the Arctic compared with that of previous times.

8. Regulatory systems in the Arctic have evolved in recent decades. Since 1992, Russia has been constructing a new system of regulatory control. Greenland, the Faroe Islands, and Iceland are in the early stages of regulatory development, while the mature systems used in Canada, the United States, and Norway have undergone and are still undergoing changes. Regulations and the use of best available technology (BAT) are, however, not consistent across the Arctic. Despite comprehensive regulatory systems and considerable public scrutiny, incidents such as spills and fires still occur.

Social and Economic Effects

9. In the regions where they occur, oil and gas activities are major contributors to regional and national economies. Oil and gas activities are drivers of social and economic change. Oil and gas activities have both positive and negative effects on people within the Arctic; populations outside of the Arctic generally benefit from Arctic oil and gas activities.

10. Industrial activity creates employment opportunities and can also stimulate local businesses leading to higher standards of living. Public revenues from taxes and royalties can be used to pay for improved public services, including schools and health care. The Arctic has relatively few inhabitants, and thus a small potential labour pool; as a consequence, oil and gas industry workers are typically brought in from other regions, in particular during the early, intensive stages of development and construction. While providing many new opportunities, this influx of people and industrial activity has the potential to disrupt traditional ways of life cause social disruption, and also introduce or increase the spread of diseases.

11. Many different indigenous peoples live in the Arctic. The subsistence hunting, fishing, herding, and gathering activities practiced by Arctic indigenous peoples extend over large areas of land and sea. Environmental effects of oil and gas activities within these areas can be disruptive to traditional ways of life. A sudden increase in income or absence of adults from the household for extended periods due to employment in the oil and gas industry can also challenge traditional lifestyles.

12. As oil and gas resources are exhausted, activity in a region will eventually close down. Closure of an oil or gas operation means the loss of employment and of public revenue. Public or private investment funds may allow some benefits to persist past the life of the operation. In some areas where oil and gas operations have declined, populations have decreased as has overall economic activity. The long-term effects of such declines are as yet unknown for Arctic regions.

13. Some degree of risk to people and society is unavoidable. Increased awareness of, and protection against, potential effects to the environment and people living and working in the Arctic remain important considerations in whether deposits are developed. An essential part of reducing negative effects and capturing benefits is effective governance, which entails clear decision-making, public involvement, and an effective regulatory regime.

14. Oil and gas activities can lead to higher standards of living, including better health care and public health services and infrastructure. However, introduction and spread of diseases through worker movements can occur at oil and gas activity centres and in other industrial areas, and exposure of humans to oil and petroleum hydrocarbons following spills may result in a variety of reversible chemical-mediated health effects. Psychologically, the trauma of an oil spill or other major accident can be profound, especially if ways of life are undermined. Stress and illness can lead to sociological effects when family and community networks are overburdened or disrupted.

Effects on the Environment and Ecosystems

15. Although anthropogenic inputs are a small proportion of the total petroleum hydrocarbon pollution in the Arctic environment, they can create substantial local pollution. Some areas around oil facilities are polluted by petroleum hydrocarbons and other substances. Chronic spills along some pipelines have led to severe local pollution. Even where stringent regulations and maintenance regimes exist, the costs to the environment and to the economy can be considerable if these regimes are not strictly adhered to.

16. Although many oil- and gas-related sources and unacceptable practices have been greatly reduced or eliminated, a complete and balanced assessment of the extent and significance of oil and gas activity impacts and oil field pollution has been hampered by a lack of detailed information from some countries. Other countries have considerable information available, but often in forms that make it difficult to access and evaluate.

17. Arctic plants and animals may be exposed in a number of ways to a large number of compounds released by oil and gas activities. One of the greatest effects on birds and other animals comes from physical coating by oil in the event of an oil spill. Even small amounts of oil on part of an organism may cause

death. Seals and whales that use blubber for insulation appear relatively insensitive to being coated with oil; baleen whales could be vulnerable if their baleen plates become fouled with oil, although this effect has not been found to date.

18. Fish readily take up oil, but they metabolize most hydrocarbons quickly. In the aftermath of an oil spill, however, fish may retain sufficient quantities of hydrocarbons to affect their quality as food for people. Even the suspicion of tainting can result in refusal to eat fish and wildlife products, affecting local consumers as well as potentially damaging valuable markets for Arctic food products. Many organisms are adapted to the natural environmental occurrence of petroleum hydrocarbons and show no major biological effects from exposure to small amounts of many hydrocarbons.

19. For most of the Arctic, petroleum hydrocarbon levels are below known thresholds for effects. In areas of local contamination, including contamination from natural sources, however, concentrations are high enough to expect effects. In the Arctic, low temperatures usually mean that hydrocarbons will persist longer in the environment, thus having more time to be taken up by plants and animals.

20. The Arctic is considered to be generally vulnerable to oil spills due to increased environmental persistence of petroleum hydrocarbons, slow recovery, highly seasonal ecosystems, and the difficulty of clean up in remote regions. Ice-edge communities are particularly vulnerable.

21. Oil spills in aquatic environments, and in particular in marine areas, have the potential to spread and affect animal life over large areas and distances from the spill site.

22. At sea, large oil spills are generally considered to be the largest environmental threat, though smaller, diffuse releases of oil can also have substantial impacts. Seabirds and mammals depending on fur for insulation are particularly at risk from spills. Due to the sensitivity of fish larval stages to exposures to crude and refined oils, an oil spill in a major spawning area could severely reduce that year's recruitment to the population. If a species or stock is already depleted, the impact of such a loss could adversely affect its recovery. A smaller spill in a time and place with congregations of fish, birds, or mammals (for example during wintering, breeding, feeding, and migrations) could have greater impacts on populations than a larger spill in a time and place where animals are dispersed. Residual oil and other ecosystem effects may be as significant to seabird populations as the initial oiling. Ecosystems are also vulnerable to chronic pollution, as contaminants or their effects may persist and accumulate.

23. Oil and gas activities that have the potential to cause impacts in the marine environment include seismic exploration and drilling and production operations that make loud noises that are carried far underwater. Avoiding drilling and seismic testing during migratory and other sensitive periods can reduce effects on sensitive species such as whales.

24. The largest effect of oil and gas activities on land in the Arctic has been physical disturbance. Because Arctic landscapes typically recover slowly, decades-old effects are still visible. Notwithstanding the major improvements in industry practices in recent decades, recent improvements cannot change the fact that large areas of tundra have been damaged by tundra travel and construction of infrastructure related to oil and gas exploration and developments. In addition to these direct physical 'footprints' on the terrestrial environment, there are also more diffuse physical near-zone impacts. Dust from roads may have an effect on physical conditions and vegetation out to a few hundred meters. Roads and other infrastructure may influence the hydrology of flat tundra landscapes. Pipelines and roads may represent impediments to migrations of animals, and traffic and human presence cause avoidance in some species. Other species may be attracted to human infrastructure and habitation.

25. The direct physical impacts and disturbances from oil and gas activities contribute to habitat fragmentation, along with impacts and disturbances from other human activities. Habitat fragmentation can affect wildlife, disrupt traditional migration or herding routes, and reduce the aesthetic value; fragmentation of habitat may adversely affect many species, particularly large predators. Even without pollution or incidents, oil and gas activities can reduce the wilderness character of a region.

26. Although new technology and methods have significantly reduced damage caused by operations, the changes are cumulative, and as activities overlap or expand the ultimate impact may in some cases be increasing.

27. Many affected areas, especially in Russia, appear not to have been characterized with respect to the risks they pose.

28. Arctic ecosystems experience high variability from year to year, including large swings in population sizes. Some species and populations will recover more quickly from population effects than others. Small changes in population are likely to remain undetected. Even large changes may be the result of other factors, including natural population cycles. In the event of significant population-level effects, ruling out other factors may be difficult or impossible.

Managing Arctic Oil and Gas Development

29. With Arctic oil and gas activity likely to increase risk is unavoidable. Sound planning and management can nonetheless help reduce negative effects and increase the benefits of oil and gas activity in the Arctic. Effective governance does not occur by chance.

30. The gain in influence by indigenous groups can prove advantageous for industry and governments, for example in settling land claims. In many cases, local residents desire not so much to slow or stop development as to have a hand in determining how it occurs. Generating lasting benefits from oil and gas activity, while at the same time reducing major disruptions, is a common goal for both national and local governments.

31. While accidents such as oil spills cannot be eliminated, planning and preparedness can reduce the likelihood of a disaster and the impacts if and when a disaster occurs. Prevention is the best approach and best practises and technologies should always be employed when oil and gas activities are undertaken in the Arctic.

32. Stricter regulations and better operating practices have reduced, and can further reduce, environmental and social impacts. However, in order for these measures to be effective, strict enforcement of existing regulations and adherence by industry to accepted international standards are essential. Better understanding of the nature and scope of effects can improve the ability to plan effectively. Resources need to be allocated to ensure that necessary monitoring and research are conducted.

33. Responding to a marine spill in the Arctic is particularly challenging. Many oil and gas activities are in locations far from population centres. Detection of oil or gas leaks is vital in reducing the likelihood of environmental damage or health risks. Employment of the best technology and practices for flaw detection allows defective or corroded pipelines to be replaced before an accident happens. Many oil and gas pipelines in Russia need reconstruction and repair using up-to-date technologies. Despite stringent engineering and environmental regulations, small oil spills are a common occurrence. Pipelines leak, accidents happen, and chronic and acute pollution is the result.

34. Although environmental clean-up (decommissioning) is required, it is not yet clear how much actual work will be done once an oil or gas installation is closed down. In some areas, sites of previous (historical) oil and gas activities urgently require remediation and clean-up.

PART C: Gaps in Knowledge

Information:

Arctic ecosystems experience high variability from year to year, including large swings in population sizes. Baseline information is often inadequate or unavailable. Such information is necessary if population-level effects are to be identified and the effects of oil and gas activities distinguished from other possible contributing factors.

There is a lack of detailed information about pollution in the vicinity of oil and gas facilities and installations, including information on practices used for waste handling and amounts of chemicals emitted or discharged to the environment. This prevented a thorough assessment of the extent and significance of local pollution associated with Arctic oil and gas activities, especially in Russia.

The Arctic petroleum hydrocarbon budget represents a useful tool for investigating current sources of contamination and considering future scenarios and potential effects of Arctic oil and gas activities. However, key components of the budget are based on assumptions due to lack of relevant information.

Monitoring and Research:

Overall, knowledge about effects on the environment and human health of oil and gas activities is limited, either because consistent information has not been collected, because incidents are relatively few, or because information is not standardized across scientific disciplines, regions or countries.

More research is needed into the many (positive and negative) factors influencing human health if the net effect of oil and gas industry on human health is to be determined in different areas of the Arctic.

Comparative studies should address the effectiveness of socio-economic mitigation and opportunity measures.

Assessments:

The oil and gas assessment has provided a number of valuable lessons for the conduct of similar future assessments and possible follow-up assessments.

Recommendations

To fill information gaps:

- *Governments and industry should develop better reporting procedures for compiling and reporting in a consistent manner, appropriate data on releases from oil and gas operations at all installations and facilities, including data on waste disposal and contamination around these facilities. Similar information should be compiled for harbours.*
- *Governments and industry should be encouraged to provide better information on infrastructure related to oil and gas activities, and associated physical disturbances.*
- *Countries should be encouraged to continue and where necessary implement new monitoring programmes to obtain baseline information necessary to detect possible population-level effects for both key species and species at risk from oil and gas activities.*
- *Countries should be encouraged to collect and compile comparable Arctic oil- and gas-related socio-economic statistics, including development of a set of key social and economic indicators (relating to income, employment, revenue, social infrastructure, and health and safety) to measure effects of oil and gas activities on a circumpolar basis and to allow meaningful comparisons to be made regarding the role of oil and gas or its proportional contribution to specific effects.*
- *Comprehensive baseline investigations should be undertaken by government and industry to allow detection of potential adverse effects on ecosystems, and to identify existing seafloor hazards or archeological sites, before petroleum activities commence.*
- *Governments and industry should provide the Arctic Council with improved access to relevant and appropriate data to enable the Arctic Council to establish an inventory of facilities and infrastructure with potential for releases or spills associated with oil and gas and compile and maintain an updated inventory of accidental releases from oil and gas activities in the Arctic as a basis for conducting periodic risk assessments.*

- *A follow-up effort should be undertaken to obtain data from long-term monitoring efforts in regions that have experience with large oil spills.*
- *Spills under Arctic conditions should be used as an opportunity to test and validate experience from experimental, e.g. laboratory studies, and from spills outside of the Arctic. Preparations should be made to allow rapid mobilization of necessary personnel and equipment to undertake such studies in the event of a future Arctic spill.*
- *Monitoring programmes should be developed to improve the compatibility and comparability of the data, including bridging the gap between the more persistent, high-molecular components currently monitored and specific compounds of petroleum hydrocarbons that elicit most of the toxicological effects (e.g., volatile aromatic compounds) that are generally not included in monitoring programmes but which are recorded in laboratory experiments, to allow assessment of the environmental concentrations of these more toxic compounds.*

To fill knowledge gaps:

- *Undertake new research and continue existing research to provide better information on the behaviour and fate of oil in ice-covered water.*
- *Continue existing research necessary for developing effective techniques for dealing with oil spills in areas of sea ice, and with large spills on land.*
- *Better integrate environmental monitoring and toxicological studies so that results from these two fields can be compared.*
- *Continue existing research and where necessary conduct more studies using oil spill trajectory models to determine areas most at risk from oil spills and set priorities for response strategies, in particular in sensitive areas.*
- *Continue existing monitoring and, where necessary undertake new monitoring to provide the necessary data for improving the petroleum hydrocarbon budget of the Arctic, in particular to allow better estimates of inputs associated with natural seeps, riverine transport, and produced waters (disposal methods, location, volumes, and composition).*
- *Conduct research into natural petroleum seeps especially offshore and quantify their output volumes.*
- *Use natural seeps for research purposes.*
- *Before petroleum activities commence, monitoring should be instituted in a programme designed to document the effects of oil and gas activities and distinguish these from other sources of contamination or disturbance, including clear identification of methods utilized to assure quality control for all aspects of the monitoring process. The monitoring programme should continue through the decommissioning and reclamation phase. Prior to initiating oil and gas activities, Arctic States should ensure that funding is available within government and/or industry for monitoring.*
- *Continue existing monitoring and where necessary conduct new monitoring of groundwater reservoirs and water systems near onshore wells and pipelines.*
- *Continue existing research and where necessary, conduct new research and monitoring to better understand short- and longer-term effects on the ecosystem, focusing on risks associated with oil spills, including prevention, clean-up, and response.*
- *Conduct further research on indicators of the cumulative effects of activities, which can be applied across the Arctic in the next twenty years to help document the extent of changes.*
- *Continue research to improve or develop new technologies for drilling and seismic operations to reduce potential impacts.*
- *Conduct comparative research on social and economic effects to evaluate the effectiveness of various measures for mitigating negative effects and achieving positive benefits with regard to economic opportunity, cultural traditions and practices, and social well-being.*
- *Conduct research to develop better approaches to document population-level and ecosystem-level effects of oil- and gas-related activities and oil spills.*
- *Enhance research on ecosystem and social vulnerability to oil and gas activities, with particular emphasis on cumulative effects.*
- *Undertake health studies in communities affected or likely to be affected by oil and gas activities taking into account multiple determinants of health.*
- *Institute monitoring of infectious disease among the work force at oil and gas facilities to enable more prompt and effective treatment of the occupational cohort and reduce the transfer of disease from workers to communities as oil and gas activities expand in the Arctic.*
- *Expand research on the sensitivity of Arctic flora and fauna to oil and gas activities and oil spills.*
- *Support continued research into unconventional resources to determine their economic viability, to develop technology to extract them safely, and to determine the environmental consequences of their development.*
- *Increase research on the link between ozone reduction, associated UV increase, and toxicity of released oil.*

To address future assessment needs:

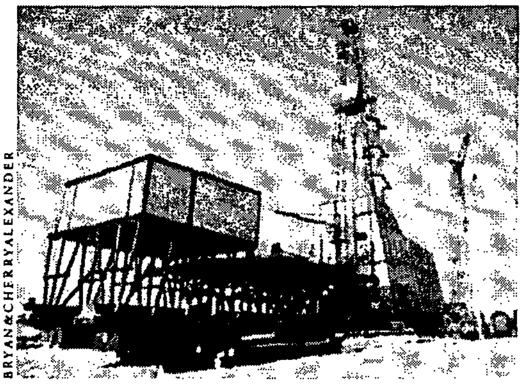
- *Consideration of the effects of climate change on oil and gas activities and associated infrastructure as well as the longer-term effects of Arctic oil and gas activities and their impact on the Arctic environment and climate should be included in any future follow-up to the Arctic Climate Impact Assessment (ACIA).*
- *Consideration should be given to conducting a further assessment of information on contamination around oil and gas installations and facilities, and in harbours; waste management procedures; and the status of oil and gas pipeline infrastructure in the circumpolar region.*
- *An assessment should be made of the extent to which plans exist for decommissioning unused infrastructure and rehabilitating the environment.*

Introduction

Oil and gas are among the most valuable non-renewable resources in the Arctic today. Oil seeps have been known and used for thousands of years in northern Alaska, Canada, and Russia. Commercial oil extraction started in the 1920s and expanded greatly in the second half of the 20th century. More activity is expected in the future. Oil and gas activities will remain a major economic driver in the Arctic, extending across many regions and ecosystems, affecting many peoples and communities, both inside and outside of the Arctic. The effects of these activities should be assessed, both to establish a baseline against which future changes can be measured, and to help understand the consequences of oil and gas development over time.

BRYAN&CHERRYALEXANDER

▲ Nenets reindeer herders camp by gas drilling rig in the Bovanenkovo field, Yamal, Western Siberia, Russia



BRYAN&CHERRYALEXANDER

▸ Gas drilling platform on the tundra in the Bovanenkovo field, Yamal, Western Siberia, Russia.

Purpose of the Assessment

In 1997/98, the Arctic Monitoring and Assessment Programme produced its first assessment, Arctic Pollution Issues (see Box). That report included a chapter on petroleum hydrocarbon contamination in the Arctic. The new assessment, *Oil and Gas Activities in the Arctic: Effects and Potential Effects*, updates and expands upon the 1997/98 report. In addition to covering petroleum hydrocarbon pollution in greater detail, the new assessment addresses additional topics related to oil and gas activities in the Arctic. A detailed history of each country's oil and gas operations and possible future activities has been added. Also included is a chapter on social and economic effects, which were not previously considered by AMAP. Furthermore, the assessment examines effects at levels of biochemistry, individual organisms, populations, and the ecosystem, the last of which has not previously been done. The assessment does not address contributions of the use of arctic fossil fuels to climate change, nor does it address pollution issues such as heavy metals and radionuclides, which are associated with oil and gas activities in addition to other human activities. AMAP has already produced assessments on climate, persistent organic pollutants (POPs), metals, and radionuclides.

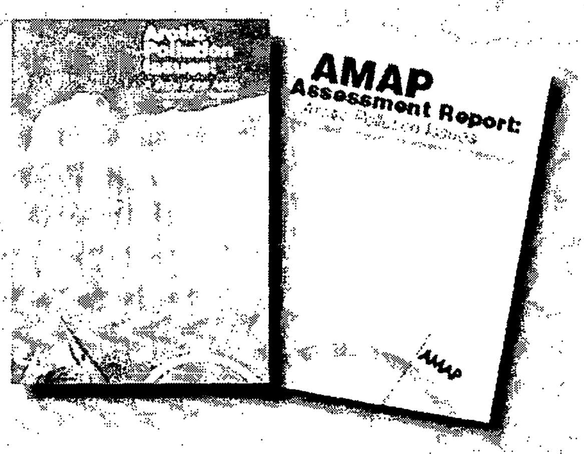
The main findings of the 1997/98 report have been confirmed and extended. Petroleum hydrocarbon contamination is not a widespread problem in the Arctic, apart from areas where human activity has been intensive. The Arctic is generally considered to be vulnerable to oil spills due to slow recovery of cold, highly seasonal ecosystems, and the difficulty of clean up in remote, cold regions, especially in waters where sea ice is present. Seasonal aggregations of some animals such as seabirds, marine mammals, and spawning fish make them particularly vulnerable to a spill at those times and places. Oil spills and industrial activities excluding oil and gas activities remain the largest human sources of petroleum hydrocarbons in the Arctic. Routine oil and gas operations currently contribute a very small fraction of the total input. Natural sources, particularly natural seeps, are larger than human sources.

One motivation for producing this report is the increasing demand for oil and gas worldwide combined with more interest in and access to arctic resources. Since the 1970s, arctic regions have been producing billions of dollars worth of both oil and gas. There is considerably more that could be developed. In arctic Alaska, offshore oil and gas activity is likely to increase. In Canada, natural gas field development and pipeline construction may begin in the Mackenzie Delta, subject to approval, with oil and gas exploration and development expected to follow in the nearshore Beaufort Sea. In Norway, Barents Sea gas production is about to begin, while exploration and development

The 1997/98 AMAP Assessment of petroleum hydrocarbon

In 1998, the *AMAP Assessment Report: Arctic Pollution Issues*[a] was published, presenting the first AMAP scientific assessment of contaminants in the Arctic. The results of this assessment were also presented in a plain-language version of the assessment, *Arctic Pollution Issues: A State of the Arctic Environment Report*[b], released in 1997. The publications addressed a number of different contaminants and related issues, including persistent organic pollutants, heavy metals, radioactivity, acidification, climate change, and petroleum hydrocarbons.

The findings from AMAP's first assessment have led to a series of further investigations of most of the topics covered at that time. For petroleum hydrocarbons, the results of the latest assessment are presented in *Oil and Gas Activities in the Arctic: Effects and Potential Effects* and summarized here. The 1997/98 assessment recommended action to reduce the risk of oil spills and further study to identify areas of particular vulnerability to such oil pollution. This recommendation has been acted on (see pages 34-35).



[a]AMAP. 1998. AMAP Assessment Report: Arctic Pollution Issues. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xii+859 pp.
[b]AMAP. 1997. Arctic Pollution Issues: A State of the Arctic Environment Report. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xii+188 pp.

continue. In Russia, onshore and offshore development and production is already ongoing or is on the horizon in many regions, including some without previous oil and gas activity. Tanker shipment is also increasing rapidly in Russian and Norwegian arctic waters. Greenland and the Faroe Islands continue to explore for offshore oil and gas, and exploration activities are starting around Iceland.

As oil and gas activities continue, society must respond to the positive and negative impacts that they have on people and the environment. The purpose of the assessment is to document what is known about the effects of past and current oil and gas activities, to project the likely course of such activities and impacts for the years to come, and to make recommendations based on the assessment. Such information can then be used by all concerned with the decisions that are to be made about if and how oil and gas activities proceed.

As is the nature of assessments, there is insufficient information to fully answer all questions or address all topics of concern. Nonetheless, a great deal of material has been compiled and assessed in the scientific background report, *Oil and Gas Activities in the Arctic: Effects and Potential Effects*, which draws on more than a thousand studies to investigate many aspects of oil and gas activities and their effects on the environment and people. Teams of scientists with expertise in the many different fields required to undertake a comprehensive assessment of all the effects of oil and gas activities in the Arctic have worked on each chapter. Their work has been subjected to national and international peer review. In addition to drawing together the available information, chapter teams have prepared new analyses of the role of oil and gas activities in the Arctic. These include the first estimates for the inputs of petroleum hydrocarbons to the arctic environment and their subsequent redistribution (a hydrocarbon "budget" for the Arctic), an assessment of ecological vulnerability across the entire circumpolar region, and assessment of socio-economic and health impacts.

Scope of the Assessment

AMAP's assessment of arctic oil and gas activities has been produced in two parts. The scientific report, *Oil and Gas Activities in the Arctic: Effects and Potential Effects*, contains a comprehensive assessment of all the effects of oil and gas activities in the Arctic. In addition, *a plain-language overview* (this report) presents the main findings of the scientific assessment in a concise and accessible form, providing a distillation of the current state of knowledge about oil and gas activities in the Arctic. This overview is intended not to replace the scientific report, but to make its key findings accessible beyond the scientific community. All statements in this overview are supported by *Oil and Gas Activities in the Arctic: Effects and Potential Effects*. The lead authors of the scientific report and the members of the AMAP, in consultation with the other Arctic Council Working Groups and Permanent Participants, have reviewed and approved the contents of this report.

The overview is organized differently than the scientific report. To help provide context and some understanding of oil and gas activities, the introduction includes a description of the various activities related to oil and gas in the Arctic. Then the assessment's main findings are presented in two sections, the first considering past activities and impacts up to the present, the second looking to the future. Key findings are summarised at the end of the report. The Executive Summary to the overview report contains recommendations that were developed on the basis of the findings of the scientific assessment.

Assessment 2007: *Oil and Gas Activities in the Arctic: Effects and Potential Effects*

Chapter 1 provides the rationale for and limitations of the 2007 oil and gas assessment. Chapter 2 reviews the history of oil and gas activities in the Arctic, including technology, regulation, monitoring, and oil spill preparedness and response capabilities, as well as other factors that influence the course of industry activity. Chapter 3 presents several case studies on social and economic effects, covering local, regional, and national perspectives. Chapter 4 describes the sources and concentrations of petroleum hydrocarbons in the Arctic, including the first petroleum hydrocarbon budget for the region. It also addresses inputs of other chemicals used in the oil and gas industry. Chapter 5 discusses effects of petroleum hydrocarbons and oil and gas activity on terrestrial and aquatic environments and human health. Chapter 6 examines environmental impact assessments and vulnerability of species and habitats within the arctic ecosystem, including the mapping of vulnerability to oil and gas impacts. Chapter 7 gives the key findings of the entire assessment, and is the basis for this overview report.

▼ SDC (Steel Drilling Caisson) rig and rubble field, Arctic Canada.

TOM SMITH

The Arctic

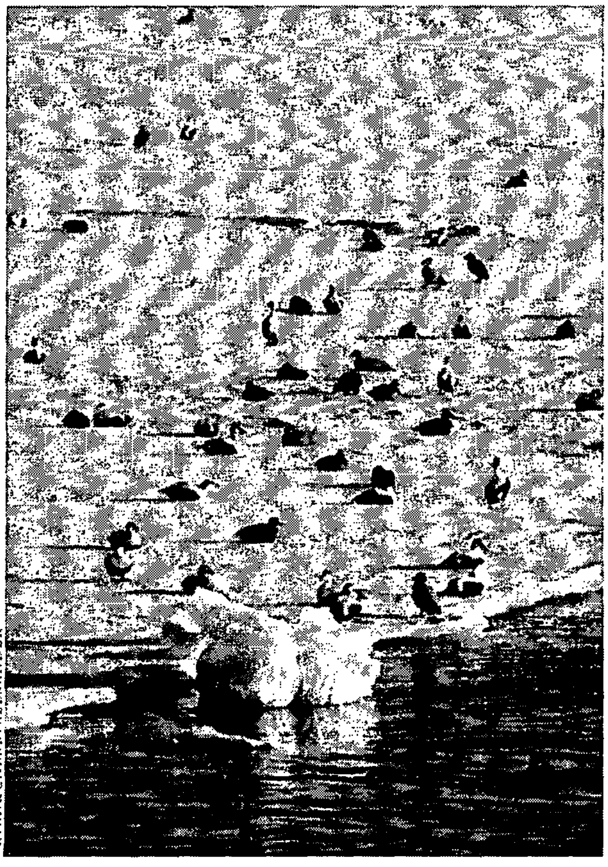
The Arctic centers on the deep, in part permanently and in part seasonally ice-covered Arctic Ocean, nearly surrounded by the lands of North America and Eurasia. The Arctic is characterized by ice: sea ice, ice sheets, glaciers, and permafrost. But it also contains considerable variation in terrain, climate, ecology, and human presence, as well as seasonal extremes of light and darkness. More extensive descriptions of the Arctic can be found in many places, including AMAP's 1997 *State of the Arctic Environment Report*. The current assessment focuses on the Arctic oil and gas regions as indicated on the map on page 5. The scientific report on which this overview is based also includes descriptions of the marine and terrestrial ecosystems of the Arctic, covering their ecological characteristics and the species that inhabit or migrate to them.

With regard to oil and gas, several aspects of the Arctic are noteworthy. Depending on where the boundary is drawn, the Arctic has between 2 million and 4 million inhabitants, most of whom live in cities or large towns. Arctic oil and gas reserves are a long distance from major markets. Conducting oil and gas operations in the region is difficult and expensive, as is transporting the products to market. Few inhabitants also means a small potential labor pool, so most workers are typically brought in from other regions, especially during the labor-intensive construction phase. Despite low numbers, arctic residents comprise over two dozen different indigenous peoples. Their subsistence hunting, fishing and gathering activities occupy extensive areas of land and sea. The influx of people and industrial activity has the potential to disrupt traditional ways of life while also providing many new opportunities. A detailed discussion can be found in the *Arctic Human Development Report*.[c]

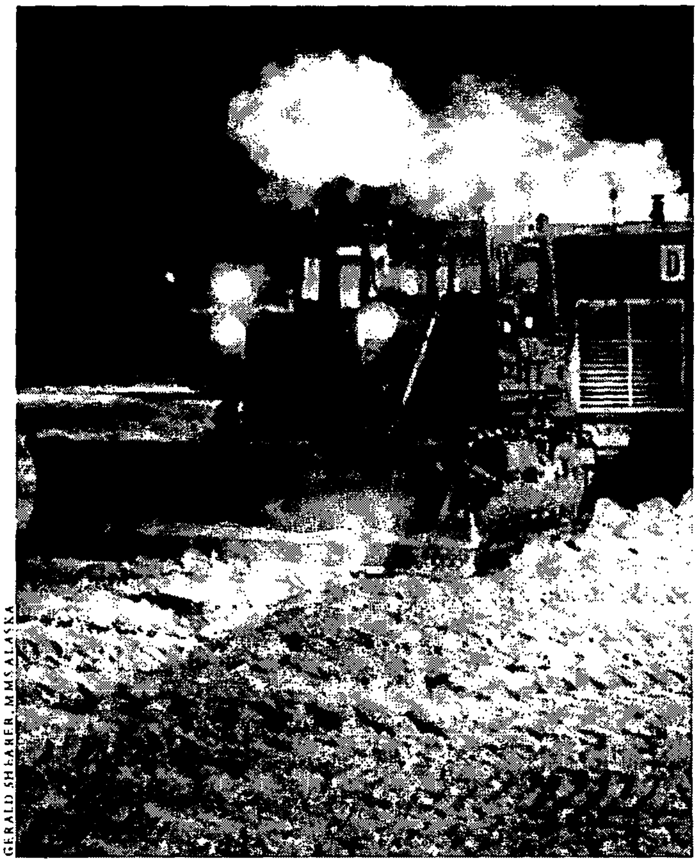
The Arctic experiences large seasonal variation, including extended periods of darkness and cold in winter and sunlight in summer. A burst of productivity in the short spring and summer has to sustain resident plants and animals through the rest of the year. This burst of productivity also attracts vast numbers of migratory species, especially birds, from throughout the world. The marginal ice zone is particularly productive and seasonal. Arctic ecosystems experience high variability from year to year, including large swings in population sizes. The Arctic has relatively few species, but considerable variation within species to fill various ecological roles. There are several types of Arctic char, for example, which can exist even in the same lake or river system. Many species, especially birds, migrate annually back and forth between arctic and temperate or tropical regions.

▼ Eider ducks resting at the floe edge.

▶ Steel tracked dozers, such as this one pulling a camp train in Alaska, are being phased out and replaced by rubber tracked tractors.

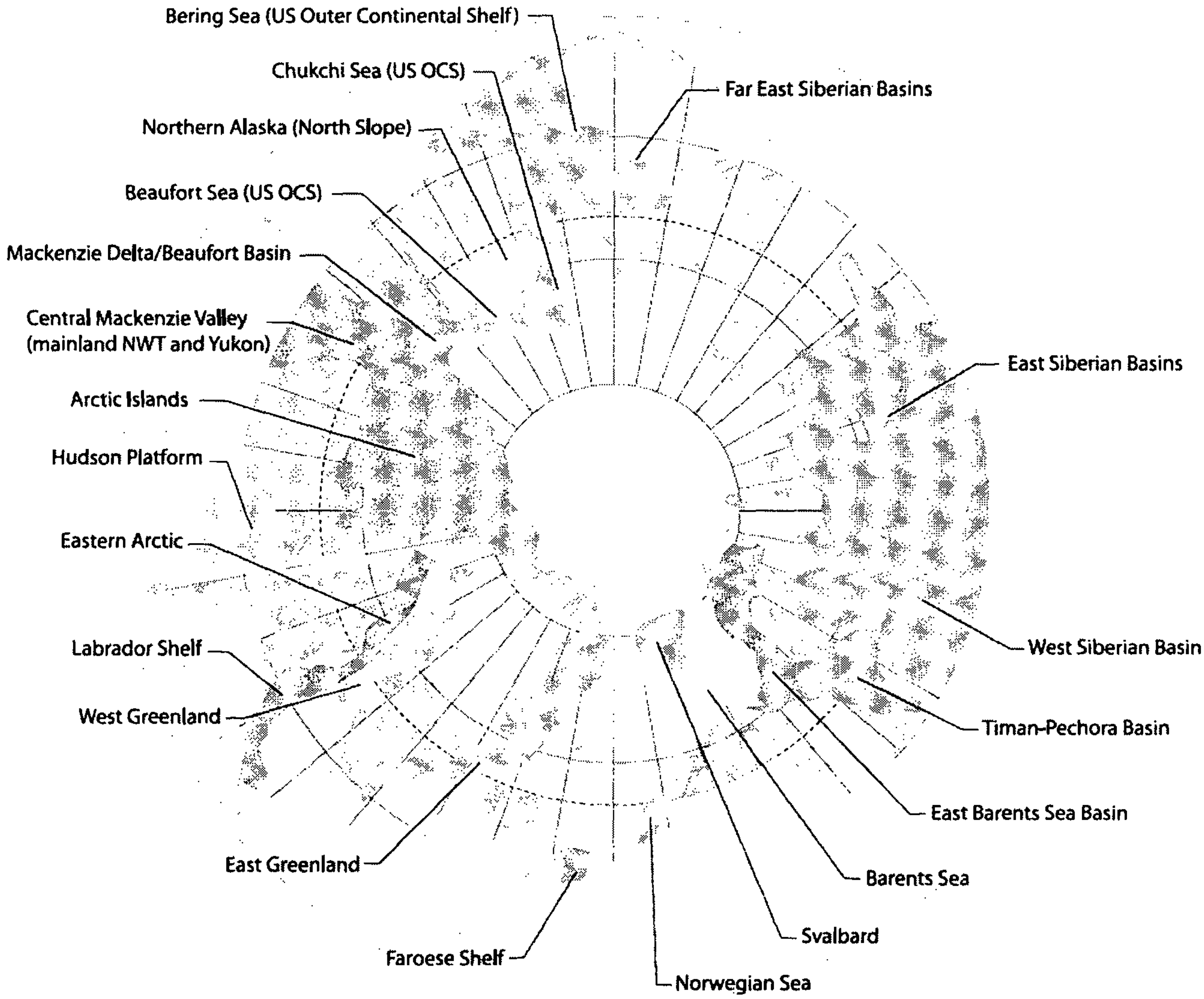


BRYAN & CHERRY ALEXANDER



GERALD SHEARER, MMS ALASKA

[c]AHDR, 2004. Arctic Human Development Report. Stefansson Arctic Institute. 249 pp.



▲ Major Oil and Gas Provinces (OGP) and basins around the Arctic.

The projected effects in the Arctic from global climate change indicate major changes in sea ice, permafrost, and other physical characteristics of the region. Population sizes and distributions of plants and animals are expected to change significantly, including the introduction to Arctic regions of species now found farther south, and possible disappearance of some species. Oil and gas activities, too, may have to change in response to climate effects.

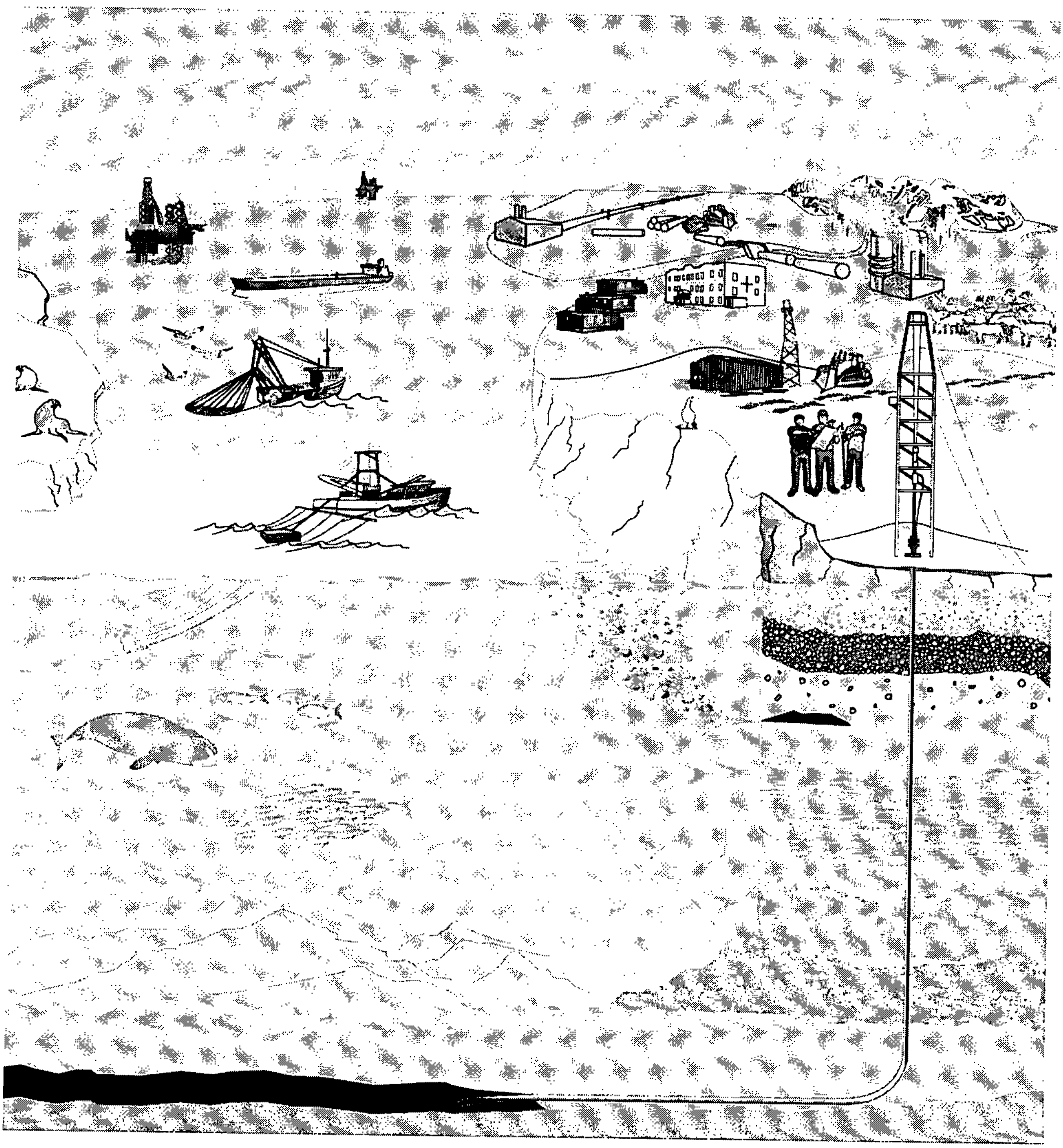
Oil and gas operations, too, must cope with swings in temperature, light, and accessibility. On land, many operations today take place in winter, when the tundra is frozen. Equipment can be moved more easily in off-road areas and precautions can be taken to minimize impacts. At sea, by contrast, much activity is concentrated in the ice-free summer months, including seismic surveys as well as shipments of fuel and supplies by barge or tanker. The ability to cope with spills will vary greatly by time of year and weather conditions, as well as the volume and characteristics of the oil spilled. Spills in broken sea ice and under ice remain the most difficult to respond to.

Finally, the Arctic contains some of the world's largest remaining areas of wilderness. Fragmentation of habitat may adversely affect many species, particularly highly mobile species such as reindeer and caribou and sparsely populated species such as brown or grizzly bears and other large predators. Many animals have dense seasonal aggregations on breeding grounds, along migratory pathways, or along the ice edge and in open-water polynyas in the sea ice, making them temporarily vulnerable to even a localized event. Aesthetically, the Arctic is a symbol of pristine nature. Its protection is an important goal for many people. Even without pollution or accidents such as spills, oil and gas activities can reduce the wilderness character of a region.

Oil and gas activities

Oil and gas operations comprise many activities. These activities are in turn connected to their environmental and social surroundings in many ways. The schematic diagram shown here illustrates how oil and gas activities fit into the landscape and how they can affect the environment and people.

▼ Generalized schematic diagram of oil and gas activities.

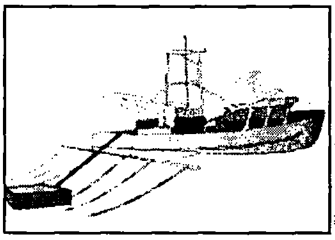


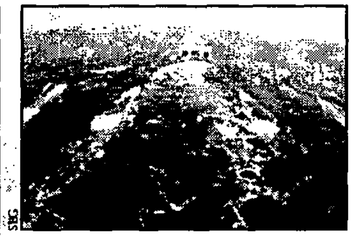
Lifecycle phases

Oil and gas activities include several phases and many distinct steps. The following diagram illustrates the main sequence and the specific activities that take place within each phase. In oil and gas regions with multiple fields, several phases may be taking place at the same time.

Lifecycle Phase — **Activities Included**

Evaluation

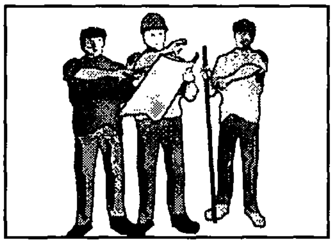




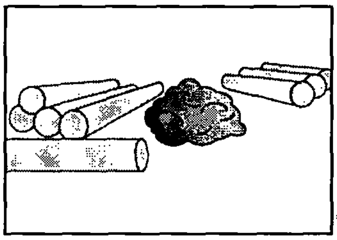
Leasing/licensing, resource studies, seismic studies, exploratory drilling, environmental studies, public consultation

Development

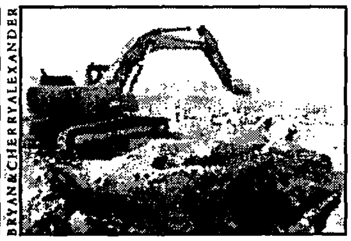
Delineation drilling; 3-D seismic; cost analysis; technical studies; environmental field work; public consultation; regulatory application and review, including environmental impact assessment



Construction



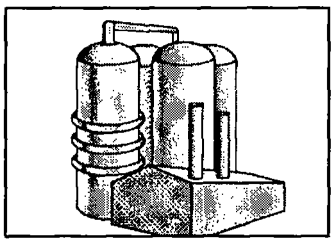
BRYAN&CHERRY ALEXANDER



Detailed design of facilities; production drilling; construction of facilities and pipelines

Production

Waste injection; waste management; spill prevention, preparedness, and response; environmental monitoring; transport, storage and refining



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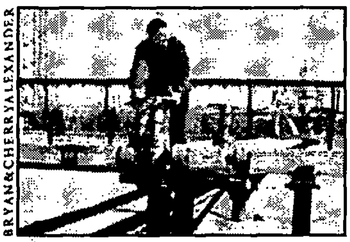
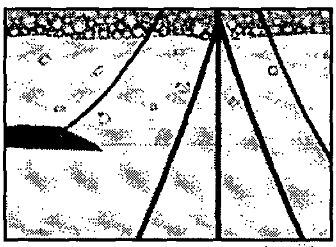
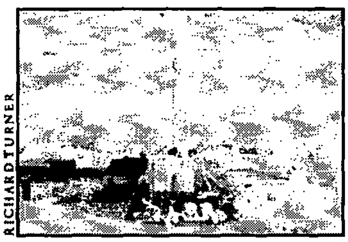


Enhanced Development



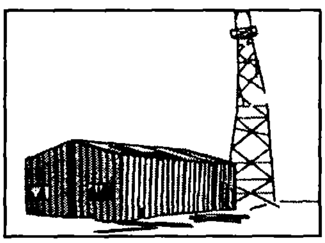
RICHARD TURNER



Satellite field development; enhanced oil recovery

Decommissioning

Plug wells; rig removal and decommissioning; land reclamation and restoration



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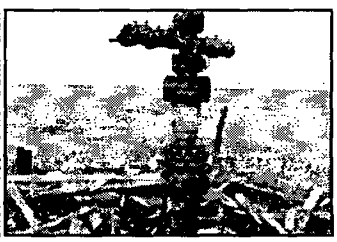


The chemicals associated with oil and gas activities

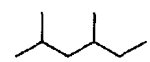
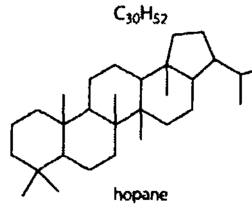
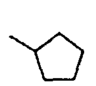
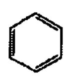
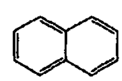
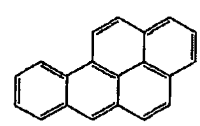
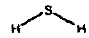
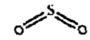
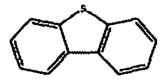
Crude oil and natural gas are composed primarily of organic compounds, made of hydrogen and carbon and thus known as *hydrocarbons*. Hydrocarbons associated with oil and gas are known as *petroleum hydrocarbons*, though they can also be found in coal and peat. Petroleum hydrocarbons are natural in origin, though as described in the next section, they still have the potential for harm. They tend to be biodegradable, unlike persistent compounds associated with other forms of industrial pollution.

Smaller, lighter molecules such as methane are gaseous at room temperature. Natural gas, therefore, is made up primarily of a few simple hydrocarbon molecules, though other compounds such as hydrogen sulfide are sometimes present, too. Larger and more complex molecules are liquids or solids at room temperature. Because of the many ways that carbon and hydrogen atoms can combine, often together with other elements such as oxygen and sulfur, the number of compounds found in oil is in the thousands. Although the concentrations of the various compounds vary from field to field, the composition of crude oil is broadly consistent around the world.

Hydrocarbons are often associated with oil and gas reserves and with human use of fossil fuels. They can also be created or released in various other ways. Living organisms can produce some hydrocarbons, as can burning in industry, agriculture, and natural events such as forest fires. The decay of plant material to form peat is a major source of hydrocarbons in some areas. Coal deposits can also release large quantities of hydrocarbons. The mere presence of petroleum hydrocarbons, therefore, is not necessarily linked to the presence of human activities or petroleum. Furthermore, volatile hydrocarbons can move long distances with moving air masses.

Oil and gas activities also involve other chemical compounds. These can be placed in two main categories: substances used to help in drilling operations and other phases of oil and gas production, and natural substances produced along with oil.

The term *drilling mud* refers to a mixture of clay, *base fluid*, and chemical additives, used to control pressure in the borehole, lubricate and cool the drilling bit, flush out the drill cuttings, and strengthen the sides of the hole. Oil-based drilling muds contain significant amounts of hydrocarbons (in the range of one or more percent), whereas the hydrocarbon content of water-based muds is usually in the range of hundreds of parts per million. Drilling muds account for the largest vol-

Class of compounds	*Description*	*Examples*		
Alkanes	*Alkanes* are compounds with one or more carbon atoms joined by single bonds in a chain, which may include branches. Hydrogen atoms are attached to the carbon backbone-like structure. The simplest alkanes, with one to four carbon atoms, are gases. Alkanes with more than twelve carbon atoms tend to be solids at room temperature.	CH_4 methane	C_8H_{18}  2,4-dimethylhexane	C_5H_{12}  pentane
Cycloalkanes	A *cycloalkane* is an alkane formed in one or more rings. Cycloalkanes come in many different configurations, from short rings with only three carbon atoms to larger *cycloparaffins* and those with two or more rings.	C_6H_{12}  cyclohexane	$C_{30}H_{52}$  hopane	C_6H_{12}  methylcyclopentane
Aromatics	Carbon atoms can also form rings of six atoms that have bonds that are one-and-a-half times the strength of a single bond. These chemicals are known as *arenes* or *aromatics*. If they have more than two rings joined together, they are known as *polycyclic aromatic hydrocarbons*, or PAHs.	C_6H_6  benzene	$C_{10}H_8$  naphthalene	$C_{20}H_{12}$  benzo[a]pyrene
Sulfur compounds	In addition to hydrocarbons, oil and gas reserves may contain sulfur compounds. Some, such as hydrogen sulfide, can be lethal and pose a threat to workers at drill and production sites. Others, such as sulfur dioxide, are pollutants both during production and during burning of oil and gas. Other compounds have an atom of sulfur incorporated into the hydrocarbon structure.	H_2S  hydrogen sulfide	SO_2  sulfur dioxide	$C_{12}H_8S$  dibenzothiophene

ume of chemicals used in oil and gas activities. Smaller amounts of chemicals such as herbicides, anti-fungal agents, anti-corrosion compounds, lubricants, and paints are used in other stages of oil and gas extraction, processing, and transportation.

Base fluids used to be primarily oil-based, and their discharges made up a substantial part of the pollution from oil and gas activities in some regions. Due to technological advances and stronger regulatory regimes, water-based fluids have largely replaced oil-based fluids in recent years. Water-based fluids are far less harmful to the environment. While in some cases they may be discharged offshore, in onshore drilling they are contained or reinjected.

When oil is brought to the surface, water and other materials come with it. This *produced water* may contain petroleum hydrocarbons, acids, various metals, production chemicals, and radionuclides. Disposing of large volumes of produced water and its contaminants can be a major environmental challenge.

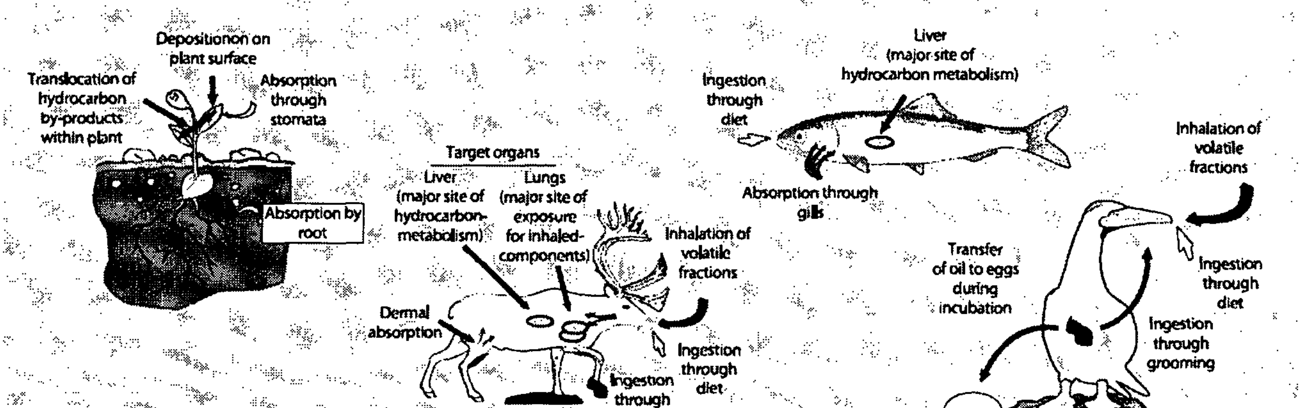
Toxicology of petroleum hydrocarbons

One reason for concern about oil and gas activities is the impact of toxic compounds on the environment and on people. The diverse types of arctic plants and animals may be exposed in a number of ways to a large number of compounds released by oil and gas activities. Exposure can occur from oiling of skin, fur, or feathers, by uptake across gill membranes, from the inhalation of gases, or the ingestion of released oil. The biological effects of hydrocarbon exposure can range from non-detectable to death, depending on the amount and type of hydrocarbons taken in and the duration of exposure. Numerous responses short of death have been observed, from the sub-cellular level to the population level (see Box). Vertebrates, including humans, are able to rapidly metabolize certain groups of hydrocarbons, such as PAHs, but the byproducts are often more harmful than the original PAHs. Some of these are carcinogenic. On the other hand, some microorganisms are able to use hydrocarbons as a carbon source and food supply.

Fish and aquatic invertebrates are sensitive to exposures to crude and refined oils and to numerous pure petroleum hydrocarbons. Larval stages of fish are among the most sensitive, with exposure often leading to mortality, partly because the many developmental processes in early life stages are particularly sensitive, and partly because they cannot move away from oil. For example, Baltic herring embryos suffered physiological impairment and anatomical deformities when exposed to oil in laboratory experiments. Invertebrates appear to be more tolerant than fish, even though they accumulate higher levels of petroleum hydrocarbons because they can neither metabolize nor excrete them as well as vertebrates can. Continuing research is identifying other potential impacts. Genetic effects have been detected from PAH exposure, for example, but their significance is not yet clear. Impacts to humans are discussed further on page 28.

Measuring the toxicity of petroleum hydrocarbons is often complex. The acute toxicity of a chemical is usually determined in laboratory studies. For example, fish may be exposed to a range of concentrations of a chemical to determine the level at which half the fish die within a given period. For petroleum hydrocarbons, this approach can be difficult. Many compounds either do not dissolve in water or evaporate quickly so that the concentration level changes over the course of the experiment. Acute lethal toxicity can therefore be difficult to measure, though it is the most commonly stated measure of toxicity. Other measures, such as the "lowest observable effect level" and other non-lethal responses are becoming more common. These approaches still face the problem of establishing the concentration levels at which the effects occurred.

In the environment, other factors can affect chemical toxicity, too. Ultraviolet light from the sun can interact with PAHs already absorbed into some animals. This is particularly of concern for animals that are somewhat translucent and that inhabit shallow water, such as larval fish. The mechanism is not clearly understood but the combination of ultraviolet light and prior exposure to PAHs is many times more toxic than either the light or the PAHs alone. In humans, skin reddening may be worsened by the combination of exposure to petroleum hydrocarbons and sunlight. For the Arctic, where decreasing levels of ozone in the stratosphere are leading to increased exposure to ultraviolet light, research is needed to determine if exposure to these chemicals may further increase the danger from ultraviolet exposure.



Routes of exposure

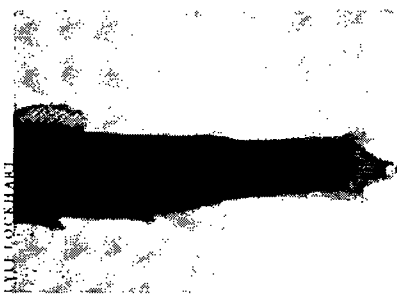
Types of effects from oil and gas activities

Oil and gas activities can affect the natural environment and people in many ways. Petroleum hydrocarbons are toxic to plants and animals, sometimes at very low concentrations. While routine oil and gas activities have produced relatively little hydrocarbon contamination, accidents such as oil spills are a different story. Oil spills can kill large numbers of animals by covering them in oil, and create long-term contamination that can affect populations and ecosystems for decades. On land, physical disturbance through industrial-scale activity can have impacts from the scale of individual gravel pads covering sections of tundra to changes in water flow of streams and rivers to the fragmentation of wildlife habitat. The slow recovery of disturbed areas in the Arctic suggests that the footprint of oil and gas activities will remain for several decades. Humans can be affected through pollution and also through social and economic changes resulting from the scale and scope of oil and gas activities.

Sections II and III of this report describe the major findings of the assessment with regard to these various types of effects in the Arctic (see Table below). Additional background information on certain effects is provided here in the Introduction. Toxicological effects and the difficulties of measuring them are described on the previous page (see Box). The challenges of detecting population-level effects from oil and gas activities are described on the next page (see Box).

Where different types of effects are discussed

Toxicological effects	Significance of levels of petroleum hydrocarbons in the Arctic, and significance of cold on toxicological effects.	Pages 20-21 - *Petroleum hydrocarbon concentrations are generally low*
	Toxicological impacts on people.	Page 28 - *Human health can suffer from pollution and social disruption, but revenues can improve health care and overall well-being*
Oil spills	Impacts of spills on land, including a description of the 1994 Komi Republic pipeline rupture.	Pages 22-23 - *On land, physical disturbance is the largest effect*
	Effects of marine spills, including those from subarctic spills such as the *Exxon Valdez*.	Pages 24-25 - *In marine environments, oil spills are the largest threat*
	Potential for impacts from arctic spills.	Pages 34-35 - *Seasonal patterns determine vulnerability in arctic ecosystems*
Physical disturbance	Impacts of infrastructure and activity on land surface and habitats.	Pages 22-23 - *On land, physical disturbance is the largest effect*
	Effects of offshore activity through noise and offshore construction.	Pages 24-25 - *In marine environments, oil spills are the largest threat*
	Significance of further habitat fragmentation and disruption.	Pages 34-35 - *Seasonal patterns determine vulnerability in arctic ecosystems*
Social and economic effects	Ways in which people are affected.	Pages 26-27 - *Impacts on people, communities, and governments can be both positive and negative*
	Implications for health care and related services.	Page 28 - *Human health can suffer from pollution and social disruption, but revenues can improve health care and overall well-being*



Detecting population-level effects

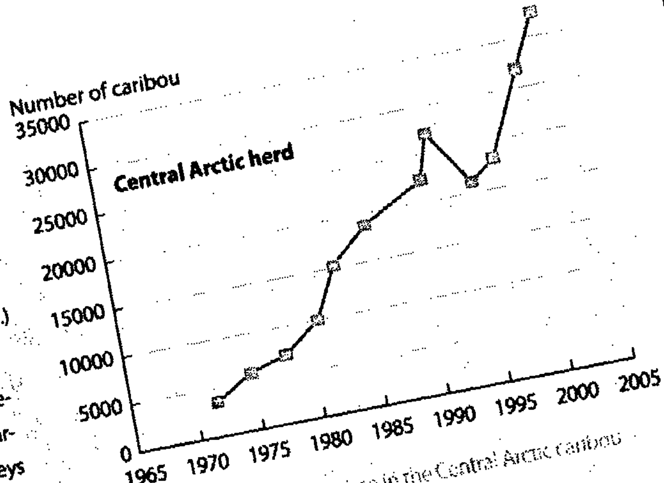
Oil and gas activities have many types of effects, but what do they mean for entire populations? ("Population" refers to a group of animals that tend to reproduce within the group, rather than with animals from other groups. Examples include bird colonies, caribou herds, or fish stocks. For effects on human populations, see page 28.) Several factors make it difficult to answer this question.

First, population parameters are poorly known for many Arctic species. Estimates of population size usually involve considerable margins of error because of the difficulty in conducting routine surveys and the large geographical expanses involved. Also, measurement of the reproductive health of the population, such as birth and death rates, the number of breeding adults, and rates that young animals are entering the breeding population are difficult to obtain in remote populations. Even where data exist, small changes in population are likely to remain undetected. Even large changes may be the result of other factors, including natural population cycles.

Second, even when declines are found, determining a specific cause and ruling out other factors may be difficult or impossible. For example in the case of pollution, all the individuals in the population are unlikely to have the same exposure, and the most highly exposed may have died as a result. Surviving animals may thus have lower levels of contaminants, especially for petroleum hydrocarbons, which are usually metabolized quickly. For migratory species, impacts from petroleum hydrocarbons may occur outside as well as within the Arctic.

Third, baseline information is often unavailable. This is especially true for oil spills, which can disrupt an entire ecosystem. Before-and-after comparisons cannot be started after the fact. For regular operations, some studies can be undertaken ahead of time to establish a baseline, but even these are unlikely to measure all relevant variables. Furthermore, change alone is not sufficient to indicate effects, as other factors in the ecosystem may play a role.

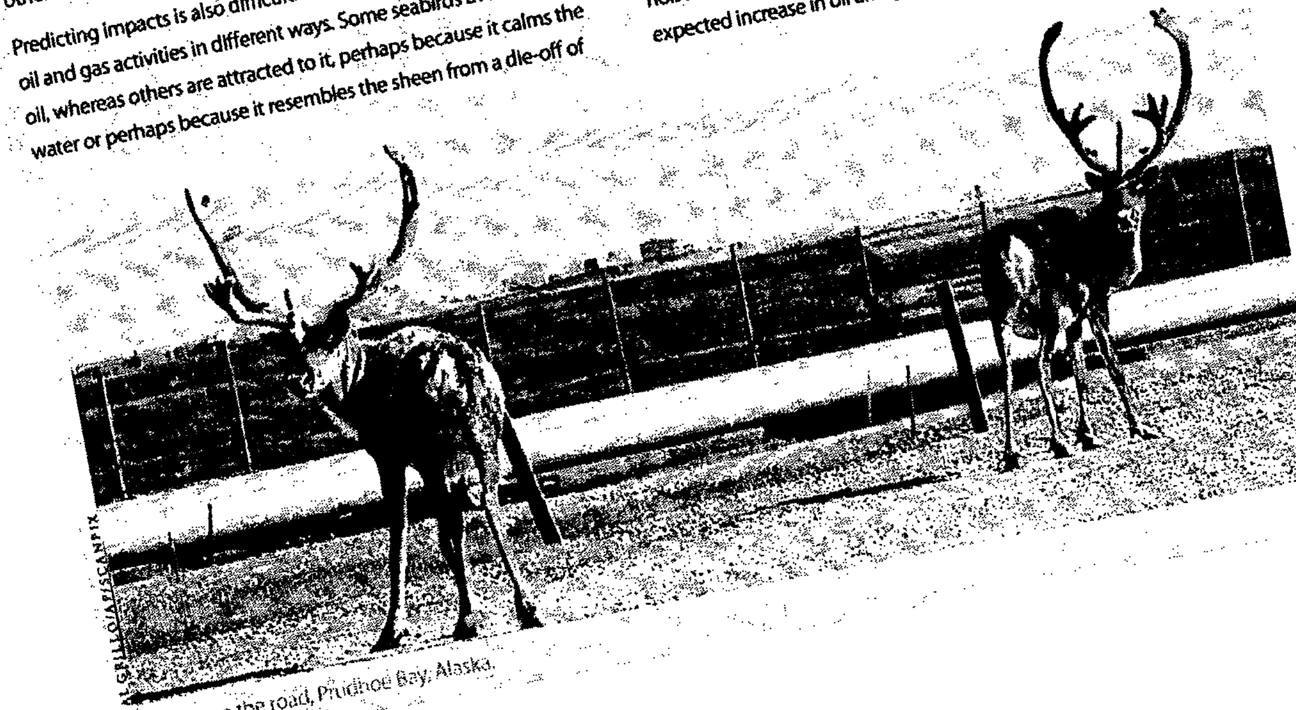
Predicting impacts is also difficult. Different species may react to oil and gas activities in different ways. Some seabirds avoid spilled oil, whereas others are attracted to it, perhaps because it calms the water or perhaps because it resembles the sheen from a die-off of the fatty invertebrates the birds prey on. On land, some predators are attracted to infrastructure and human activity, resulting in impacts to local prey or the need for nuisance animals to be removed.



Population changes over time in the Central Arctic caribou herd, Alaska

Some species and populations will recover more quickly than others (see Box on page 35 on seabirds). Other causes of mortality, reproductive rate, and long-term population trends are among the factors that will determine the ability to recover quickly. Vulnerable species will require greater protection during recovery, possibly including restrictions on harvests.

Non-lethal impacts can be more difficult to demonstrate. Even well studied cases of caribou-industry interactions such as the Central Arctic Caribou Herd in Alaska are inconclusive. The caribou have changed their distribution and show signs of disturbance, but the population actually showed a substantial increase during the first two decades of oil activity on the North Slope (see Figure). The increase, however, does not rule out long-term negative effects. A more recent decline in population may indicate delayed effects or may be the result of other factors including natural cycles. The study of cumulative impacts from several stresses, including changes in preferred habitat, changing climate, and man-made stresses such as noise and dust, is an important area of research, especially with the expected increase in oil and gas activity in the Arctic.



Caribou on the road, Prudhoe Bay, Alaska.

Implications of climate change for oil and gas impacts in the Arctic

The *Arctic Climate Impact Assessment*[d], another large-scale assessment produced by the Arctic Council, describes changes in climate and ecosystems that are projected over the coming decades in the Arctic. The report also discusses implications for various human activities, including construction and infrastructure. While *Oil and Gas Activities in the Arctic: Effects and Potential Effects* does not examine climate change in detail, it is nonetheless clear that environmental change will affect oil and gas activities in the Arctic, positively and negatively, in various ways.

The most striking change that is projected is the retreat of sea ice around the Arctic. Less sea ice may improve access to ports and thus some onshore areas as well as to parts of the offshore. Transportation by vessel, including tanker, will be aided by a longer shipping season, although changes in ice patterns may create new problems. More open water is likely to create larger waves and more coastal erosion. Facilities on the coast and offshore may need to be stronger to withstand additional wave stress. Icebergs, too, may become more common if calving of glaciers in Greenland especially increases, threatening offshore platforms and tanker traffic.

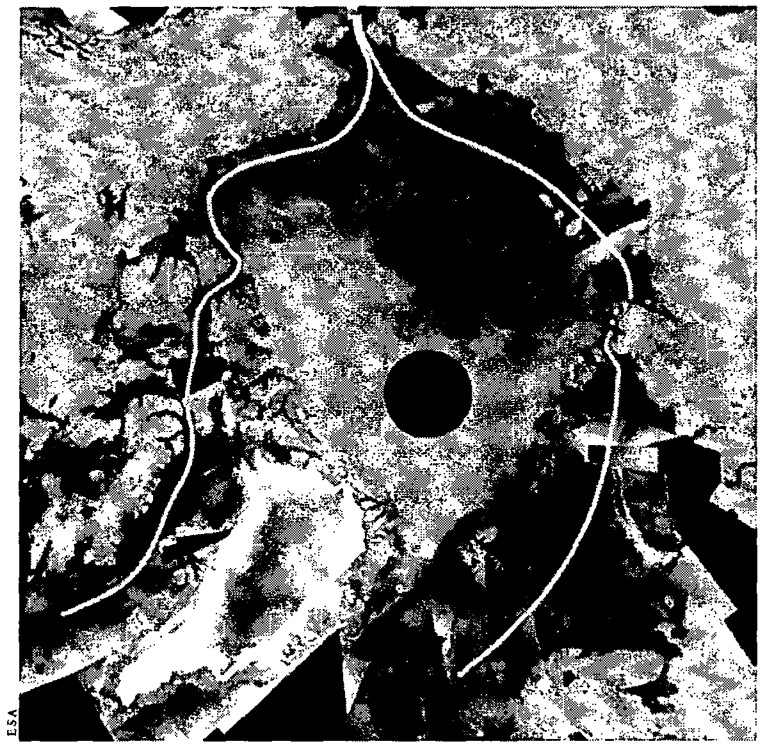
Another major change is the thawing of permafrost on land. Many arctic facilities today use permafrost as a solid foundation for buildings, pipelines, and roads, or for containing waste materials. Considerable care is often given to maintaining the integrity of the permafrost to avoid costly damage to infrastructure if the underlying ground melts and gives way. Warming may degrade permafrost, harming existing facilities, releasing waste materials, and making future development on land more complicated and expensive. The season for ice roads may shorten, restricting exploration activities as well as construction. Whether climate change will make the Arctic more or less attractive for oil and gas activities remains to be seen.

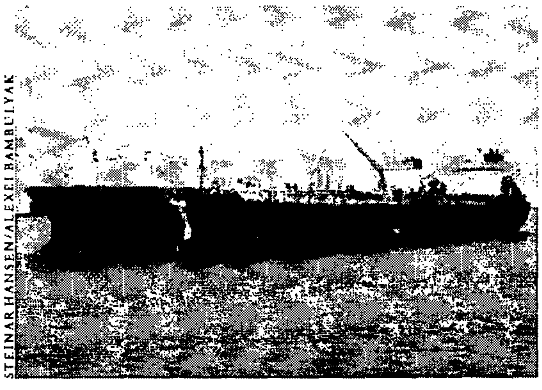
In addition to direct impacts on infrastructure and industry activity, climate change will have indirect effects as well. As ecosystems respond to climate change, the distribution and abundance of many species may change. Some species may become threatened or endangered. If oil and gas activities are predicted to have an impact on such species, environmental regulations and requirements may become stricter. It is also possible that shifts in the distribution of fish stocks may attract commercial fisheries to arctic waters, where they may overlap with offshore oil and gas activities. The same is true for traditional indigenous practices such as marine mammal hunting, if climate change leads to shifts in the areas where those activities are carried out. Here, too, the implications of climate change for oil and gas activities are not yet clear.

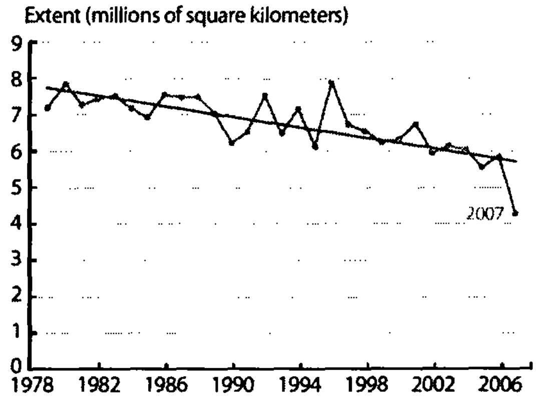
▼ Arctic sea ice conditions, summer 2007, showing open Northwest Passage.

▶ Transfer of condensate between tankers in Sarnesfjord, Norway.

▼▶ Recent observations of summer sea-ice extent.



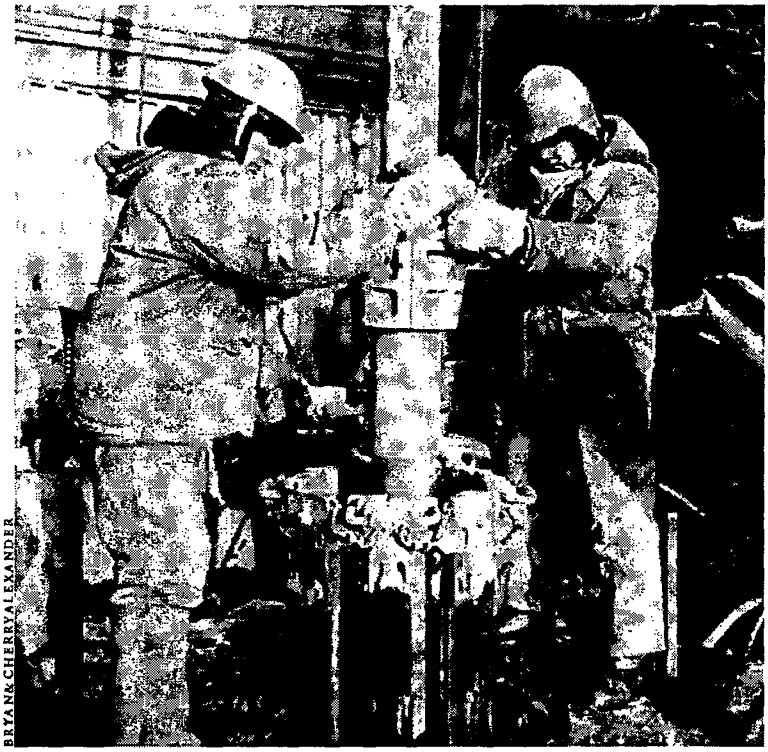




[d]ACIA, 2004. Impacts of a Warming Arctic: Arctic Climate Impact Assessment (ACIA), Cambridge University Press, 139 pp.

Oil and Gas Activities to the Present

Commercial oil and gas activities have been taking place in the Arctic for over eighty years. More widespread and intensive operations have occurred in several places since the 1960s. There is a great deal of experience on which to draw in assessing the effects of oil and gas activities. This section presents key findings concerning the history, extent, and social and environmental effects of oil and gas activities in the region to the present. These findings are the foundation for the next section, which examines the likely course of oil and gas activities in the next decade or so.



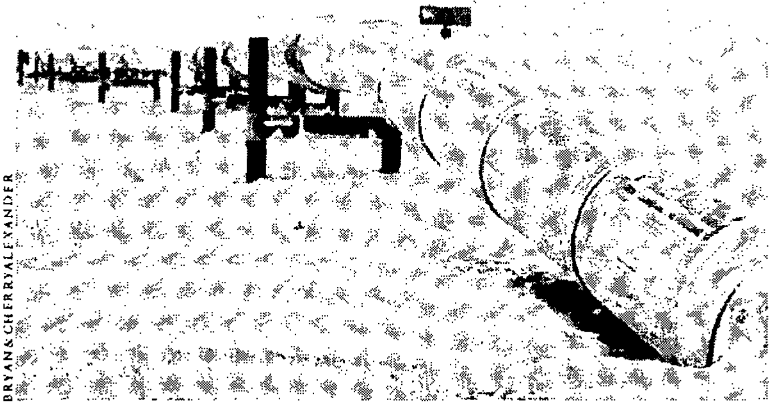
BRYAN & CHERRY ALEXANDER

▲ Workers on a gas drilling rig in the Bovanenkova field, Yamal, Western Siberia, Russia

Extensive oil and gas activity has occurred, with much oil and gas produced and much more remaining

In some arctic areas, oil seeps have been known and used by indigenous peoples for centuries or longer. Commercial oil activities in the Arctic started in the 1920s at Norman Wells, Northwest Territories, Canada. In 1933, a refinery was built there to provide fuel for local use. In the 1920s and 1930s, oil and gas exploration was also carried out in northern Russia and in Alaska. During World War Two, a 925-kilometer pipeline was built to transport oil from Norman Wells to the newly built Alaska Highway to provide fuel for the military. Although this pipeline was abandoned in the 1940s, eventual expansion of the field took place in the early 1980s with a pipeline being built south to Alberta. Following World War Two, extensive oil and gas exploration started in northern Alaska, northern Russia, and the Mackenzie Delta area of Canada.

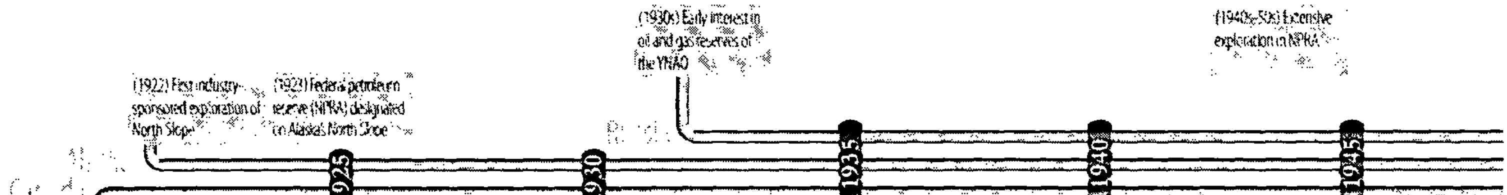
▼ The mile marker 0 zero at the start of the Alaska Oil Pipeline Prudhoe Bay, Alaska

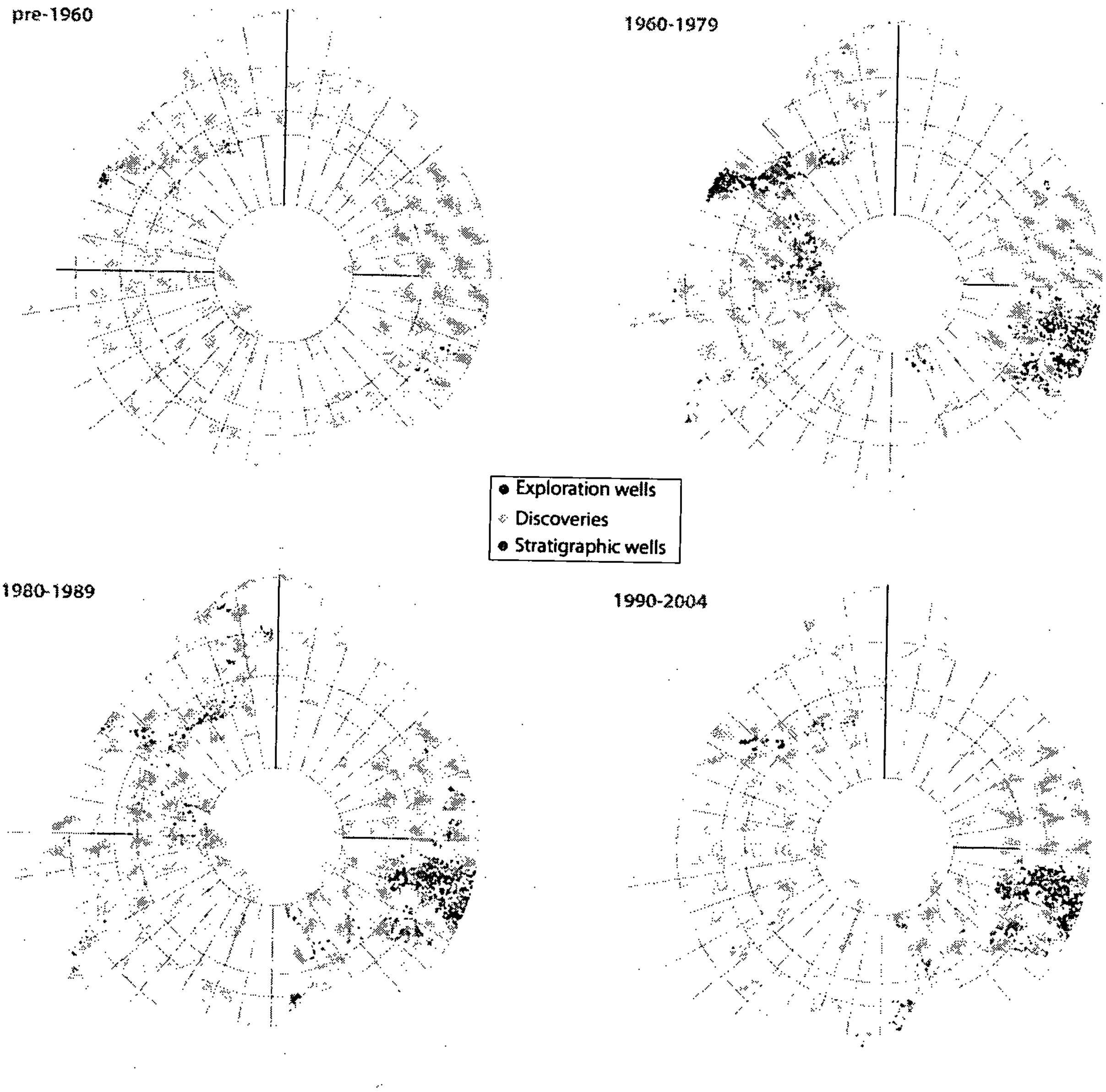


BRYAN & CHERRY ALEXANDER

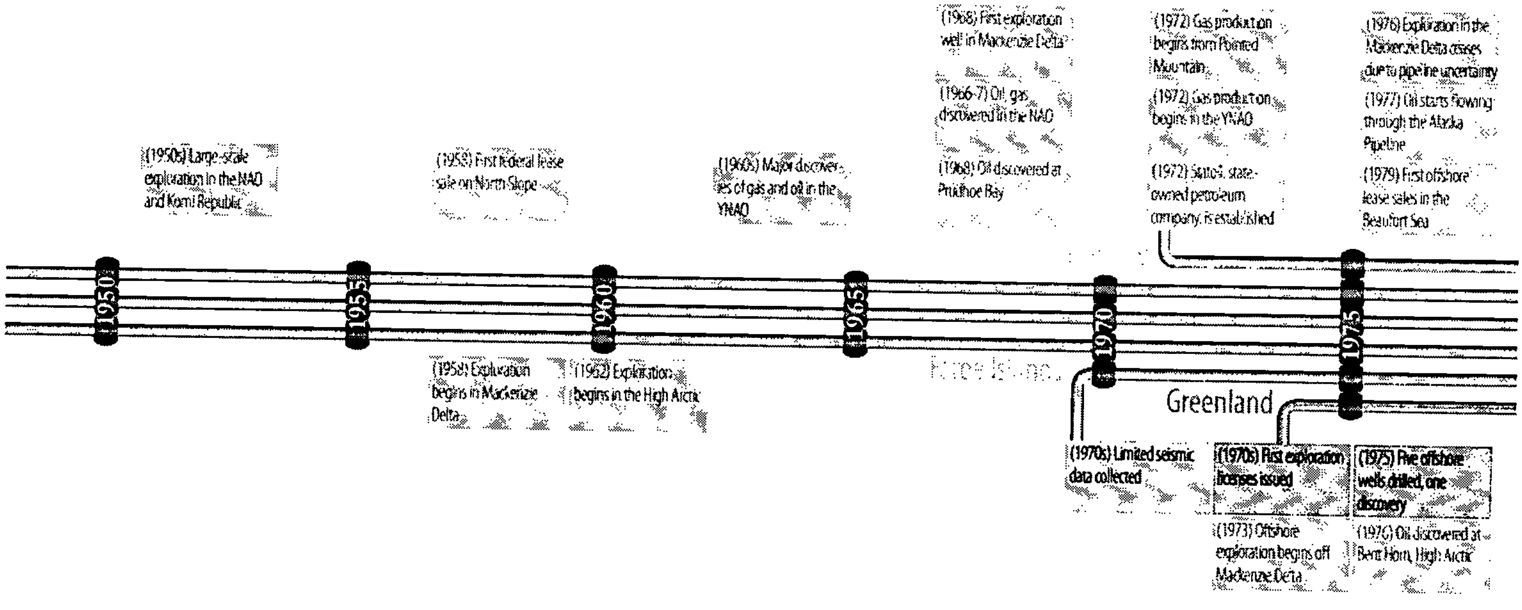
By the 1960s, large oil and gas reserves had been discovered in the Yamalo-Nenets Autonomous Okrug and the Nenets Autonomous Okrug in Russia, on Alaska's North Slope, and in the Mackenzie Delta. All four areas are remote from potential markets, requiring the construction of long pipelines. Production in arctic Russia began in 1972 from the Yamalo-Nenets region, extending to the Nenets region in the 1980s. The Trans-Alaska Pipeline System was completed in 1977, allowing production to begin from Prudhoe Bay and nearby fields. The Mackenzie Delta and Beaufort Sea, by contrast, still await the construction of a gas pipeline. Plans were developed in the 1970s, but costs were too high, land claims unsettled, and social impacts uncertain. The plans were put on hold at that time, although construction is being proposed again.

A large barrier to arctic oil and gas operations is the cost of transporting the product to markets. Once a pipeline or tanker facilities have been built, however, the development of additional fields can become more attractive. The spatial extent of oil and gas activities can expand over time, as roads and feeder pipelines are built to connect new drilling sites. The incentive for such growth can be high when production at the original fields declines, leaving excess transportation capacity. One result is that a region may experience several lifecycle phases at the same time. Production and enhanced development continue in the core area, with construction on the margins, and exploration farther out.





▲ Expansion of exploration drilling activity in arctic oil and gas provinces. Locations of drilling during different periods.



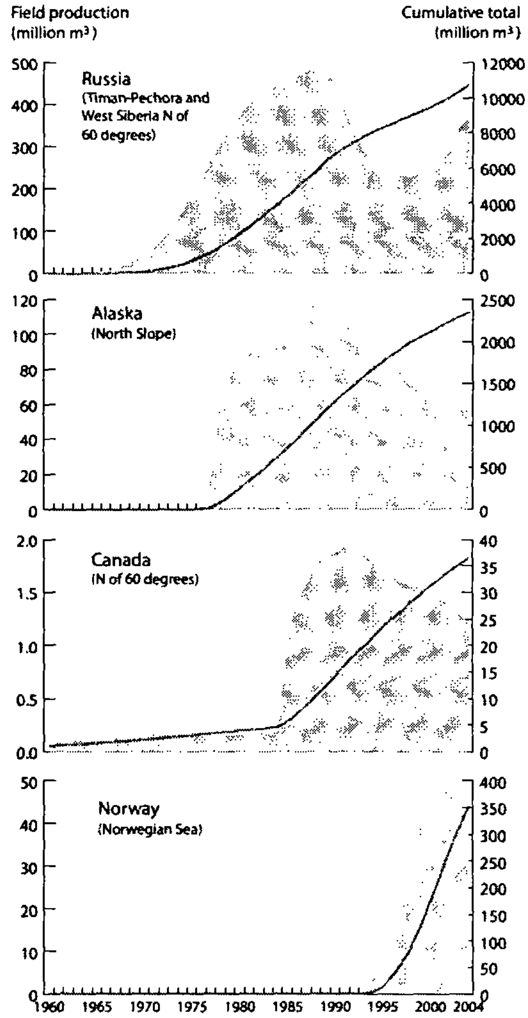
▸ Annual and cumulative oil production in arctic areas, by country.

▸▸ Annual and cumulative gas production in arctic areas, by country.

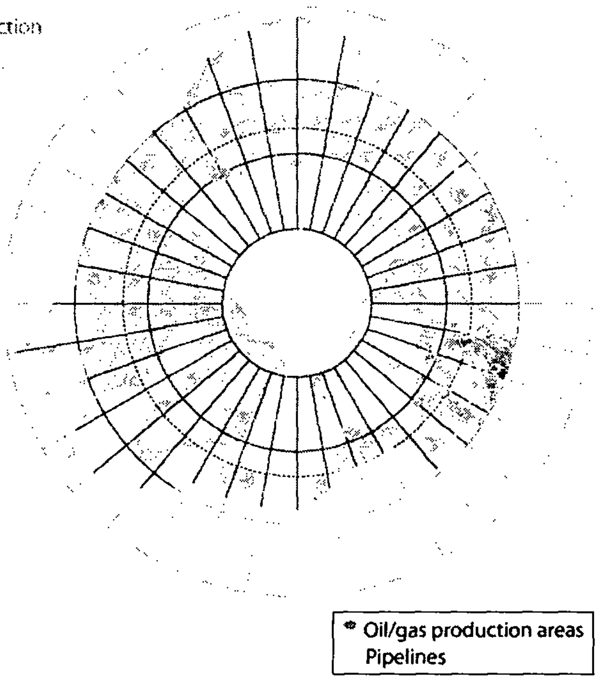
Note: Scales on the graphs differ considerably. For comparison, the upper graphs (Russia) also include the production curves for other countries shown on the same scale.

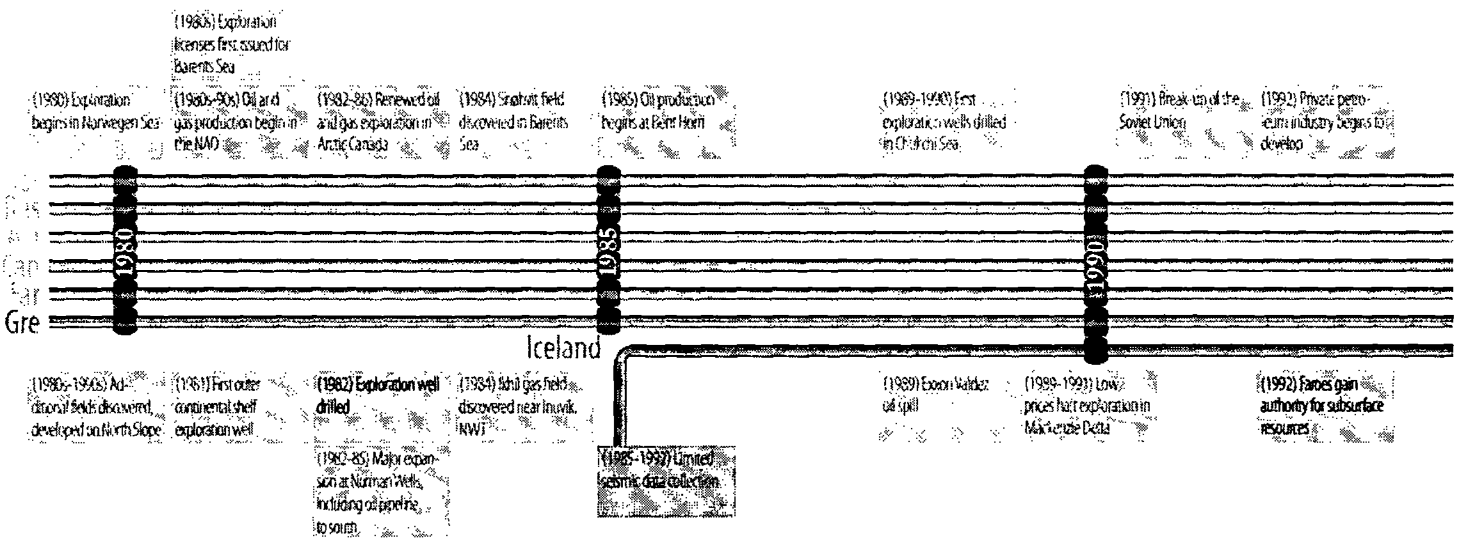
The level of activity or production, however, does not necessarily follow a simple curve or trend. As the graphs of arctic oil and gas production show, production typically begins with a steep rise once transportation infrastructure is built. Over time, additional fields are brought into production, which may sustain overall production levels or at least reduce the speed of decline as in northern Alaska. Other factors play a role, too. The break-up of the Soviet Union led to a period of low production in the 1990s, though levels have since risen again.

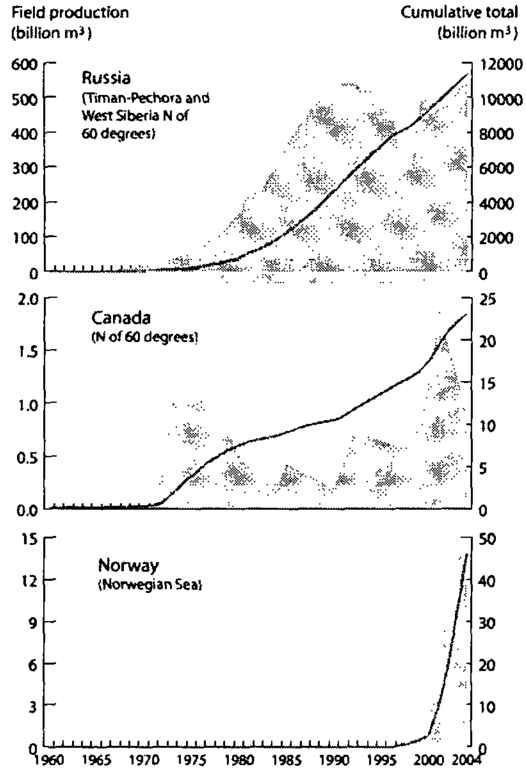
By the 1980s and 1990s, oil and gas activities had extended farther in the Arctic. Canada had developed Bent Horn, a small field in the islands of the High Arctic, which produced oil for over a decade before decommissioning. In Alaska, exploration extended offshore, leading to development and production of nearshore fields. Norway's oil and gas activity reached the Barents Sea, identifying major gas fields from which production will soon begin. Exploration activities in the Russian offshore have also identified large potential resources. In the 2000s, tankers began to deliver oil from arctic Russia to Europe. Exploration in the Mackenzie Delta and Beaufort Sea has begun again in anticipation of a pipeline through the Mackenzie River Valley. Alaska, too, may see a gas pipeline built in the near future, allowing extensive North Slope gas reserves to enter production alongside its oil.



▸ Oil/gas production areas in the Arctic.







Cumulative production from the Arctic to date is in the billions of cubic meters of both oil and gas. Today, the Arctic produces about a tenth of the world's oil and a quarter of its gas. Of these amounts, about 80% of the oil and 99% of the gas currently come from the Russian Arctic. As discussed later (see pages 32-33), considerable resources remain to be exploited in the Arctic, both in areas where activity is currently taking place, and perhaps in new areas such as Greenland, Iceland, and the Faroe Islands. Oil and gas activities will remain part of the Arctic for many decades to come.

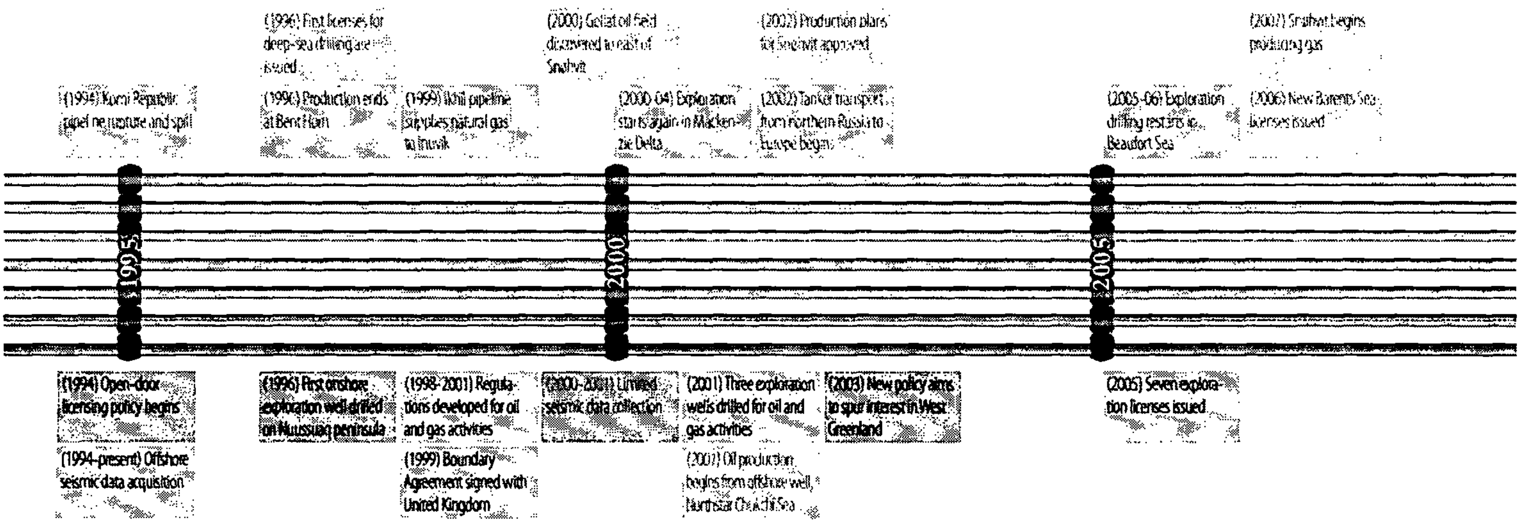
Measuring oil and gas

Quantities of oil and gas are measured in various ways. Units of volume can be converted easily, for example from barrels to cubic meters, or cubic feet to cubic meters. Other conversions are more complex. Different reservoirs have crude oil with different densities. A tonne (1000 kg) of one oil may have a different volume than a tonne of oil from another oilfield.

One measure for gas is the *petroleum equivalent*, or the amount of gas required to produce as much heat as a given quantity of petroleum. In this case, the composition of the gas, especially water vapor content, affects the amount of heat produced and thus the petroleum equivalent. Different countries may measure heat content differently, making direct comparisons difficult.

Some approximate conversions:

Oil	
Cubic meter	6.29 barrels 0.855 tonnes 1000 liters
Barrel	0.159 cubic meters 0.136 tonnes 42 U.S. gallons
Gas	
Cubic meter	35.3 cubic feet
Cubic foot	0.0283 cubic meters
Cubic meter petroleum equivalent	1008 cubic meters of gas 35600 cubic feet of gas
Barrel petroleum equivalent	5660 cubic feet of gas 160 cubic meters of gas



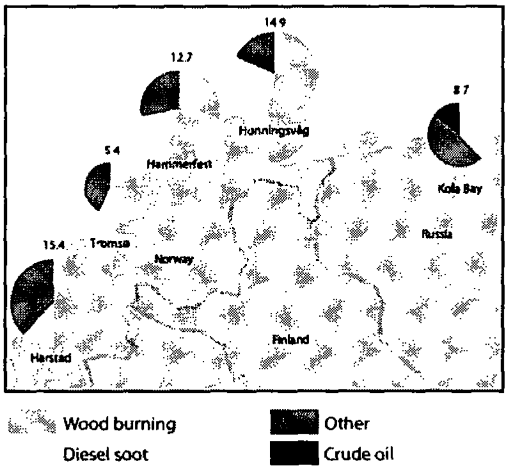
Natural seeps are the major source of petroleum hydrocarbon contamination in the arctic environment

Petroleum hydrocarbons found in the environment have a number of sources. They are transported from these sources by air and water. To assess the relative magnitude of various sources and the fates of petroleum hydrocarbons in the arctic environment, a petroleum hydrocarbon budget was created (see Figure). This budget compiles what is known from the best available information about sources, movements, and eventual fate of petroleum hydrocarbons in the arctic environment. Completion of the budget required filling in several data gaps with expert opinion and informed conjecture.

Eighty to ninety percent of petroleum hydrocarbons entering the arctic environment at present are thought to come from natural seeps. For example, oil seeps are found along the Mackenzie River, Northwest Territories, Canada, in the intertidal zone along the Alaska coast, and undersea in Scott Inlet and Buchan Gulf in the eastern Canadian Arctic. Methane is released from submarine "mud volcanoes" in the southern Beaufort Sea. Oil spills are the largest human source, followed by industrial activity excluding oil and gas activities in the region, and then the use of petroleum products such as fuel and lubricating oils, some of which escape as exhaust or from leaks. Excluding oil spills, oil and gas activities themselves are a relatively minor contributor of petroleum hydrocarbons. Long-range transport of petroleum hydrocarbons from industrial areas to the south is another input, although relatively minor and dispersed.

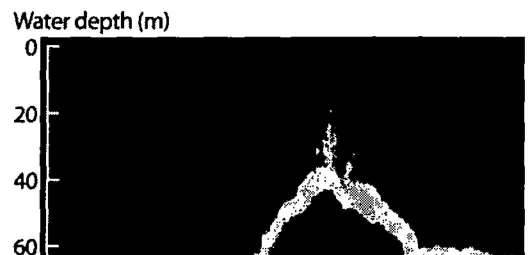
Even if human inputs are a small proportion of the total, they can create substantial local pollution. Some areas with high human activity, such as harbors, have sediment levels of petroleum hydrocarbons and other substances that are several times higher than in sediments from more remote areas. A lack of detailed information about oilfield pollution in many areas, particularly from northern Russia, prevents a more thorough assessment of its extent and significance. Transport and spills from general use of refined petroleum products also account for a significant part of the petroleum hydrocarbon pollution. Even on Alaska's North Slope, only half of reported oil spills between 1995 and 2002 were from the petroleum industry itself. Many non-industry spills are not reported.

Today, many industrial sources have been greatly reduced or eliminated. For example, from the 1970s until their discharge was banned in the 1990s, oil-based drilling muds were the main pollutant from offshore drilling.

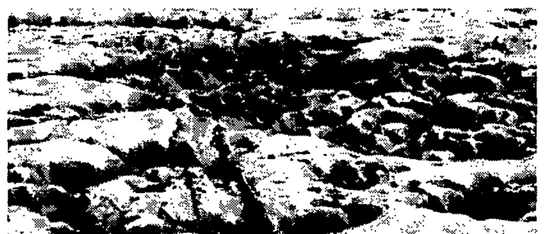


PAH contamination (mg/kg dry weight) in bottom sediments from harbours in northern Norway and Russia, showing the contributions from various sources.

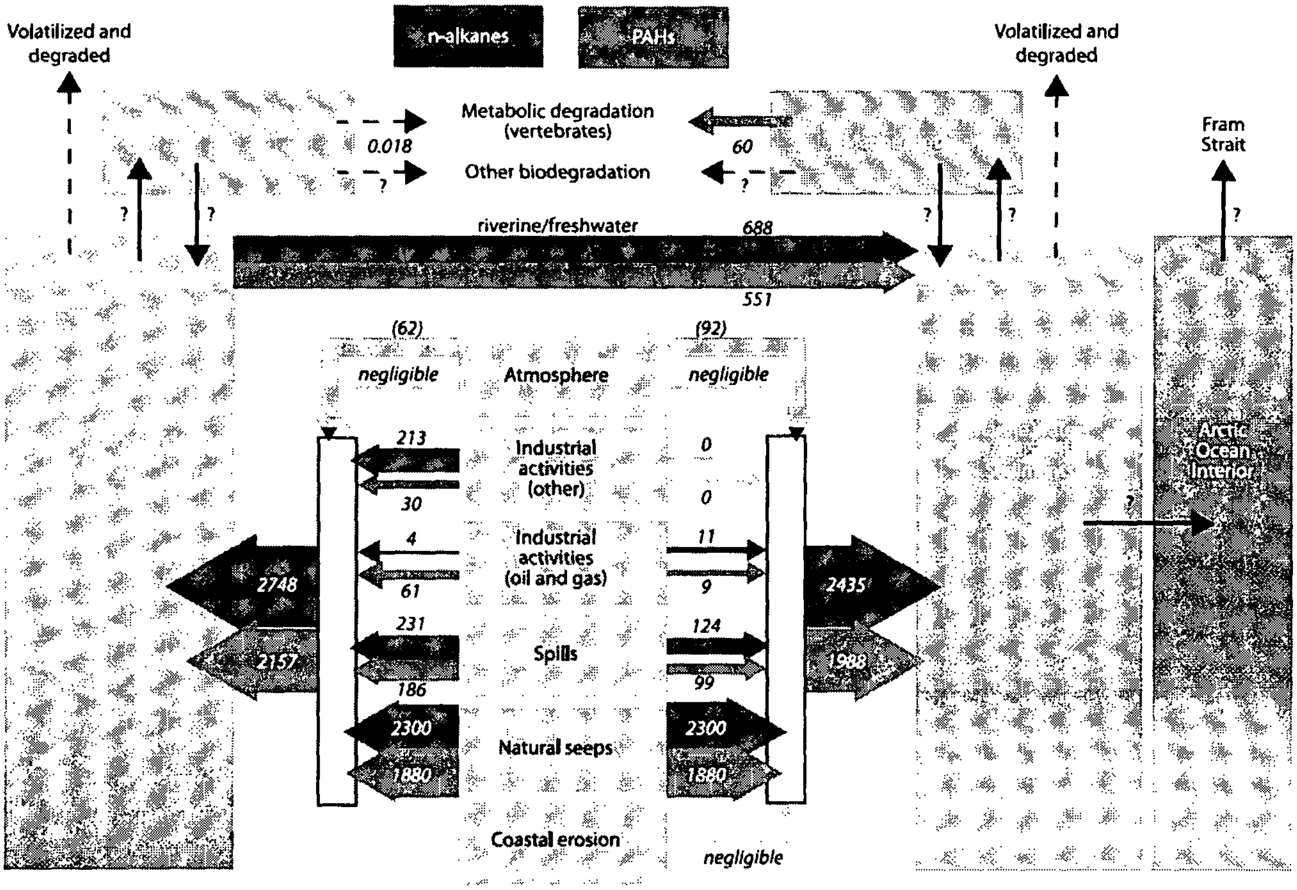
Seep in pond near Cape Simpson, Alaska.



Echo sounder cross-section of the Kopanoar mud volcano with methane venting from crest, central Canadian Beaufort Shelf.



Seabed multibeam image of the Kugmallit Bay pockmarks (active methane vents), Central Canadian Beaufort Shelf.



▲ Schematic diagram of the petroleum hydrocarbon budget of the Arctic; inputs via the atmosphere are primarily non-petrogenic. Units: tonnes per year.

The petroleum hydrocarbon budget of the Arctic

The petroleum hydrocarbon budget of the Arctic developed for this assessment is the first of its kind. It attempts to quantify amounts of petroleum hydrocarbon compounds associated with different sources and their movement between different environmental compartments. Not all the data needed for the budget are available, and so several assumptions have been made. The result is that the budget should be treated as qualitative rather than quantitative. The budget also covers the entire Arctic. The proportions of each source or movement are likely to vary considerably from one local area to another.

The budget uses selected petroleum hydrocarbons. Many of the chemicals that make up crude oil are not measured in the environment. Many of these chemicals also have sources other than petroleum. The budget uses selected alkanes and PAHs, which together make up about ten percent of crude oil. The ratios of particular compounds in these groups can help identify whether their presence is a signal of petroleum or another source. They are also persistent and ubiquitous. Finally, datasets for these compounds are among the most comprehensive for petroleum hydrocarbons in the Arctic.

Many assumptions have been made to fill gaps in the available data. These assumptions are best estimates, but they are still estimates and not measures. The major ones are:

- Natural seeps to the marine environment are based on rough estimates for the globe and for northern Alaska. There are few if any direct measurements of marine seepage rates anywhere.
- Natural seeps on land have been estimated at approximately the same as marine seeps.
- With little evidence for natural seeps in Russian rivers, the compounds measured there were considered to be either from sources other than petroleum, or associated with spills in the watersheds and thus placed in the "spills" category.
- Some of the quantities used for spills are based on using an average spill loss rate for various types of transportation (ship, rail, pipeline, and other means).

Although this approach results in large uncertainties with respect to some of the inputs, the budget nonetheless provides insight into relative magnitudes of the main sources of petroleum hydrocarbons to the Arctic over the past decade or so. Projections of peak activity two to three decades in the future show that increasing oil and gas activity may result in that sector providing inputs greater than half of those from natural sources. Further work on the budget, especially with new and better data, will create a more accurate picture of the sources and fate of petroleum hydrocarbons in the Arctic.

Petroleum hydrocarbon concentrations are generally low

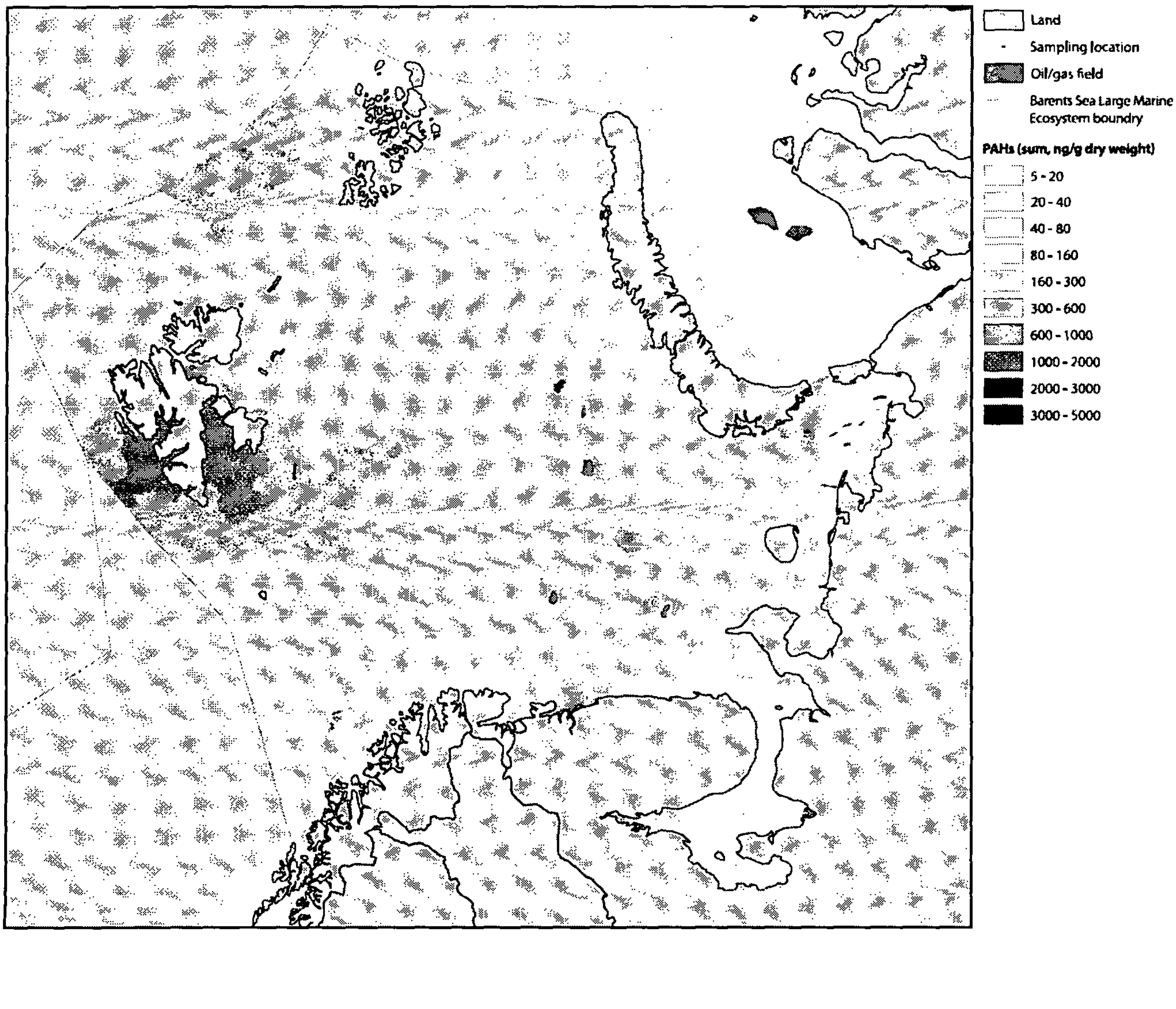
Hydrocarbons are naturally occurring compounds, and are found throughout the world. The Arctic is no exception. Away from areas of human activity, petroleum hydrocarbon levels are generally low on land, in rivers, and in the ocean, confirming the results reported by AMAP in 1997/98. The levels of PAHs in the air in the Canadian Arctic, for example, are a thousand times lower than levels in British cities, and ten to a hundred times lower than in rural Britain. Recent studies of sediments in the Barents Sea confirm results from the 1990s showing low levels of petroleum hydrocarbons, although two- and three-ring PAHs have increased in some areas.

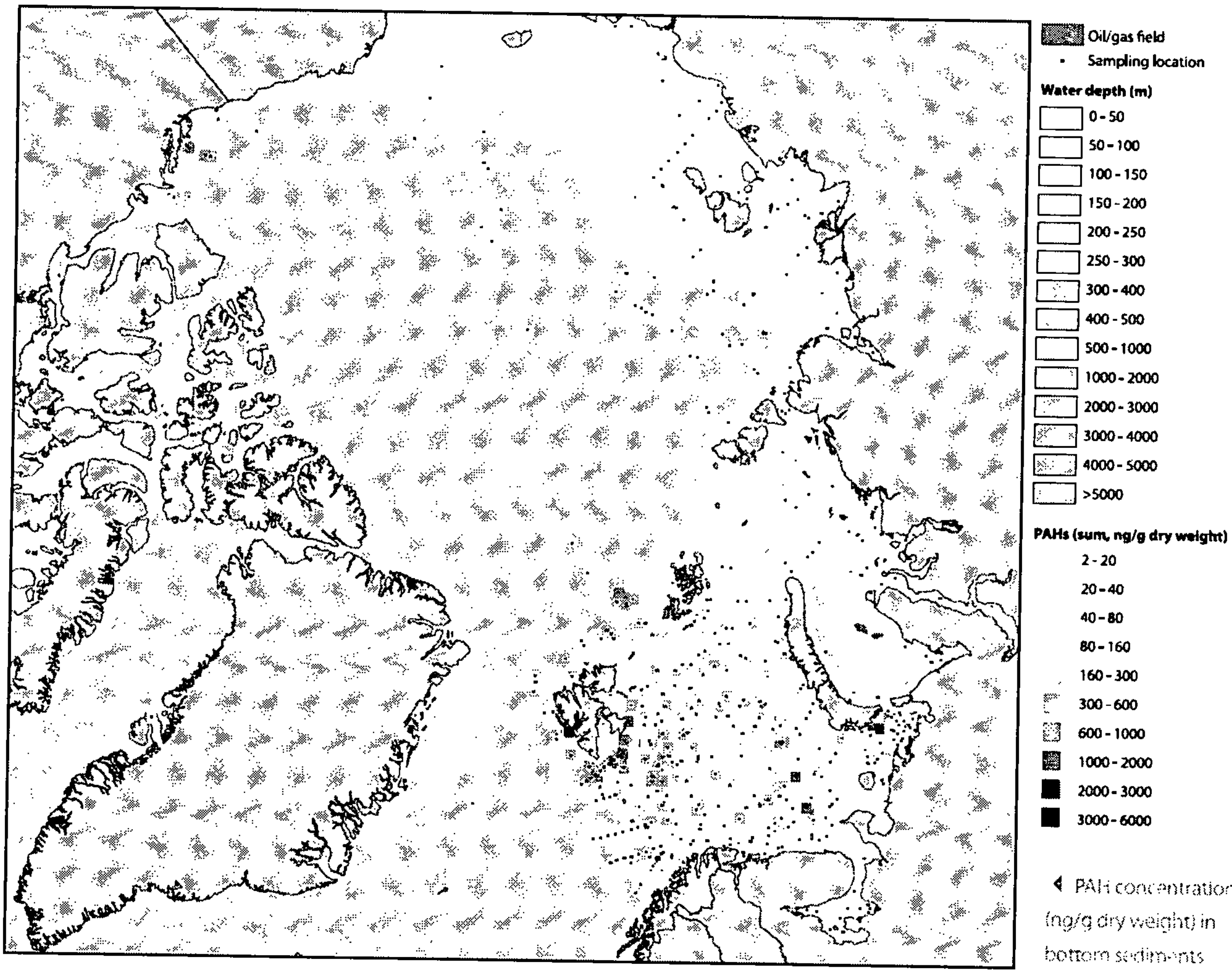
Some areas, however, show greater concentrations. Svalbard, for example, has coal-rich geological structures that weather and erode, releasing hydrocarbons into the surrounding waters. Water in the Mackenzie River has ten times the PAH levels of smaller rivers nearby, due to the presence of oil seeps in the Mackenzie River basin. The levels in Siberian rivers are believed to be similar to those in smaller rivers in Canada.

There is less information about petroleum hydrocarbons on land and in freshwater systems. Low levels of PAHs have been found in fish and sediments in isolated lakes in Svalbard, Greenland, and Canada, presumably as a result of atmospheric transport from distant or nearby sources. Only in Russia has long-term monitoring been conducted on land and in freshwater systems. In other regions, relatively little work has been done. Many living organisms tend to metabolize hydrocarbons quickly. Measurements in vertebrates thus tend to reflect very recent exposures rather than cumulative exposure over their lifespan.

The significance of exposure to various concentrations of petroleum hydrocarbons depends on the levels at which biological and health effects can be expected in the species inhabiting an area. For most of the Arctic, petroleum hydrocarbon levels are below known thresholds for effects. In areas of local contamination such as harbors or high background levels such as the Mackenzie River, however, concentrations are high enough to expect effects. In the Arctic, low

▼ PAH concentration (ng/g dry weight) in bottom sediments of the Barents Sea. Fine structure and hot spots shown on interpolated maps, such as this, should be viewed with caution, however the general trends, such as the high concentrations around Svalbard are clear. Individual data are shown in map on next page. Grey shades indicate water depth (see figure next page).





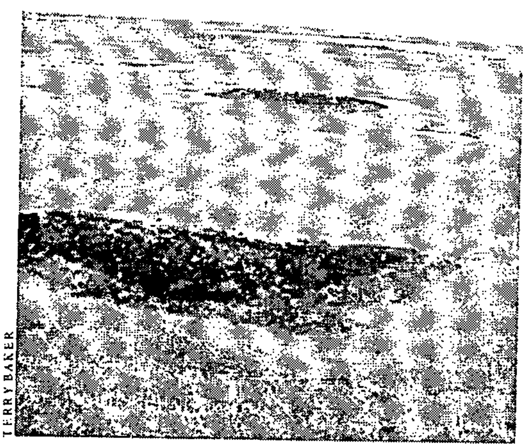
PAH concentration (ng/g dry weight) in bottom sediments around the Arctic, 2001-2005. Data are from various sources compiled by AMAP for this assessment.

temperatures usually mean that hydrocarbons will persist longer in the environment, thus having more time to be taken up by plants and animals.

In general, arctic plants and animals may be expected to have similar sensitivity to petroleum hydrocarbon exposure as that of plants and animals elsewhere in the world. Arctic conditions, however, may have implications for toxicological effects that are not yet understood. Spills in permafrost may persist for a long time, killing plants via their roots. In these conditions, the most toxic compounds may not degrade or evaporate, but remain to cause damage. Little is known about how petroleum hydrocarbon toxicity might be affected by ecological, physiological and behavioral traits that are unique to arctic species and allow them to survive under extreme climatic conditions. Thus, more research is required to determine if arctic animals are likely to be more or less sensitive to petroleum hydrocarbons. Furthermore, little research has been done with cold-adapted animals to examine the effects of temperature on toxicity. This information is necessary to determine the risk posed by the levels of petroleum hydrocarbons currently detected in various areas of the Arctic.

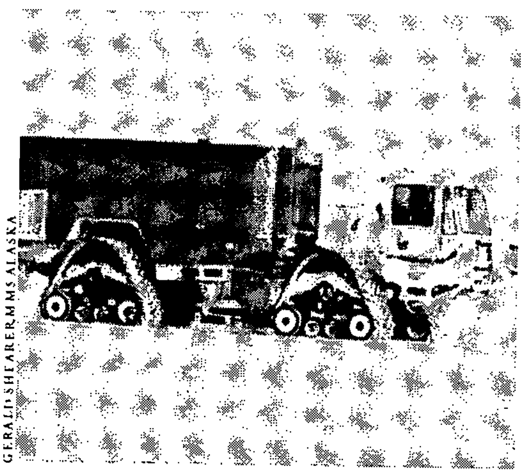
Sediment core sampling, Svalbard.

▸ Drill site and sewage sump, northern Canada.



TERRY BAKER

▸ Modern tracked seismic exploration vehicle with vibrator plate down, Alaska.



GERALD SHEARER, MMS ALASKA

On land, physical disturbance is the largest effect

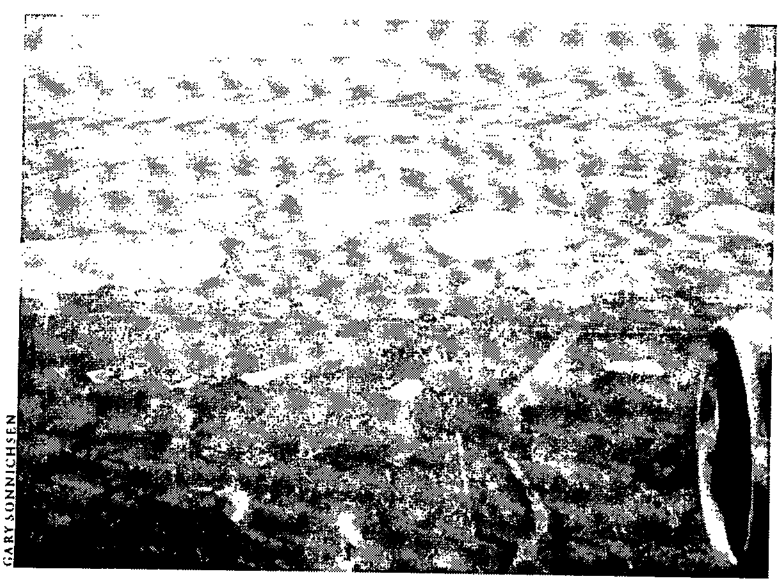
The largest effect of oil and gas activities on land in the Arctic has been physical disturbance. The physical footprint of oil and gas activities includes land covered by gravel pads, roads, and airstrips. In Alaska, Canada, and Russia, pipelines extend for thousands of kilometers. Roads and off-road vehicle tracks may impede water flow or cause permafrost to thaw. Debris and other material left on the land can affect migrating reindeer and attract foxes, bears, and wolverines. Construction typically includes the use of large quantities of gravel, often extracted from deposits or riverbeds. All of these activities may leave scars on the tundra that can persist for decades and disturb freshwater habitats.

Infrastructure can also influence a larger area than just the physical footprint. Dust from roads can affect vegetation a few hundred meters downwind. Animals such as caribou and reindeer have been shown to avoid or change behavior around pipelines and roads, with associated vehicle traffic, an effect that may extend for several kilometers. These disturbances, especially in places where industry activity is intensive such as around production facilities, can affect reindeer herders and hunters in particular by forcing animals away from their usual migration paths or preferred feeding and calving areas.

An even more widespread impact is habitat fragmentation. Networks of roads, rail lines, pipelines, settlements, and human presence can inhibit the animal movements, particularly for migratory species, such as caribou and reindeer, and other wide-ranging species, such as wolves and bears. The configuration of infrastructure influences the severity of the impacts from fragmentation. Long, linear structures such as roads or pipelines have particularly extensive effects. Some measures, such as elevating or burying pipelines, allow animals to pass and thus reduce impacts. Continuous vehicle traffic, on the other hand, increases the impact of a road. Even the use of ice roads instead of permanent roads can result in increased aircraft traffic and associated impacts from noise in summer when ice roads have melted. Extensive infrastructure can also reduce the aesthetic values that people place on undisturbed wilderness.

In assessing the significance of physical disturbance, major improvements in industry practices in recent decades need to be recognized. Newer approaches, including avoiding summer exploration on land, the use of seasonal ice roads rather than permanent gravel roads, and the use of extended-reach drilling to reduce the size and number of drilling pads, result in fewer physical impacts. This will be especially noticeable in areas where oil and gas activities occur for the first time. In areas where activities have long taken place, evidence of disturbance often comes from old sites where practices were designed on the basis of limited understanding of the arctic environment and the capabilities of now-outdated

▾ Tracks on the tudra left by seismic exploration vehicles, Mackenzie Valley, northern Canada.



GARY SONNICHSEN

technology. Such disturbance can nonetheless continue to cause problems.

Recent improvements cannot change the fact that large areas of tundra have been affected by past oil and gas activity, particularly in Russia. Tundra vegetation and the underlying permafrost are highly sensitive to disturbance. A vehicle track can remain visible for decades. Removal of plant cover and the organic soil layer can lead to thawing of permafrost, turning land into a swamp or pond. Such impacts can be seen in and around many major oil installations, such as older exploration sites on Alaska's North Slope or older facilities in northern Russia. Their effects are likely to persist for a long time. Attempts at revegetation of disturbed areas in Alaska, Canada, and Russia have generally met with varied success, depending on the vegetation type and severity of damage. Some areas have been revegetated successfully, whereas in others the new vegetation dies when watering and fertilization are stopped.

Another concern for land areas is the risk of oil spills. Pipelines leak, accidents happen, and the results may include both chronic and acute pollution. A number of oil spill experiments in Canada, Greenland, and Alaska have shown that plants are directly impacted by spilled oil. Many plants die immediately upon contact. Some long-term experiments have shown that the oil can continue to affect plants directly if it moves into the root zone. Studies have shown that the most toxic components in the spilled oil can remain in soils for decades, and do not degrade unless exposed to the atmosphere. In cold conditions, spills take a long time to degrade. To date, however, most spills on land appear to have had relatively modest environmental impacts, particularly at any distance from the spill site (see Box).

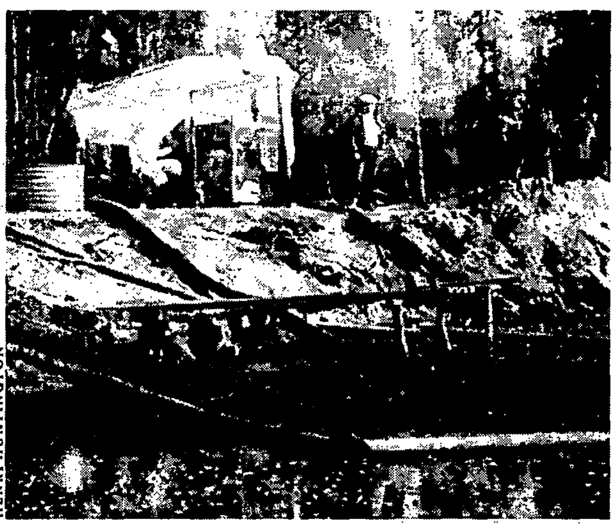
The 1994 Komi Republic oil spill

In 1994, a 52-kilometer section of pipeline in the Komi Republic, Russia, ruptured in 23 places. A dam built to contain the spilled oil failed, releasing probably more than 100,000 tonnes of oil. The oil contaminated 116 hectares, and an additional 164 hectares were damaged during the response effort. Nearly three square kilometers of land and many kilometers of the Kolva and Usa river waterways were contaminated from this single event. Extraction of sand and gravel to make roads and dams during the spill response stripped vegetation from the surface, leaving only barren subsoils. Similarly, sites where heavy equipment or fire was used to contain or remove oil were heavily affected. In the end, much of the oil was recovered or burned.

Along streams where oil was present for only a short time, plants were already growing again in the spring of 1995. Areas that were covered in oil for longer periods took longer to recover. By 2003, 14 hectares were still damaged. Where oil had been cleaned up in 1995, petroleum hydrocarbon levels in the soil were moderate and vegetation was growing. In places where oil had not been removed, no plants were growing, even though the oil had largely disappeared. The ecology of the Kolva River changed as well. For example, the abundance of European grayling decreased by 90% between 1995 and 1998, though had increased slightly by 2000. The overall effects on the ecosystem remain poorly understood.

The 1994 pipeline rupture was not an isolated incident. As with many pipelines built during the period prior to the break-up of the former Soviet Union, leaks were common and maintenance was minimal. A 1999 study of pipelines in the region found that chronic leaks had severely contaminated 745 hectares with over 130,000 tonnes of oil. More recently, Russia has undertaken major overhaul of its pipeline system, replacing and repairing many of the older pipe with modern systems.

HENRY HUNTINGTON



HENRY HUNTINGTON

Cleaning-up oil after the Komi spill.

In marine environments, oil spills are the largest threat

At sea, large oil spills are generally considered to be the largest environmental threat, though smaller, diffuse releases of oil can also have substantial impacts. In contrast to spills on land, large marine spills are difficult to contain and may spread over hundreds if not thousands of kilometers. Nearshore facilities and tanker routes near land pose a greater risk of coastal damage than offshore facilities from which spills may disperse more widely in the ocean. Large spills are fortunately rare events, but their impacts can be lasting and substantial.

To date, there have been no large oil spills in the arctic marine environment from oil and gas activities. Large spills in southern Alaska (*Exxon Valdez*) and the North Sea in Europe give some indication of the likely impacts should such a spill occur. A smaller spill in the Gulf of St. Lawrence, Canada, in 1969 as ice was breaking up affected thousands of young harp seals as they migrated from their whelping sites on the ice. Based on these and other experiences, the potential impacts of an arctic spill are likely to be severe for arctic species and ecosystems. In the Arctic, seasonal aggregations of animals, such as marine mammals in open water areas in sea ice, seabirds at breeding colonies or feeding sites, or fish at spawning time, may be particularly vulnerable, regardless of the size of the spill. This risk includes smaller, diffuse spills that might occur from increased shipping in the Arctic. Oil can be picked up on the breast feathers of adult birds and transported to the nest and cover the eggs, the most sensitive stage to oil toxicity, and fledgling birds in the nest.

One of the greatest effects on birds and other animals comes from physical coating by oil. This can interfere with many physiological processes. Stressed animals can also be more susceptible to toxic effects of petroleum hydrocarbon exposure. For seabirds and fur-bearing animals such as sea otters, oil reduces the insulating qualities of feathers and fur. Particularly in cold environments, these animals can suffer hypothermia and die, as happened to nearly 1000 sea otters and more than 100,000 seabirds following the *Exxon Valdez* oil spill in Alaska in 1989. Animals can also ingest oil while preening their feathers or licking their fur, leading to death or other biological effects in both the short- and the long-term. While fish metabolize hydrocarbons quickly, they may retain enough to affect their quality as food. Tainting of fish products has been reported in several spills in subarctic seas and even in the Cameron River in the Canadian Arctic. Such tainting has led to the closing of fisheries, decline in consumption of fish, and reduced sales of fish.

In the aftermath of an oil spill, chronic seepage from residual oil can keep petroleum hydrocarbon levels elevated in bottom-dwelling invertebrates, some of which are prey for seabirds and other animals. Recent studies from the subarctic suggest that this lingering effect is the reason that five of the nine seabird species injured by the *Exxon Valdez* spill have not yet recovered. Black oystercatchers and harlequin ducks continue to show signs of exposure to oil nearly two decades after the spill.

Whales and most seals, which rely on blubber rather than fur for insulation, are generally less vulnerable to oiling. However, seals that form large groups during pupping may be more vulnerable, as are the pups themselves. Oil may affect the eyes and

▼ River tanker transferring oil to ice reinforced tanker, Ob Bay, Russia.

MBESD/ALEXEI BAMBULYAK

▼ Oiled seabirds, *Exxon Valdez* spill, Alaska.

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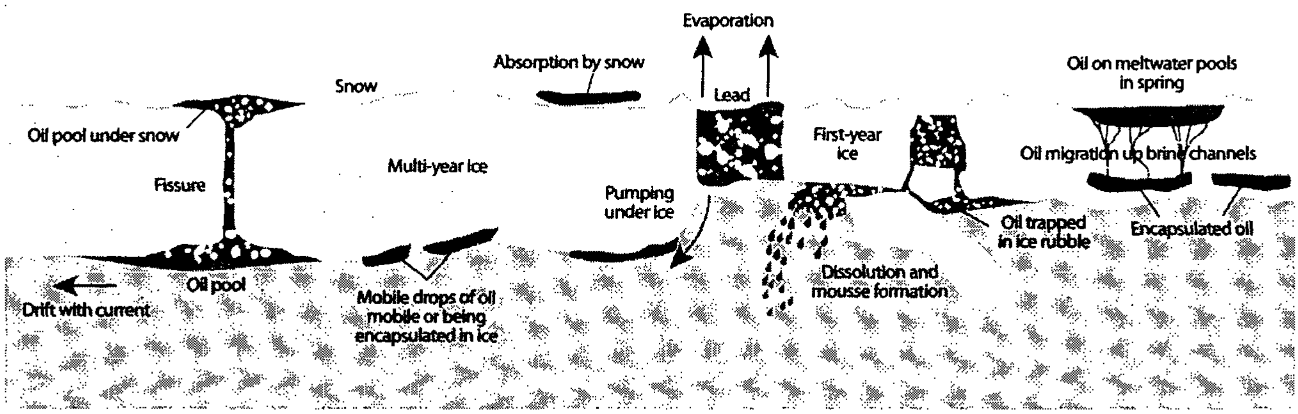


▲ Schematic diagram of the behavior of oil in ice covered water.

◀ Boom and ice.

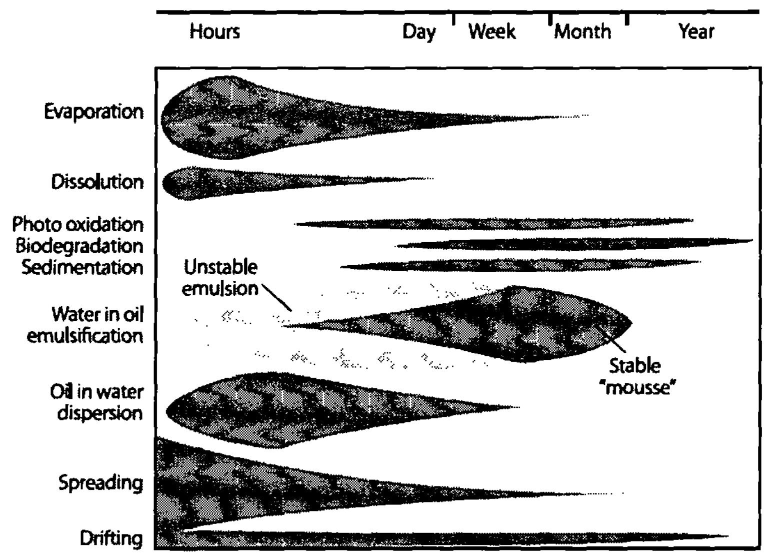
breathing in the vapors of a spill may be harmful. Baleen whales could be especially vulnerable if their baleen plates, used to trap prey, become fouled with oil, although this effect has not been found to date.

Some northern fish species, such as polar cod, arctic cod, saffron cod, and navaga, spawn under sea ice in winter. Their eggs incubate there and hatch when the ice begins to melt in spring, a time when plankton blooms occur and the larvae will have food to eat. An oil spill in such spawning areas could severely reduce that year's recruitment to the population.

In addition to spills, oil and gas activities have other impacts in the marine environment. Physical disturbance includes the construction of gravel islands and causeways, many of which have been built on the northern coast of Alaska. They can impede fish migrations and nearshore water flow. Plumes of mud, trenches and holes, and piles of excavated material can disturb bottom-dwelling animals. The use of icebreakers can affect ice habitats and create considerable noise.

Fish and marine mammals avoid sources of undersea noise such as seismic exploration or offshore drilling. However, no long-lasting effects on fish stocks or marine ecosystems have been found. Most animals seem to revert to normal behavior when the noise ceases. The effects of noise can extend tens of kilometers from the source. In the Beaufort Sea off Alaska, bowhead whales have been observed to change swimming direction in response to noise sources up to 30 kilometers away. In fact, sound has been suggested as a means of diverting bowhead whales from oil spills. Whale hunters in northern Alaska report having to travel farther offshore to find whales, which they attribute to the whales' displacement from nearshore areas by industrial noise. Animals that cannot move away from the noise may be harmed by noise. Limitations on noise-producing activities when species are concentrated or unable to move far can help reduce impacts.

▼ Fate of spilled oil - the most important weathering processes and their time windows.



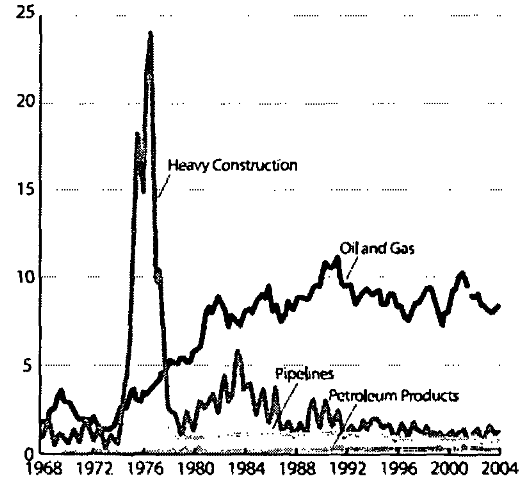
▶ Alaska quarterly oil and gas employment, 1968-2004, showing the sharp spike in construction employment during the building of the Alaska Pipeline in the mid-1970s followed by more stable, but lower, employment during the production phase.

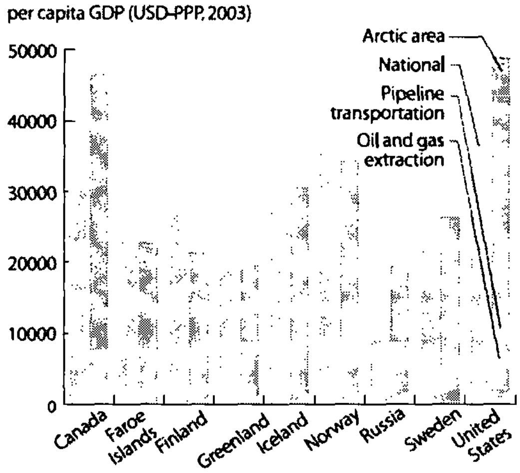
Impacts on people, communities, and governments can be both positive and negative

In the regions where they occur, oil and gas activities are major contributors to regional and national economies. As such, they are also drivers of social and economic change. Industrial activity creates employment opportunities and can also stimulate local businesses. Public revenues from taxes and royalties can be used to pay for improved public services, including schools and health care. At the same time, the magnitude and pace of development can mean more money to handle and the absence of one or more adults from the household during work periods. The arrival of large numbers of new workers can cause social and cultural disruption in small, remote communities. Impacts to the environment can be disruptive, too, if they affect traditional practices. An essential part of reducing negative impacts and capturing benefits is effective governance, which entails clear decision-making, public involvement, and an effective regulatory regime.

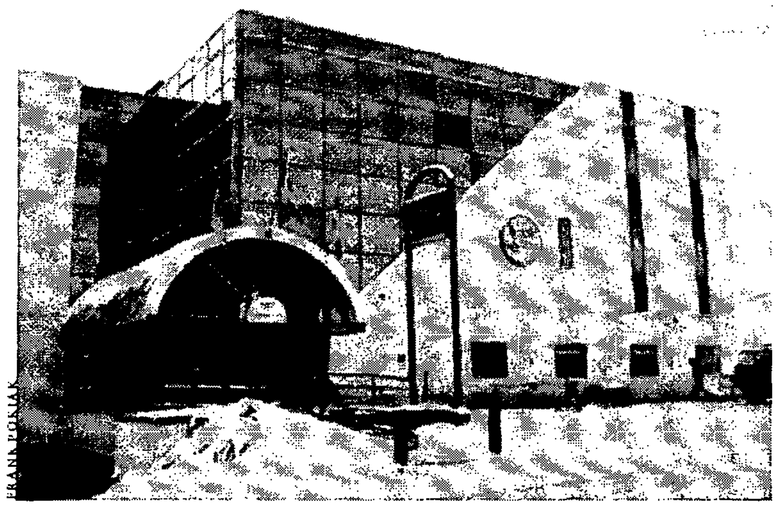
▶ GDP in Arctic regions compared with national averages (2002), showing the contribution of oil and gas extraction and pipeline transport to the regional GDP.

The lifecycle of oil and gas operations typically means that a great deal of activity occurs in early stages, particularly during construction. Employment opportunities come quickly but for many positions may not last long. There is relatively little time to train local residents, so that many workers are brought in from elsewhere, either to live or to commute for rotational jobs. In the production stage, jobs are more stable but there are fewer of them. The potential for disruption is thus higher at the beginning, precisely when local communities are learning to adapt to industry presence. Furthermore, the need for adaptive activities such as training often occurs prior to the flow of revenues that might finance them. Where oil facilities expand over time to satellite fields, opportunities may last longer and allow local residents to adapt better.





▼ Inuvialuit Development Corporation Centre, Inuvik, Canada.

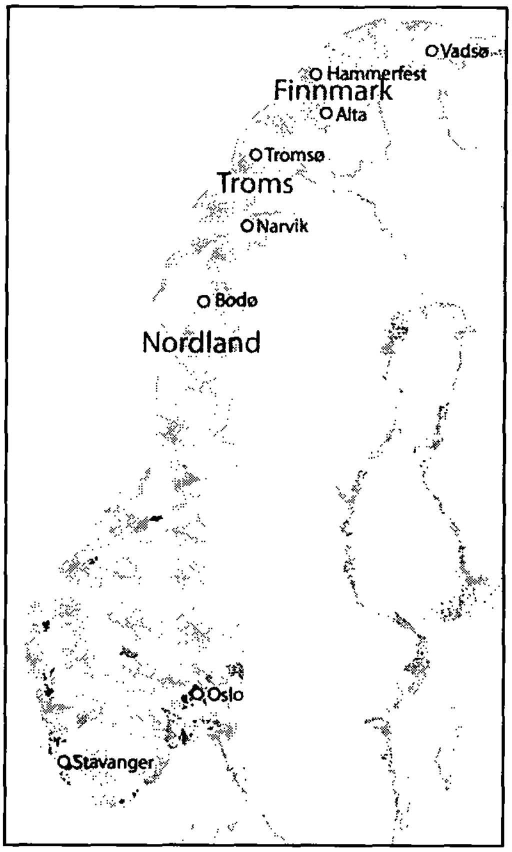


Public revenues, on the other hand, tend to be more evenly distributed throughout the life cycle. For regions that can plan accordingly, oil and gas activities can form the basis for major improvements in public services and standards of living. Norway's oil and gas policy, for example, is to develop its reserves to provide lasting benefit to the nation as a whole. The creation of public and private trust funds, put in practice in several regions and countries, is one means of capturing revenues for long-term use.

The involvement of arctic peoples in oil and gas activities is one way of harnessing the potential for benefit while also providing ways to anticipate and thereby reduce negative impacts. In Alaska and Canada, indigenous-owned businesses have become involved, particularly through oilfield services and related enterprises. The desire to develop petroleum reserves has also led to the settlement of indigenous land claims in Alaska and Canada. The public regulatory process also allows indigenous and other concerns to be heard during the decision-making process. In Russia by contrast, resources have been extracted without regard for land claims and with modest opportunity for local involvement (see Box).

Despite considerable progress in local involvement in some parts of the Arctic, oil and gas activities remain capable of creating dislocation and challenges from the rapid changes to people and communities from development. Handling the rapid and often temporary transition to a highly technical working environment was a challenge for many individuals in the Mackenzie Delta following the renewal of exploration activities there in 2000. . Such family and money-management challenges typically occur at transition times, when activity levels go up or down sharply, and not just during boom periods.

Residents of regions with oil and gas potential have typically shown interest in developing those resources, along with caution about impacts and concern for equitable sharing in economic benefits. With the benefit of experience elsewhere, Greenland is planning carefully to develop service sector capacity and to develop resources at a pace that allows local involvement to remain high. Canada's Mackenzie Delta region benefited from Alaska's North Slope experience to the west.



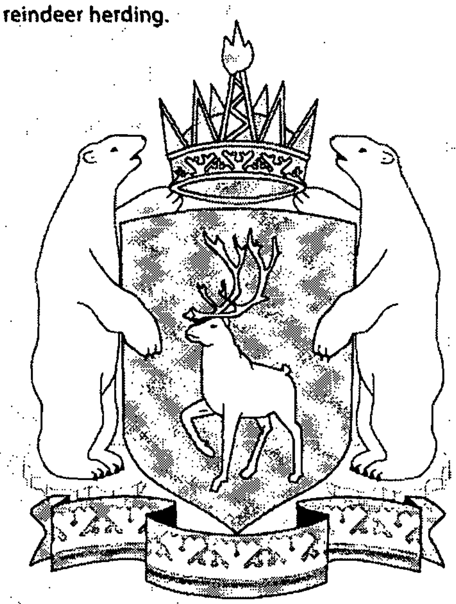
◀ Distribution of business activity around Norway from oil and gas, shown in relative levels of spending by area.

Industry-indigenous relations in Russia

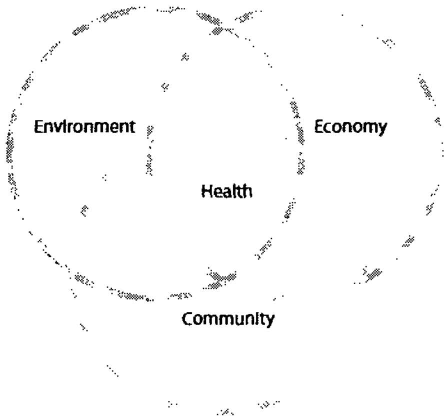
In the Union of Soviet Socialist Republics, central planning dictated where oil and gas activities took place and what measures would be taken to reduce conflicts with reindeer herders and others in the regions in question. In Russia since 1991, however, industry and indigenous peoples have developed a number of informal and formal arrangements. Despite some federal legislation intended to recognize and protect indigenous rights, only the regional governments have been involved in the arrangements made so far. Implementing national standards and practices could help ensure that effective measures are applied everywhere. Two examples show the potential and also the challenge for effective accommodation of both industry and indigenous interests.

In the village of Sabetta, in the Yamal-Nenets Autonomous Okrug (YNAO), herders rent a slaughterhouse from the oil company, which in turn buys the meat products. Personal relationships between herders and oil company personnel are a key part of this arrangement. When it comes to land use, however, herders fear that oil and gas activities and infrastructure will harm the herds. In the neighboring Nenets Autonomous Okrug, herders created their own union called Yerv. Although each herder is the official user of a specific plot of land, the herders decided to act as a group in negotiations with the oil and gas company in their area.

The YNAO, as elsewhere in Russia, has seen growing indigenous empowerment in recent years. The organization Yamal Potomkam! ("Yamal for our descendants!") was founded in 1989. Before land is transferred for oil and gas extraction, this organization must be consulted. It has also helped push for recognition of herders' communities and their traditional use areas. The YNAO has passed a number of laws protecting indigenous economies, including provisions for self-government as well as reindeer herding.



The YNAO crest includes polar bears, oil, and reindeer.



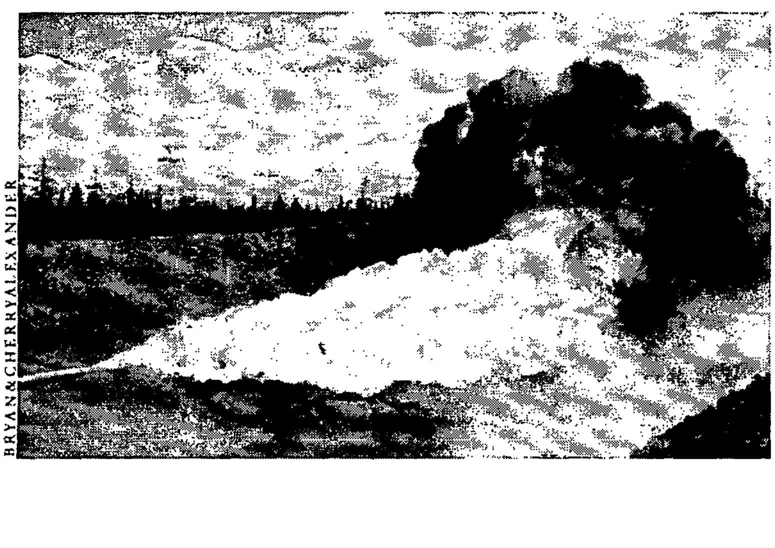
▸ Holistic approach to assessment of health of the general population.

Human health can suffer from pollution and social disruption, but revenues can improve health care and overall well-being

Another area of concern for people is human health. Petroleum hydrocarbons can be toxic and can lead to a number of reversible health problems, depending on concentrations. Oil and refined petroleum products can affect skin through contact and lungs from inhalation of vapors. Chemicals such as benzene and other volatile petroleum hydrocarbons can affect the nervous system. Long-term exposure to some petroleum hydrocarbons at moderate concentrations can cause cancer and death. Flaring or release of well gases can spread petroleum hydrocarbons and sulfur compounds, which are a threat if inhaled at high enough concentrations or over long enough periods. Exposure at levels high enough to cause adverse health effects, however, is rare outside of occupational exposure or accidental releases such as oil spills. There is as yet no reliable evidence for widespread human health impairment from exposure to petroleum hydrocarbon pollutants as a result of arctic oil and gas operations. This is consistent with the relatively low concentrations of petroleum hydrocarbons found in most areas of the Arctic.

It is nonetheless important to remember that studying human population effects is difficult. Exposure is often hard to measure and may change significantly over time depending on the nature of the oil or gas release, the weather conditions, and whether the release is on land or water. Routes of exposure (by eating, breathing, or touching the chemicals) and the specific chemicals involved affect relative toxicity. Susceptibility may be different within the population due to genetic factors, gender, and age. Few baseline data exist for many arctic populations, making subtle changes difficult to detect. The relatively small human population in the Arctic, and the diversity of the peoples of the region, make it difficult to conduct epidemiological studies to identify small effects and connect those effects to specific causes.

▾ Burning off impure gas in Gazprom's Yamsavey gas fields near Nadym, Yamal, Western Siberia, Russia. Gas flares can release large quantities of harmful pollutants.



BRYAN&CHERRYALEXANDER

Demonstrating a connection between petroleum hydrocarbons and human health in the Arctic is thus complex at best, requiring careful study. In addition to the challenges noted in the previous paragraph, many factors contribute to overall health. Social well-being, adequacy of health care, sanitation, and diet are among the many factors influencing health. On one hand, oil and gas activities can lead to social disruption and pollution exposure. Lifestyles and diets can change, likely leading to increases in obesity and diabetes. On the other hand, health care and sanitation can improve if public revenues are invested in facilities, training, and public awareness. Economic well-being can enhance personal satisfaction and educational opportunity, which can lead to better overall health. The net effects of oil and gas activity—environmental and social disruption versus economic and social benefit—require careful evaluation in each case.

One effect that has been demonstrated clearly, however, is that of psychological damage following an oil spill. Following the 1989 *Exxon Valdez* oil spill, some residents of the spill region suffered from post-traumatic stress disorder as well as generalized anxiety disorder. Such stress and illness can also lead to sociological effects when family and community networks are overburdened or disrupted. Both were consequences not only of petroleum hydrocarbon exposure, but also of disruption to lives and cultural traditions centering on their relationship with the natural environment of the area. For example, consumption of traditional foods decreased sharply due to fears of tainting by oil. Similar findings have been reported in other subarctic areas where spills have occurred and people have been exposed or had their livelihood threatened.

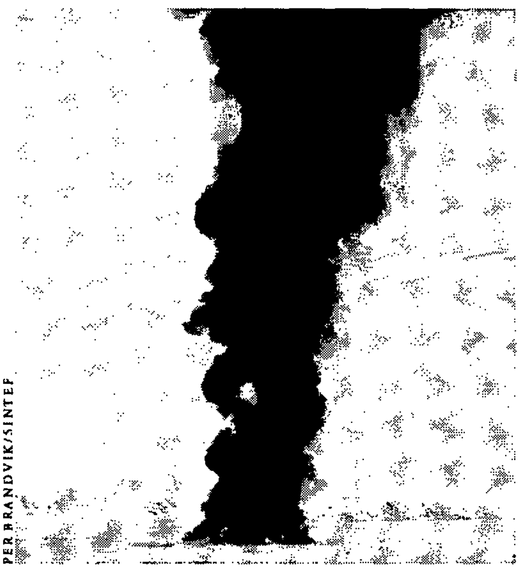
Responding to major oil spills remains a challenge in remote, icy environments

The counterpart to preventing or reducing impacts is preparedness for a major oil spill. Responding to a spill in the Arctic is particularly challenging. Many oil and gas activities are in locations far from population centers. In winter especially, reaching a spill site and taking action may be difficult, when weather may be severe and daylight is limited. On the other hand, small winter spills on the surface of land or ice can often be contained more easily and cleaned up before most biological activity begins in spring. Oil spills under ice or in ice-covered waters are the most challenging, simply because they cannot be contained or recovered effectively with current technology. New techniques such as the use of ice rather than booms to contain spills and concentrate oil for recovery by skimmers, however, have shown some promise. Dispersants and in-situ burning may also be used, although both have drawbacks that may be made worse in arctic conditions. Most response techniques require prompt action, which may not be possible in remote areas without prior staging of equipment and personnel.

A few arctic examples demonstrate some of the difficulties. In the 1994 Komi Republic pipeline rupture (see page 23), the initial response was to build containment dams around the rupture site. This worked until the dams broke in spring, releasing oil over a much larger area. Subsequent containment efforts prevented oil from reaching the Pechora River, but oil had already spread in waterways and over land. Spring flooding carried the oil farther still.

In 1980, the gas and gas-condensate well Kumzha-9 in the Pechora Delta suffered a blowout that lasted six-and-a-half years. Every day during that period, some 2 million cubic meters of gas and hundreds of tonnes of condensate spewed out of the well. In May 1981, the authorities detonated an underground nuclear explosion to try to stop the flow of gas and condensate. This approach failed, in part because the well for the nuclear device was drilled in the wrong direction. The explosion left a crater that is separated from the river by a dam. Erosion of the dam could release oil and other contaminants collected in the crater. Other attempts to stop the blowout finally succeeded in 1987.

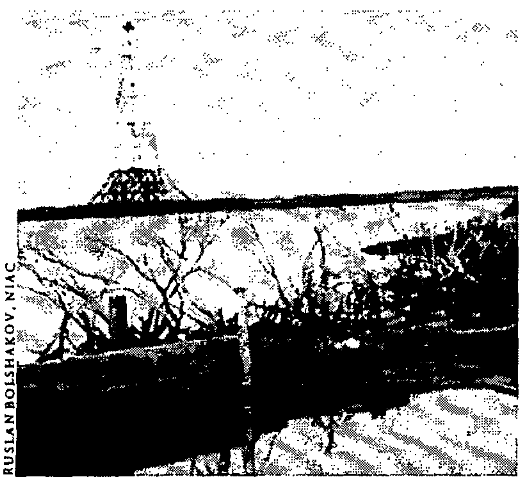
In March 2006, internal corrosion made a hole in a pipeline on Alaska's North Slope. Although the spill was much smaller in scale than the previous two examples, some 800 cubic meters of oil were spilled onto snow-covered tundra. The corrosion was not detected because routine inspections that could have revealed the thinning walls had not been carried out. Detection of and response to the leak were slowed by winter conditions, as the company placed highest priority on the safety of its workers. One consequence of the problem was reduced oil production from the North Slope during containment and repairs. This reduction cost the State of Alaska millions of dollars a day in lost revenue.


PER BRANDVIK/SINTEF

◄ Experimental in-situ burning of oil in ice.

▼ Cleaning-up the oil spill from the Prudhoe Bay transit-line leak in 2006, North Slope, Alaska.

▼◄ The Kumzha-9 drilling rig, Pechora Delta, Russia.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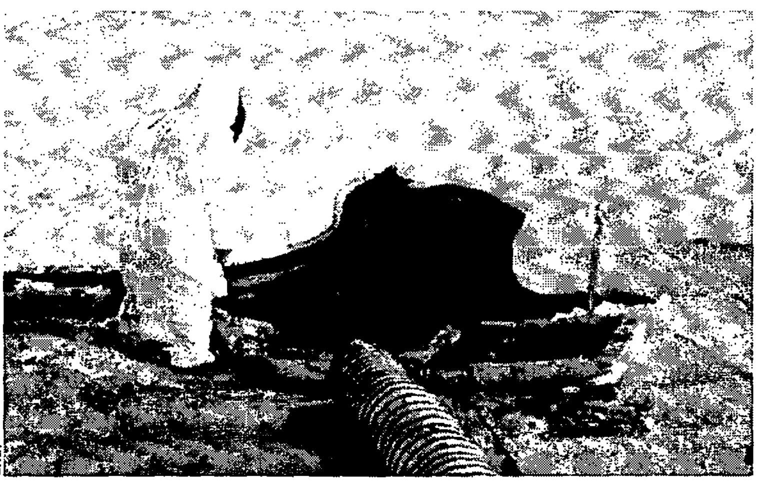

BPXA

Technology and regulations can help reduce negative impacts

Early arctic oil and gas exploration and development used equipment and techniques that had been developed for use in temperate areas. At that time, well drilling technology was limited to vertical holes and therefore required many more wells sites to produce an oil or gas field. Because the wells had to be drilled directly above the target geological formations, drilling sites were sometimes located in critical habitats or dangerous terrain. Construction techniques at that time also caused major physical and biological impacts to tundra and permafrost, which made operations less efficient as well as more damaging.

Over the past several decades, lessons from experience, public pressure, regulatory requirements, and economic concerns have combined to spur the development of new technology to meet arctic conditions and reduce impacts. Three-dimensional seismic surveys provide better information about sub-surface formations, meaning fewer exploratory and development wells need to be drilled. Production wells can be drilled in several directions from a single platform or pad, reaching as far as 20 kilometers away, reducing the number of production facilities required (see Figure on page 6). Sub-sea facilities (see Figure this page) can reduce surface presence and risk of infrastructure damage. Ice roads allow access in winter without lasting damage to vegetation or permafrost. Bans on the discharge of oil-based drilling muds, better containment of well-head releases, and similar regulatory controls have also helped reduce pollution.

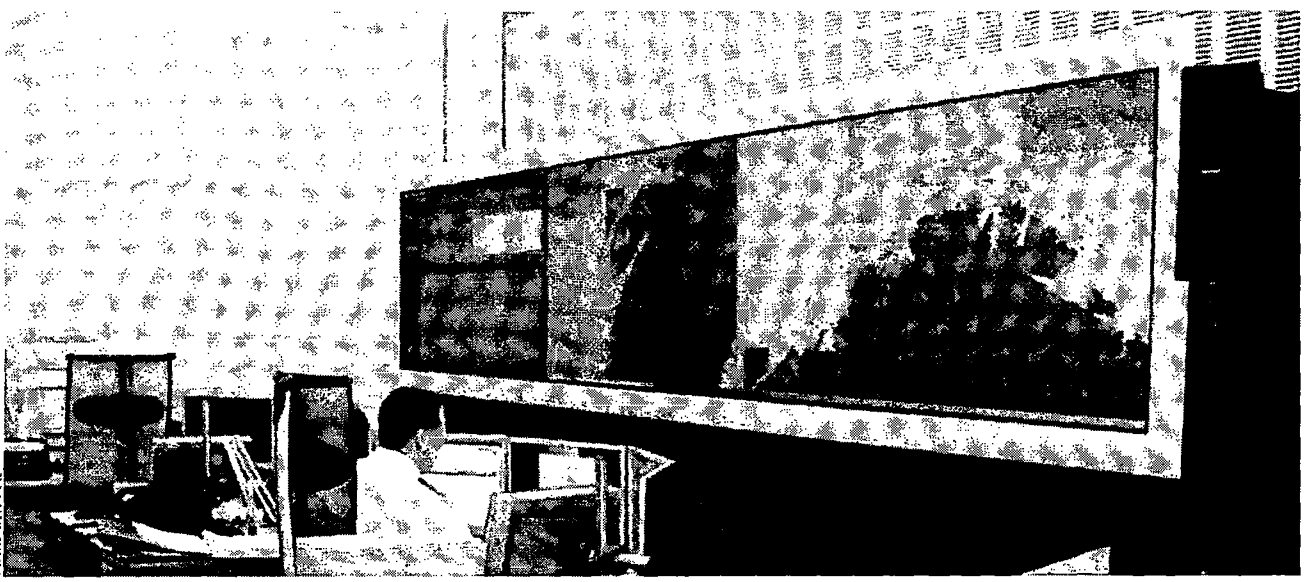
Regulations and the use of best available technology, however, are not consistent across the Arctic. International agreements, action by national and local governments, shareholder concerns, and pressure from within the oil industry have added to the push for better performance in the Arctic as elsewhere. Accepted industry standards for reporting, safety, and environmental protection are increasingly applied throughout the world in response to the requirements of financial and other institutions.

Regulatory systems are also evolving. Russia has constructed a new, modern system over the last 15 years. Greenland, the Faroe Islands and Iceland are developing regulatory systems as their activities evolve. Norway's regulatory system underwent major changes in the 1980s to a predominantly performance-based system that focuses on outcomes. The United States and Canada are incorporating more outcome-based rules in their systems.

Compared with many other oil-producing regions of the world, the arctic nations are politically stable. Transparent regulatory systems provide additional consistency, reducing uncertainty for industry. In turn, this can make large, long-term investments in exploration and infrastructure comparatively more attractive in much of the Arctic, despite its remoteness and harsh weather.

Transparent regulatory systems can also mean a greater degree of public information and oversight. The major oil companies operating in the Arctic are large and publicly traded. They are expected to meet standard accounting requirements and to provide information to regulators and shareholders. This can also mean greater public awareness of problems, for example the pipeline leaks from corrosion in Russia's Komi Republic in 1994 and on Alaska's North Slope in the summer of 2006. Such problems occur despite complex and comprehensive regulatory systems and considerable public scrutiny.

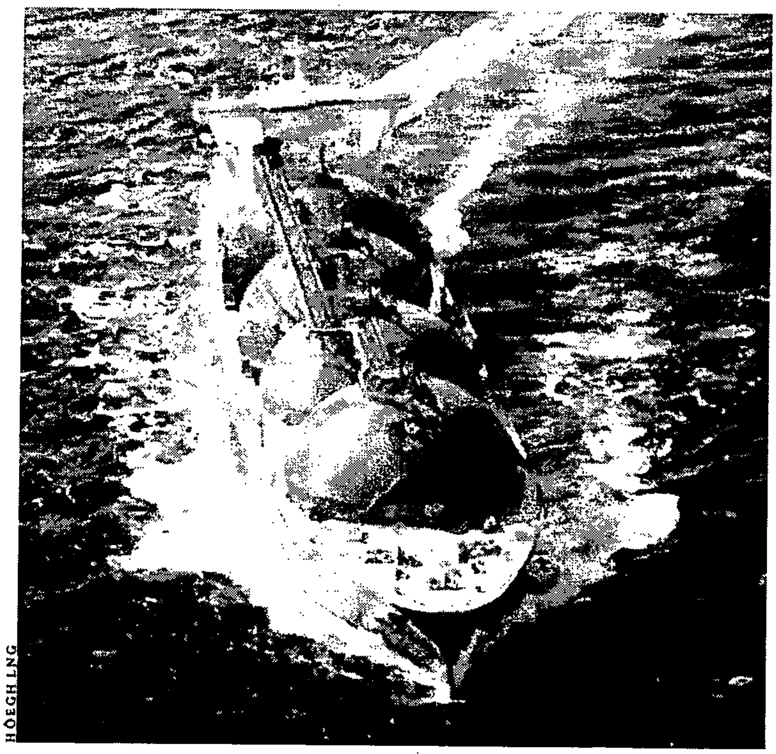
▼ The marine traffic control centre at Vadsø, Norway.



FRED EINVIK

Oil and Gas Activities in the Future

Oil and gas activity in the Arctic is expected to increase in the next decade. Projections farther into the future become increasingly speculative. Many factors will influence what actually happens, and the past is only an imperfect guide to what we can anticipate. Nonetheless, our understanding of the patterns, trends, and consequences of past activity shed some light on what we are likely to see in the coming decades. If sea ice continues to diminish, access to arctic regions may become easier and less costly, perhaps increasing the attractiveness of the region for development. Thawing of permafrost, on the other hand, may complicate development on land. Technological advances are also likely to continue to change the way oil and gas activities are conducted. This section outlines the projected levels and areas of activity, the risks entailed, and the potential for planning to reduce those risks and attendant impacts.



HOEGH LNG

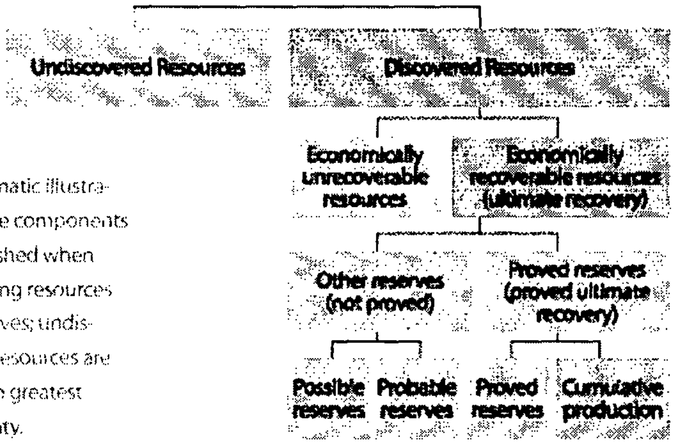
▲ Liquified natural gas (LNG) tanker, expected to become more common in the Barents Sea

More oil and gas activity is expected

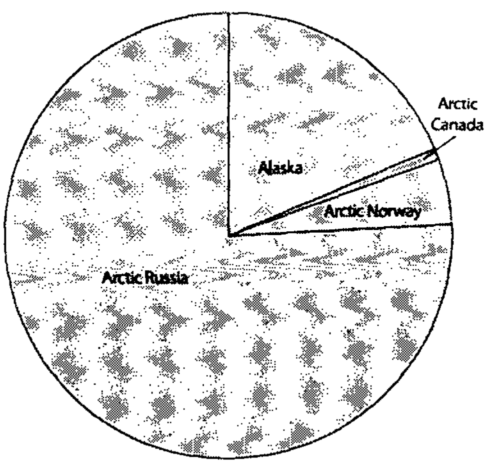
More than five percent of the world's known oil reserves and over 20 percent of its known gas reserves are in the Arctic, the vast majority of both in arctic Russia. There are estimates that as much as a quarter of the world's undiscovered oil and gas lies in the Arctic. With rising global demand, oil and gas activity in the region is expected to increase. Indeed, plans for new pipelines and for evaluation and development in new areas are underway.

In Russia, oil and gas production activities will grow in Timan-Pechora and West Siberia provinces and in the Kara and Barents seas. This development is likely to include construction of major oil pipelines from the West Siberian Basin and Timan-Pechora to a western arctic port, a Far East pipeline for arctic oil transport to the Pacific Rim, and several new marine terminals and subsequent arctic tanker traffic to markets.

In Canada, the construction of the Mackenzie Valley gas pipeline would be a major stimulus to further development and production in the Mackenzie Delta and the Beaufort Sea. In Alaska, a gas pipeline from the North Slope to southern markets is also

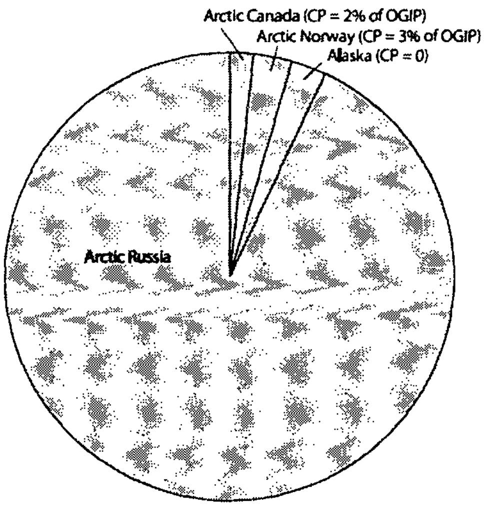


▸ Schematic illustration of the components distinguished when considering resources and reserves; undiscovered resources are subject to greatest uncertainty.



Total OOIP = 34200 million m³
(215000 million barrels)

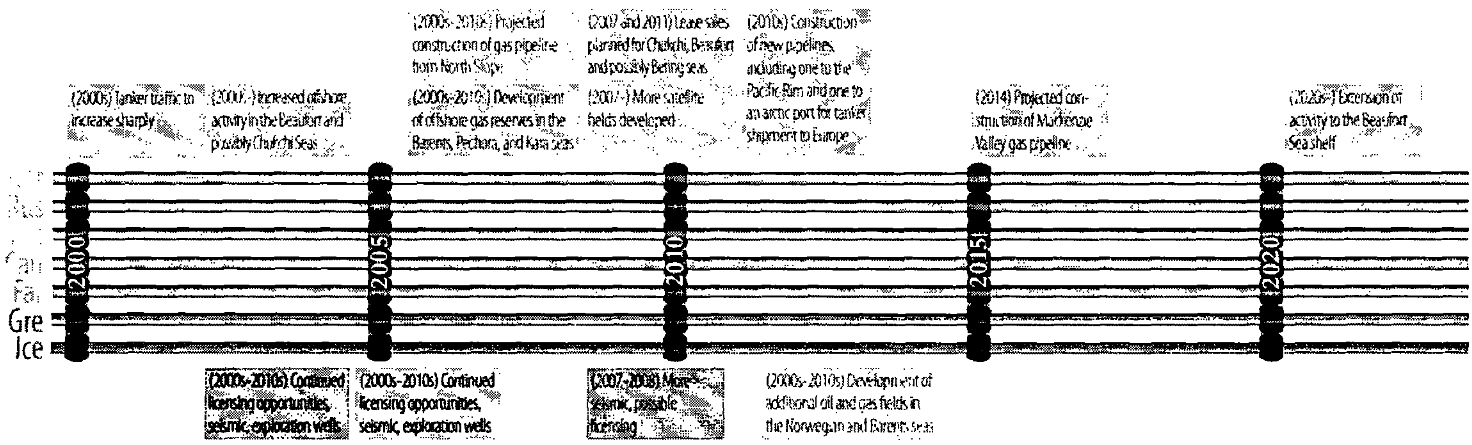
Total cumulative production = 13400 million m³
(84300 million barrels)



Total OGIP = 55600 billion m³
(1963000 billion cu.ft)

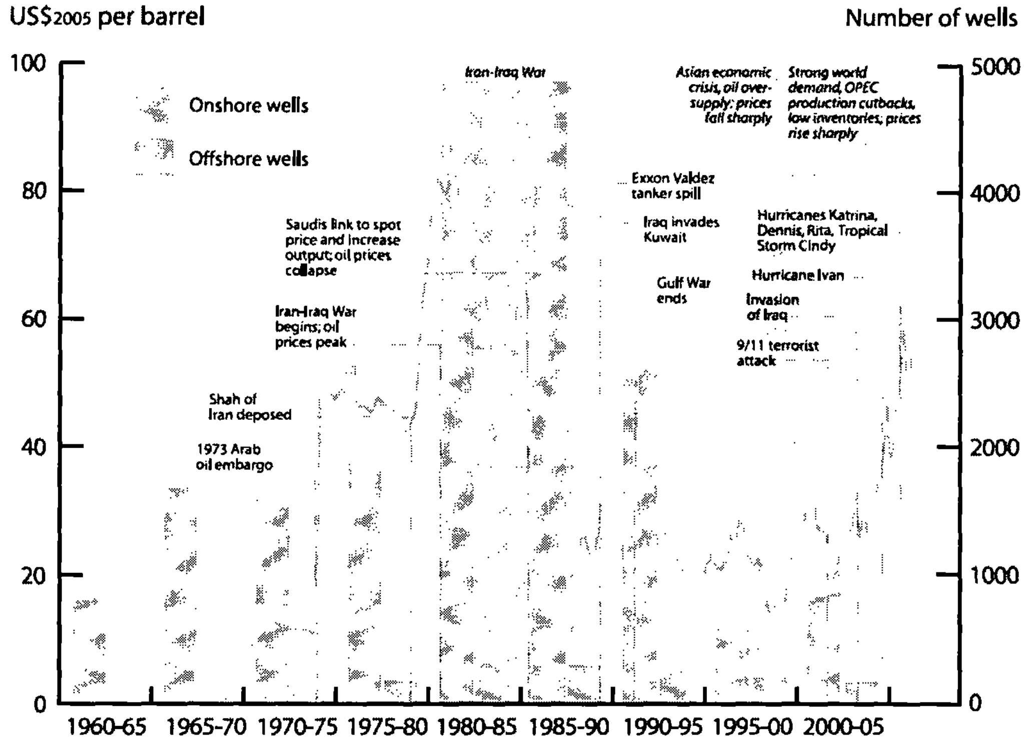
Total cumulative production = 12250 billion m³
(432400 billion cu.ft)

▸ Pie charts showing original oil in place (OOIP, ▸) and gas in place (OGIP, ▸▸) in the Arctic areas of the four Arctic producing countries, and the cumulative production to date (part indicated by lighter shading, or %).



anticipated, allowing production from large known reserves. Oil activity is expected to expand offshore and also to the west onshore.

Farther into the future, discoveries of new reserves will likely lead to further development and production. Offshore areas in Greenland, Iceland, and the Faroe Islands, Arctic Russia, and Arctic Alaska are of particular interest to both government and industry. The depletion of existing reserves worldwide may also lead to greater interest in unconventional resources such as heavy oil, coalbed methane, and potentially vast methane hydrate deposits both on- and offshore. The construction of new infrastructure for development and particularly transportation will likely extend into areas currently without such human presence.



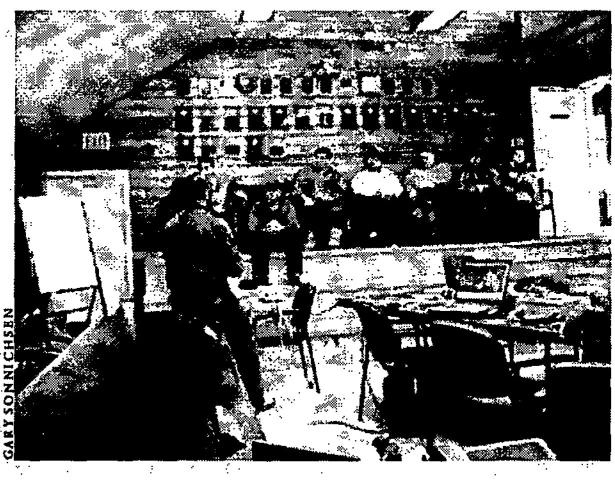
◄ Fluctuations in the price of oil (adjusted to 2005 dollar equivalents), showing response to World events, and numbers of exploration wells drilled onshore and offshore in different 5-year intervals.

Factors involved in development decisions

Many factors ultimately control whether and when oil and gas development activities will take place in the Arctic. They include international political factors such as energy demand, including demand from emerging economies, and energy security for developed countries. Other basic factors include the resource potential of various areas, the geologic nature of the deposit, long-term trends in oil and gas prices, the regulatory environment, and infrastructure capacity.

Operating costs of activities in the Arctic are typically much higher than those of temperate regions. Working conditions are harsh and challenging. Infrastructure is often limited or non-existent prior to the start of oil and gas activities. Environmental conditions include extremely low temperatures and extended darkness in winter, permafrost, sea ice, and changing climate. The regulatory and management processes can also be complex. The lead-time from discovery to development is usually much longer than for other parts of the world. A dedicated program for onshore development may take ten years or more between discovery and production.

Together, these factors and their even more complex interactions make it difficult to project future activity levels with confidence. They also make it difficult for governments and other development proponents to determine what incentives are appropriate to encourage oil and gas activity in a particular region.



GARY SONNICHSEN

Seasonal patterns determine vulnerability in arctic ecosystems

Arctic habitats are characterized by extreme seasonal change, which drives extensive animal migrations on land and at sea. The seasonal patterns of movement to, from, and within the Arctic determine to a large extent the vulnerability of arctic ecosystems. These patterns must be taken into account in reducing or avoiding environmental impacts from oil and gas activities.

Seabirds of many species arrive in the hundreds of thousands or millions to northern breeding colonies in spring. These colonies are located where there is access to abundant food in the form of zooplankton and small fish like sandlance, capelin, and polar cod. After breeding, some seabirds and seaducks like eiders aggregate for molting, a time when they are flightless. In autumn, seabirds move south to winter in areas where there is access to food. When they are concentrated at their breeding colonies, moulting and wintering areas, seabirds are particularly vulnerable to oil spills.

Shorebirds and waterfowl typically breed scattered over the vast arctic tundra and wetland habitats where they feed on the seasonal burst of insects, other invertebrates, and aquatic and terrestrial vegetation. Dispersed breeding means that they generally have low vulnerability to oil and gas activities. After breeding, however, many species of shorebirds, ducks, and geese move to coastal habitats where they feed and stage while preparing for the southbound migration. At this stage they may be very vulnerable both to oil spills and to disturbances.

Bowhead, beluga, narwhal, walrus, and several species of seals spend the winter in the southern areas of pack ice. In spring, they migrate northwards as the ice retreats. Prior to or during these migrations, these mammals give birth to their young. When they are confined in ice during wintering and migrations, dependent on the openings for breathing, these marine mammals could be vulnerable to oil spills and disturbances.

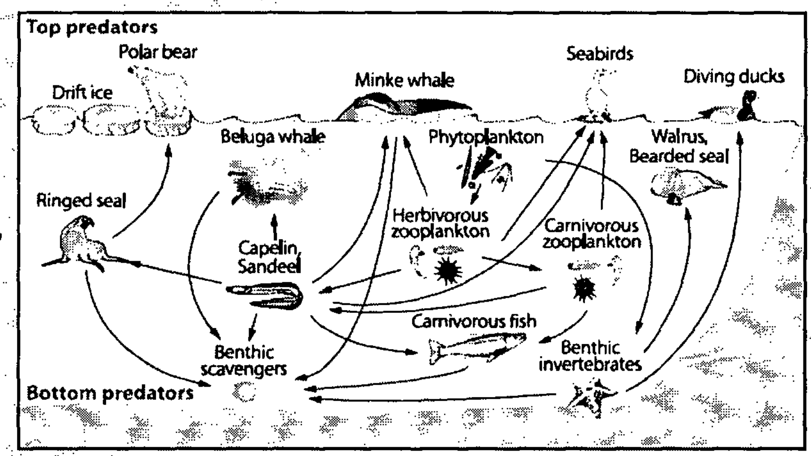
Harp and hooded seals in the Atlantic sector and ribbon and spotted seals in the Pacific aggregate on sea ice in late winter to give birth to their pups. A common feature of the location of these areas is that they are in southern extensions of winter ice, generally outside the reach of polar bears that would not be able to get back to the polar pack when the ice disintegrates in spring. After pupping, the seals aggregate for a second time sometime later in spring or early summer, when they spend much time hauled out on the ice during their annual moult. The young pups have fur to keep them warm when they are on the ice, when they are particularly sensitive to oiling. The concentrated whelping and moulting areas for these seals are vulnerable to oil spills and disturbances.

On land, reindeer or caribou perform migra-

The Barents Sea

The Barents Sea is moderately productive, but being large, it supports large fish populations. Walrus, bowheads and other large whales were seriously depleted by this previous hunting, and have been slow to recover. Despite this the region continues to support abundant marine life and active fisheries.

Now, oil and gas activity is increasing in the Barents Sea. Offshore drilling and production as well as tanker traffic are expected to rise. While normal operations may pose little additional threat, the consequences of an oil spill could be severe.

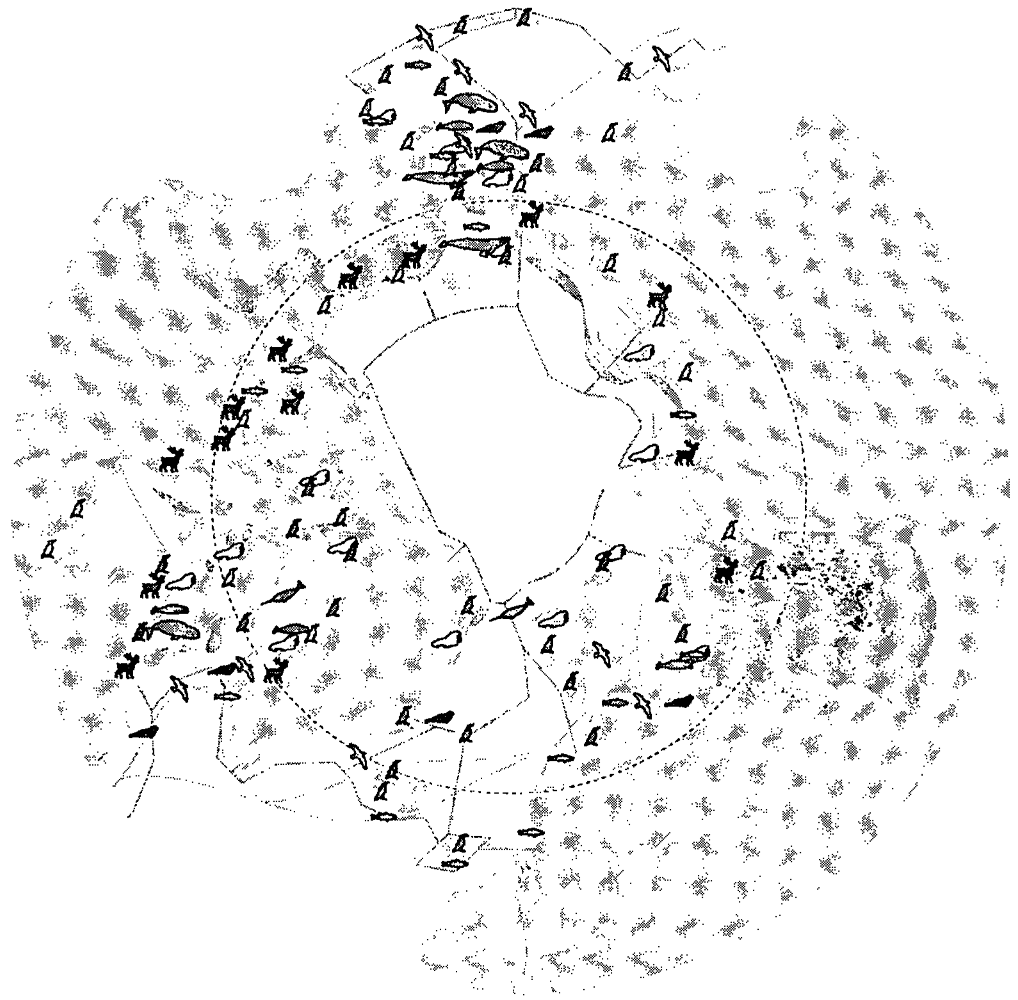


Simplified Barents Sea food web.

The Bering Sea

The Bering Sea is a very productive ecosystem, particularly the continental slope and northern shelf regions where nutrient-rich waters flow upwards from the depths. Commercial fisheries are highly valuable, and traditional hunting and fishing continue to sustain indigenous cultures along the coasts and on the islands of the Bering Sea. The northern Bering Sea is an especially concentrated region of marine life, where birds and mammals from the Beaufort, Chukchi, and East Siberian Seas spend the winter in polynyas and the marginal ice zone.

Oil and gas activities may soon occur in the Bering Sea. Disturbance to marine mammals and seabirds is possible, and the consequences of an oil spill could pose serious risk to many commercial fisheries. Indeed, the tainting of fish products, or even the perception that they are tainted, could damage the region's reputation and marketing for wild, natural fish.



◀ Illustrative map of areas in the Arctic where selected birds, mammals, and fish form major aggregations to breed, stage, migrate, or overwinter. When oil and gas activities including transportation occur in such areas, such aggregations are vulnerable to disturbances and oil spills.

tions similar to those of the arctic marine mammals. Several large herds winter in the boreal forest or taiga, migrating in spring onto the arctic tundra and even across sea ice onto islands. Reindeer or caribou use specific areas as calving grounds in summer that offer suitable feeding conditions for the calves and their mothers. These calving areas are particularly vulnerable areas with respect to disturbances.

Seabird populations and oil spills

Seabirds are among the most vulnerable species to an oil spill. This is true both for immediate impacts and, in some species at least, for long-term impacts. Marine oil spills can deplete seabird populations, leaving entire colonies deserted. Oiled birds are the focus of much media attention after a spill. The long-term consequences of these effects are, however, another and more complicated matter. The effects of chronic, diffuse oil pollution on seabird colonies is also still uncertain.

Many factors influence what happens to a seabird population after it has been exposed to an oil spill. If a colony is wiped out, it must be re-colonized. This can be relatively rapid, if abundant colonies are located nearby. It can be slow if other colonies are distant or already declining for other reasons, and thus unable to produce extra birds for re-colonization.

The biological characteristics of a seabird species are also critical in determining its ability to recover. Some seabirds reproduce slowly. Thick-billed murres, for example, do not breed until they are four or five years old, and each female lays only one egg per year. Such species take many years to produce enough young for the population to grow. A catastrophic event, such as extreme weather, disease, or an oil spill, can thus have long-lasting effects.

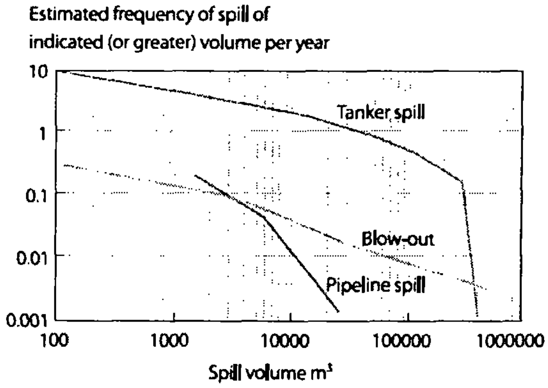
Not surprisingly, the short- and long-term impacts depend in part on the status of the colony or population prior to catastrophe. A colony that is thriving may have more birds than can find space or food to support reproduction. If some birds are killed, a larger percentage of the survivors may be able to breed, thus speeding recovery. Conversely, a colony that is declining or otherwise under stress is unlikely to be resilient. Management and prevention efforts should therefore take account of such risks when identifying vulnerable populations and areas.

Many risks remain

The history of oil and gas activities, including recent events, indicates that risks cannot be eliminated. Tanker spills, pipeline leaks, and other accidents are likely to occur, even under the most stringent control systems. Transportation of oil and gas entails risk to areas beyond production regions. Containing or cleaning up an oil spill in sea ice remains difficult at best. Pollution cannot be reduced to zero, although adherence to strict regulations and sound engineering practice can greatly reduce emissions. Physical disturbance is likewise inevitable wherever industry operations occur, although the extent and impacts of disturbance can be reduced.

Some degree of risk to people and society is also unavoidable. Dislocation, stress, crime, substance abuse, the introduction of diseases, and other problems are likely to appear or increase as development moves into previously isolated areas. They may be offset by other social, economic, and health-care benefits, but that judgment is likely to vary by individual, by circumstance, and by region, and cannot be predicted accurately. Furthermore, detriments and benefits are unlikely to reach everyone in the same way. Some people will receive greater benefits and some will experience negative impacts.

Assessing vulnerability is one way of anticipating where problems are most likely to occur. Ecosystem vulnerability is the degree to which an event or change would cause serious disruption. Risk is the size of the impact combined with the probability that it will happen. An attempt to map ecological vulnerability has been made as part of this assessment. Further work is needed to calculate respective risks for various activities and regions. The results of such an exercise can be used in planning the oil and gas activities and appropriate mitigation measures and restrictions.

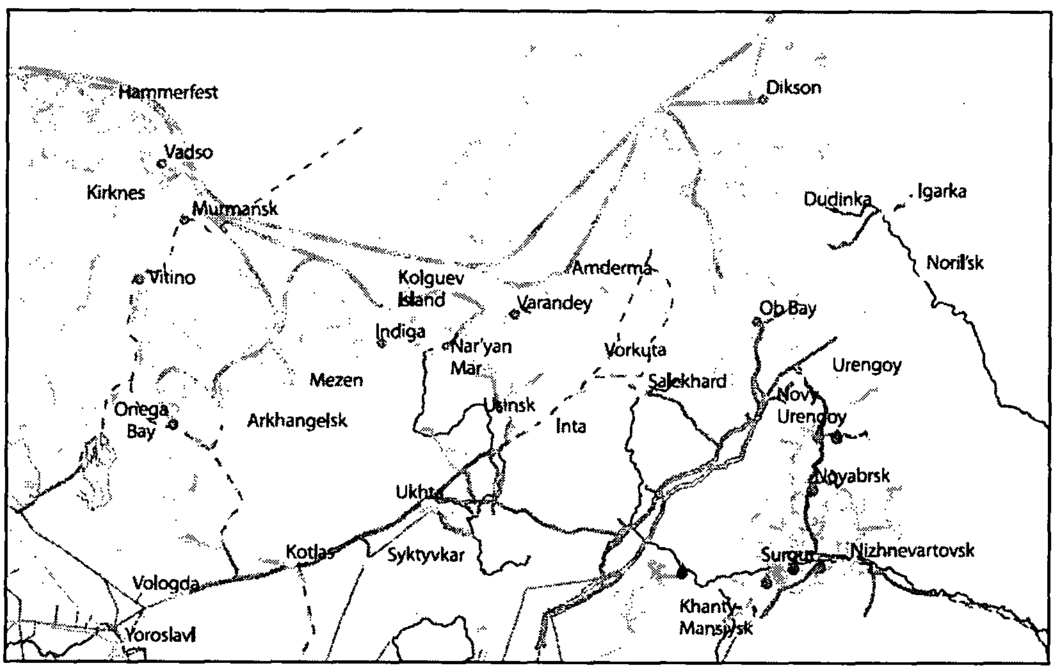


▸ Relationship between frequency and volume of releases to the marine environment from different sources (worldwide).

The termination of oil and gas operations is a process with which there is minimal experience in the Arctic. Decommissioning involves varying degrees of removing equipment and infrastructure and repairing any damage done to the surrounding area. Depending on regulatory requirements, some things may simply be left in place, whereas others are removed. Both options involve the potential for release of pollution and further disturbance. Although environmental cleanup is required, it is not yet clear how much actual work will be done once an oil or gas installation is closed down.

Socially, closure of an oil or gas operation means the loss of employment and of public revenue. Public or private investment funds may allow some benefits to persist past the life of the operation. In some areas where oil and gas operations have declined, however, populations have gone down as has overall economic activity. The long-term effects of such declines are as yet unknown for arctic regions.

▸ Map of main oil and gas transport routes from Russian Arctic production areas.



Planning and management can help reduce risks and impacts

With activity likely to increase and risk unavoidable, sound planning and management can nonetheless help reduce negative impacts and increase the benefits of oil and gas activity in the Arctic. Indeed, better planning and management have helped reduce impacts since the early years of industry activity in most parts of the Arctic. But more can be done.

The learning curve is readily apparent in planning societal responses. Canada learned from Alaska, Norway has studied both countries, and Greenland and the Faroe Islands are acting on lessons learned elsewhere. In Russia, more attention is being given now to environmental and social and economic effects. The key lesson is that effective governance does not occur by chance. Learning from experience is not confined to national governments, but includes regional and local governments as well as indigenous organizations, which now have better networks and wider experiences to draw on.

The gain in influence by indigenous groups is not necessarily a loss to industry or government. Many land claims in Canada and Alaska have been settled, providing land and resource ownership to indigenous peoples while allowing development to proceed. In many cases, local residents desire not so much to slow or stop development as to have a hand in determining how it occurs. Public processes and greater involvement have made progress towards this goal, reducing legal and other disagreements over development. Nevertheless, disagreements and disputes will continue. Their management will be a key challenge as oil and gas activities move into new areas.

Generating lasting benefits from oil and gas activity while reducing major disruptions is a common goal for both national and local governments. The creation of funds, public and private, is one approach that has been used to harness revenues for long-term benefit. Large public funds can help avoid large economic swings while providing for the future. Avoiding extensive pollution, damage, and major oil spills is the counterpart to securing benefits. While incidents such as oil spills cannot be eliminated, planning and preparedness can reduce the likelihood and the impacts if and when a disaster occurs. Stricter regulations and better operating practices and compliance monitoring have reduced, and can further reduce, environmental and social impacts.

The regulatory process in most countries is comprehensive and complex, involving many agencies and jurisdictions. Enforcing regulations, however, requires commitment by governments, which can be aided by strong public pressure and industry cooperation. When industry is the major contributor to public revenue, stringent enforcement may be difficult to sustain. The alternative, however, is increased risk.

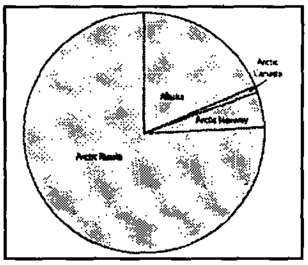
The basis for regulations, likewise, can be strengthened by sound research and monitoring for impacts as well as compliance with regulations. Detecting pollution or other impacts early can help identify damaging activities. Better understanding of the nature and scope of impacts can also improve the ability to plan effectively. Monitoring and research must be undertaken, as must engineering development and other innovations required to reduce impacts and risks. Such expenditures are often easy to cut for short-term gain, but as with relaxing enforcement, the result is likely increased risk and long-term cost.

Future exploitation of arctic oil and gas resources depends in part on global markets and geopolitics, and in part on continued support within the region. Tangible benefits have accrued in those regions where oil and gas activities have occurred, but with tangible negative impacts as well. The authors of this assessment hope that their work provides a firm foundation for decisions about if and how to proceed with future oil and gas activity in the Arctic.

BRYAN & CHERRY ALEXANDER

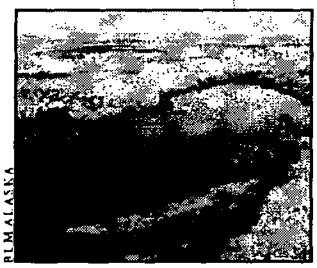
▲ Meeting between Nenets reindeer herders and gas company officials, Yamal, Siberia, Russia

Key Findings



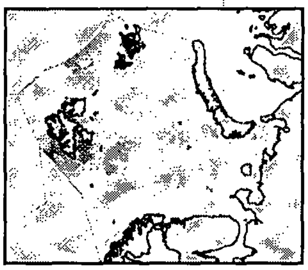
1. Extensive oil and gas activity has occurred in the Arctic, with much oil and gas produced and much remaining to be produced

Commercial oil and gas activities in the Arctic began in the 1920s in Canada and increased greatly in the 1970s, particularly in Alaska, Russia, and Norway. Billions of dollars worth of oil and gas have been produced to date, and new fields are under development in several countries. Russia has had an order of magnitude more activities and production than all other Arctic countries combined.


BLM ALASKA

2. Natural seeps are the major source of petroleum hydrocarbon contamination in the arctic environment

Petroleum hydrocarbons are naturally occurring compounds. Their major source in the Arctic is natural seeps. Human activity contributes petroleum hydrocarbons, too. Oil spills and industrial activities excluding oil and gas activities are the largest human sources. Excluding oil spills, oil and gas activities are currently responsible for a very small fraction of petroleum hydrocarbon inputs to the Arctic, although this is expected to rise with increased oil and gas activity. These seeps are excellent research opportunities for understanding the physical chemistry and environmental consequences of oil releases.



3. Petroleum hydrocarbon concentrations are generally low

The highest background levels of petroleum hydrocarbons are found in areas with natural sources, such as the Mackenzie River area and the waters surrounding Svalbard. These levels are still relatively low. A few contaminated sites and areas of extensive industrial activity, such as some oil facilities and harbors, have high levels of petroleum hydrocarbons.


ERIC HULTEEN

4. On land, physical disturbance is the largest effect

Exploration, construction, and infrastructure have damaged some areas of tundra and other terrestrial ecosystems. Oil spills have also had local impacts. Over time, the impacts associated with new developments have decreased as industry practices have improved and regulations have become more stringent. Ice roads eliminate lasting transportation corridors. Directional drilling reduces the number of platforms used. Effects, however, can be cumulative and last for decades.


EVOSTC

5. In marine environments, oil spills are the largest threat

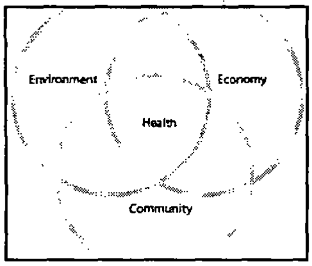
To date, no major oil spills have occurred in arctic seas. Experiences from elsewhere, including the subarctic, show that the environmental consequences could be severe. A spill that occurred in a time and place that animals were aggregated could be especially disastrous. The frequency of large spills is low, but the overall risk increases with increased activity.


FRANK POKIAK

6. Impacts on individuals, communities, and governments can be both positive and negative

Oil and gas activities bring income and employment to individuals and regions. This revenue can improve living standards, support public health and cultural programs, and be harnessed for long-term use to sustain benefits after oil and gas activities have ended. The arrival of sudden wealth, new migrants, and environmental impacts can also disrupt social patterns, creating a variety of problems. Effective governance is a crucial part of maximizing benefits and minimizing negative impacts on society.

Key Findings



7. Human health can suffer from pollution and social disruption, but revenues can improve health care and overall well-being

Oil and gas activities produce pollution and other forms of environmental and social disruption, which can lead to health effects. Few signs of health impacts directly associated with oil and gas activities have been found in the Arctic. Increased government revenues can support better health care, and improved economic status can also lead to better health and well-being for individuals.


FRED EINVIK

8. Technology and regulations can help reduce negative impacts

Improved technology and more stringent regulations have greatly reduced the environmental impacts of arctic oil and gas activities over the past several decades. The application of best practices across the region can help further. Compliance is critical if these gains are to be realized.

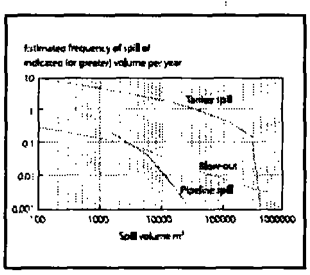

PER BRANDVIK/SINTEF

9. Responding to major oil spills remains a challenge in remote, icy environments

There are no effective means of containing and cleaning up oil spills in broken sea ice. Responding to such spills in winter would be even more difficult, given the likelihood of harsh weather and the limited daylight. On land and unbroken sea ice, small winter spills may in fact be easier to clean up, if the work can be done before spring. Prevention remains the best means of limiting the impacts of a spill, but further work is needed on response techniques, particularly for oil under ice or in broken ice, such as in situ burning and the use of ice to contain spills as well as the effectiveness of dispersants in extreme cold. Preparedness can also be enhanced by improved training of response crews and by stationing response equipment at appropriate locations in the Arctic.

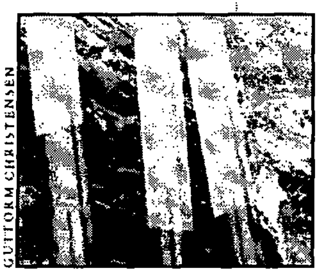
10. More oil and gas activity is expected

With perhaps as much as a quarter of the world's remaining oil and gas and generally stable political environments, the Arctic is likely to remain attractive for oil and gas activity. The next decade may see new gas pipelines in the Mackenzie River Valley in Canada and from Alaska's North Slope. New oil and gas pipelines and increased tanker traffic will carry Russian oil to market. In the longer term, other areas, such as Greenland, the Faroes, and Iceland, may move from exploration to development and construction.



11. Many risks remain

Exploring for and producing oil and gas in the Arctic entails risk. Accidents cannot be entirely prevented. Some impacts are inevitable, even with the best technology and practices. Preparing for worst-case scenarios can help identify areas, species, and times of particular vulnerability, allowing extra precautions to be taken.


GUTTORM CHRISTENSEN

12. Planning and monitoring can help reduce risks and impacts

The likely impacts from oil and gas activities can be anticipated based on experience to date. Learning from those experiences can help improve planning so that negative effects, including impacts on northern communities and traditional ways of life, can be avoided or minimized and positive effects can be better achieved. Environmental monitoring can track effects and help evaluate new approaches. Compliance monitoring and enforcement can ensure that best practices are indeed used.

Sources of photography in this report

Photographers and suppliers of photographic material

Bryan and Cherry Alexander (www.arcticphoto.com) – cover, pages 1, 2, 4 (left), 7 (#3, #4, #6), 13, 14, 28, 37

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Christy Bohl, Minerals Management Service (MMS), Alaska - page 25

Per Brandvik/SINTEF (Per.Brandvik@sintef.no) – pages 29, 39 (#9)

BLM: Bureau of Land Management, Alaska (2003) – pages 18 (middle), 38 (#2)

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ESA: European Space Agency (www.esa.int) - page 12

Anita Evenset (anita@akvaplan.niva.no) – page 21

EVOSTC: Exxon Valdez Oil Spill Trustee Council (www.evostc.state.ak.us/) – pages 10 (#2), 24 (lower), 38 (#5)

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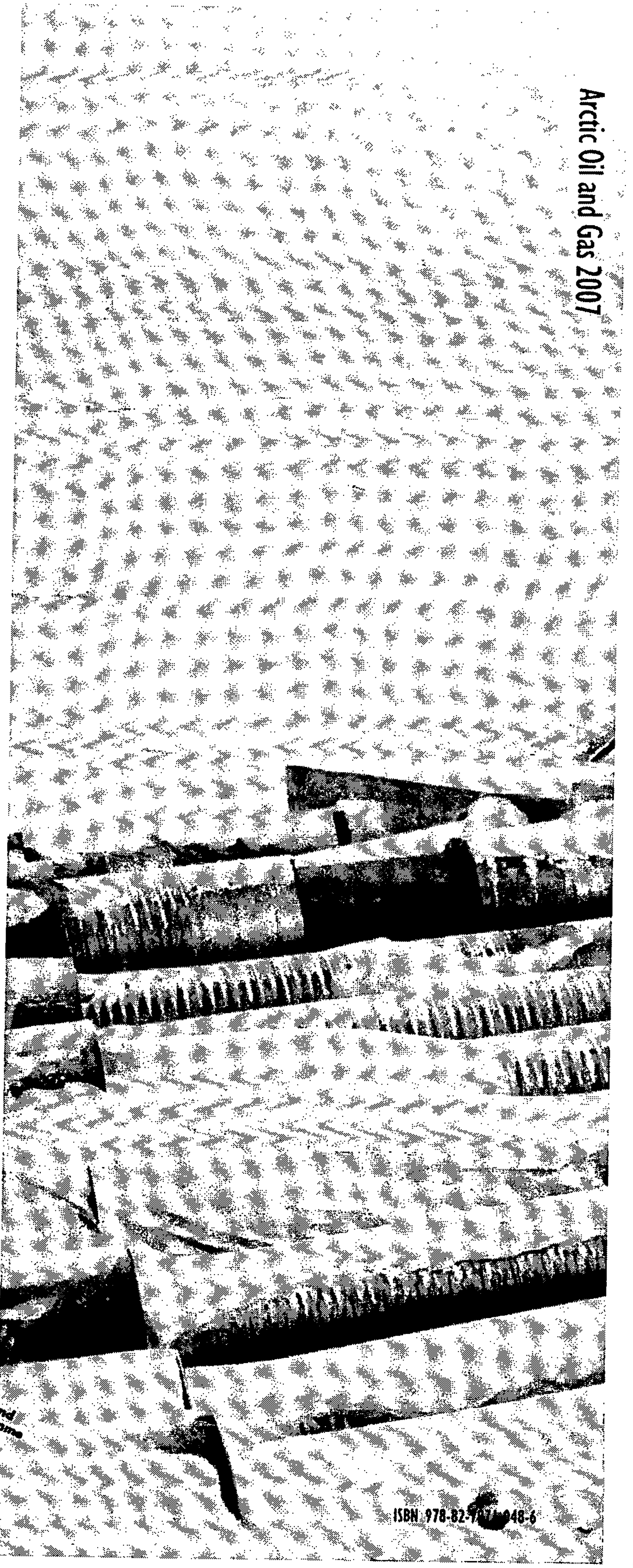
Russian basin, pipeline, field and production data presented on graphics on pages 5, 15, 16, 17, 35, 36 is by permission of IHS Inc. (www.ihs.com, © 2007, all rights reserved)

Arctic Oil and Gas 2007



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ISBN 978-82-7971-048-6