VERIFYING OBLIGATIONS RESPECTING ARMS CONTROL AND THE ENVIRONMENT: A POST GULF WAR ASSESSMENT

Edited by

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Verifying Obligations Respecting Arms Control and the Environment: A Post Gulf War Assessment

Final Report

Edited by
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PREFACE

Military operations often cause considerable damage to the natural environment. Such damage can occur as an unintended side-effect of normal military activities. At other times, manipulation of the environment itself may be used as a means of inflicting damage upon or impeding the activities of opponents. As an example of the latter, the Gulf War of 1991 saw particularly pernicious effects on segments of the Kuwaiti and Persian Gulf eco-systems resulting from the deliberate release of oil into the waters of the Gulf and the ignition of massive oil-well fires.

A number of international agreements have been developed with the goal of either limiting damage to the environment in times of war or of limiting the development of certain kinds of weapons whose prime destructive mechanism is to cause harm through manipulation to the environment. In view of the recent events of the Gulf War, questions arise whether obligations under international law respecting arms control and the natural environment have been breached and whether any lessons can be drawn respecting future efforts to verify such breaches.

Several meetings of international experts have wrestled with the issue of what currently constitutes international legal obligations in this field. There has been little focus, however, on how to verify compliance with these legal obligations respecting arms control and the environment. In other words, assuming that such legal obligations do exist, what would constitute evidence of a breach and how can such evidence be collected.

At the invitation of the Arms Control and Disarmament Division of External Affairs and International Trade Canada, the Toxicology Research Centre agreed to host a Workshop with the objective of bringing together a group of experts from academia and government to undertake an initial exploration of existing provisions for verification respecting arms control and the natural environment, with a view to identifying appropriate improvements, if any. Although the discussions and conclusions of this Workshop were tentative in nature, they focused particularly on the Environmental Modification Convention and, therefore, should be relevant to the Second Review Conference of that Convention. Participants were generous in providing their time and in preparing written texts of their presentations.

Readers should note that the views expressed in these proceedings are those of the authors and not necessarily those of External Affairs and International Trade Canada, of the Canadian Government, or of the Toxicology Research Centre.

H. Bruno Schiefer
Toxicology Research Centre
August 1992

KEYNOTE ADDRESS

ARMS CONTROL AND THE ENVIRONMENT IN THE POST GULF NEW WORLD ORDER

KEYNOTE ADDRESS

Peggy Mason, Ambassador for Disarmament,
External Affairs and International Trade Canada

Introduction

It is a distinct privilege and pleasure for me to be here with you in Saskatoon today. For those of us actively concerned with arms control and disarmament, the last twenty-four months have surely presented an unprecedented period of challenge and opportunity. In my view, 1992 promises to provide a radically different point of departure in terms of arms control verification. Verification will be a significant function of the arms control and disarmament process in the yet to be defined "New World Order." Whether the bipolar relationship which has existed heretofore expands into a multipolar world or evolves into a unipolar one, as some analysts suggest, the arms control world will be different.

It seems clear that multilateralism promises to become a more significant factor. Indeed, four prominent scholars -- two Canadians and two Americans -- concluded, in a recent study entitled Verification to the Year 2000, that through the next decade multilateral agreements will become more complex and more significant than bilateral treaties.[1] It is upon this multilateral dimension of arms control negotiations that Canada continues to focus its attention.

Since the signing of the Convention on the Prohibition of Military and Any Other Hostile Use of Environmental Modification Techniques (ENMOD Convention), some fifteen years ago, there has been a significant evolution in the development of multilateral arms control agreements. The dramatic transformation which has taken place regionally in Europe within the last two years, and the re-emergence of the United Nations as a significant player in the global context, have served as catalysts in this process. They have served in the redefinition of the broader context within which the role of multilateral verification is destined to take on a higher profile.

Multilateral Verification

To be successful, multilateral arms control and disarmament agreements must incorporate a package of effective, mutually supporting and well-defined verification provisions. Verification, in this context, encompasses a wide spectrum of methodologies and techniques. At one extreme, parties to a treaty might simply agree to a complaint and consult mechanism. The verification provisions under Article V of the ENMOD Treaty reflect this approach. Although this mechanism is useful, it is sometimes characterized as "token" rather than "real" verification. At the other end of the verification spectrum, a treaty might call for intrusive measures including the presence of inspectors on-site in a variety of circumstances.

Verification effectiveness is often seen in direct correlation to the degree of intrusiveness countenanced within a treaty mandate. For verification of compliance in the longer term, however, it may be necessary to determine what is the minimum

degree of intrusiveness in the verification process which will provide the level of confidence that all parties will require in terms of compliance with treaty obligations. To accomplish this, an understanding of synergistic effects, brought to bear by a number of mutually interacting methods of verification, will be essential.

The ENMOD Treaty

In the 1960s and 1970s, a number of agreements, of which the ENMOD Convention is one, were concluded on partial measures of arms control and disarmament. Another such treaty was the Biological and Toxins Weapons Convention, on which a special experts group has been meeting for the last two weeks in Geneva in an attempt to improve upon existing verification provisions. Though limited in scope, it was felt that such measures could play a significant role in fostering confidence and stimulating progress towards the adoption of further measures in disarmament.

The problem of artificial modification of the environment for military or other hostile purposes began to attract increasing international attention in the early 1970s, especially after the United Nations Conference on the Human Environment, which was held in Stockholm in 1972. The importance of the problem arises from the fact that scientific and technical progress opens the possibility not only of influencing the natural environment in beneficial ways -- for instance, by artificially induced rainfall, prevention of hail-storms, fog dispersion, neutralization of the destructive force of hurricanes and typhoons -- but also of using environmental modification techniques for military or other hostile purposes. This negative potential led to efforts to achieve an international agreement prohibiting such modification for hostile purposes before the techniques involved had become fully developed by States.

In 1974, the question was examined at a summit meeting held in Moscow between General Secretary Leonid I. Brezhnev of the Soviet Union and President Richard M. Nixon of the United States. A joint statement was issued in which the two countries, among other things, recognized that the use of environmental modification techniques for military purposes could have widespread, long-lasting and severe effects harmful to human welfare.

In 1975, the Soviet Union and the United States submitted to the Conference of the Committee on Disarmament (CCD) separate but identical texts of a draft convention. After intensive negotiations during its 1976 session, which led to a number of changes in some of the provisions of the identical texts, the CCD included in its report to the General Assembly of the United Nations the text of a draft convention, together with comments, dissenting views and reservations thereon.

On 10 December 1976, the General Assembly adopted resolution 31/72, which referred the Convention to all States for consideration, signature and ratification and requested the Secretary-General of the United Nations, as depositary of the Convention, to open it for signature and ratification at the earliest possible date.

The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques was opened for signature and ratification on 18 May 1977 and entered into force on 5 October 1978. Today there are 55 parties to the Convention and 17 signatories.

The Gulf War

The invasion of Kuwait by Iraq, some eighteen months ago, and the resolute response by the United Nations as a result, have served to sensitize world awareness concerning the global implications of regional disputes. Most certainly the Middle East peace process has become a central ingredient in the design of what President Bush now refers to as "the New World Order."

From our perspective, here today, the Gulf War has served as a catalyst to bring under review what was fifteen years ago considered to be a peripheral agreement but what is now, in the post Gulf War scenario, a very real issue. Combined with — but separate from — the United Nations Conference on the Environment and Development scheduled for Brazil in June of this year, 1992 appears destined to be the year of global attention to the environment.

Saskatoon Workshop

Turning directly to the meeting before us, I want first to express a real note of gratitude to Dr. Bruno Schiefer for having agreed to organize and host the Workshop. But beyond that, I want to acknowledge on my own behalf and on that of my predecessors in this office, the very deep appreciation for the research support which Dr. Schiefer has provided to the Department of External Affairs and to the United Nations over the years, beginning with the "Yellow Rain" controversy in 1981 and continuing right up to the present. Much of what Dr. Schiefer, and more lately Dr. Sutherland and others here at the University of Saskatchewan, have accomplished, has shaped the way in which the United Nations now reacts to the challenges posed in the Chemical Weapons (CW) and Biological Weapons (BW) fields.

On reviewing the participants of this Workshop, one cannot but conclude that we constitute a rather eclectic group. Law, science, technology and the sometime subtle art of diplomacy are all represented here today. While the major conferences held on this subject to date -- Ottawa, London and Munich -- have focused on the legal aspects almost entirely, we will move on from there and have the opportunity here to include the scientific, technical and security related dimensions also. We will be able as well to consider the possible use of satellite and aerial observation and to benefit -- on a real time basis -- from the experience of the United Nations Special Commission.

As the person designated to lead the Canadian delegation to the ENMOD Review Conference in Geneva in September 1992, I look forward particularly to the "lessons learned" portion of the agenda and to learning from all of you how we might benefit <u>from our collective experience</u>, taking into account the multidisciplinary nature of the problems before us.

The timeliness of this meeting is not in doubt. The preparatory meeting (PREP COMM) for the ENMOD Review Conference was just held in Geneva last week. It seems that <u>most</u> of the necessary decisions were taken to enable the Conference to get under way on schedule in September. But, I regret to say, not without the usual dreary procedural wrangling which, in my view, is a part of the "old think" that we ought to have been able to shake off by now.

It is all too reminiscent of the 1991 Review Conference of the Biological and Toxins Weapons Convention (BIWC) -- where, again, I had the privilege of leading the Canadian delegation. There, we managed in the end to take some of the necessary decisions, particularly regarding the establishment of a verification experts working group. Canada characterized the results as "solid", if unspectacular, progress. But in a time of "unprecedented challenge and opportunity" -- words we hear over and over again -- dare we not hope for more than a few incremental steps forward? In the ENMOD context, we shall see.

There is no doubt in my mind that this Workshop is going to be extraordinarily helpful to me as we make our final preparations for the Review Conference.

In terms of our deliberations here, one basic issue is to determine how to collect evidence and what form that evidence might take in terms of verification of non-compliance. An ancillary question is whether or not the ENMOD Convention has been breached by the type of activities which were initiated by Iraq in Kuwait and in the Gulf. I know that Paul Fauteux, in his paper for Ecodecision, will focus on this issue, among others. Finally, we might focus on the synergistic effects of a variety of expertise and inspection techniques to improve the effectiveness, including the cost-effectiveness, of the verification process.

Finally, I want to express my appreciation to you all for agreeing to participate in this Workshop on a matter which is likely, in one form or another, to be with us for some time. Our discussion will, I trust, be informal and frank. I hope, as a result, our collective expertise will permit us, as Canadians, to portray, promote and defend the interests of Canada and the common values of Canadians in the world in ways that promote concrete progress towards, if not new, at least more world order in the waning years of the 20th Century.

References

1. S. Graybeal, et al., Verification to the Year 2000, Arms Control Verification Studies, No. 4, (Ottawa: External Affairs and International Trade Canada, 1991).

SESSION 1

SETTING THE CONTEXT: REVIEW OF EXISTING AGREEMENTS ON ARMS CONTROL AND THE ENVIRONMENT, AND THEIR VERIFICATION PROVISIONS

Chairperson: Ambassador Philippe Kirsch

INTRODUCTION

Ambassador Philippe Kirsch, Q.C.
Deputy Permanent Representative of Canada
to the United Nations

The impact of the Gulf War on the Environment has understandably very quickly attracted considerable attention. Among the various conferences that have been held so far, this "Workshop on Verifying Obligations Respecting Arms Control and the Environment" has probably assembled the widest variety of disciplines. Each and every one of us looks at the issue from a different perspective, and, to a degree, we may all suffer a little from partial vision. It is a dubious honour for me to be the first to have to prove it.

Appropriately, this panel will begin its substantive work with an overview of the Convention on the Prohibition of Military and Any Other Hostile Use of Environmental Techniques (ENMOD Convention), by Dr. Fred Roots. Appropriately, because that Convention is probably the one that focuses the most explicitly on the Environment as a whole; it does include specific verification provisions -- a subject matter which is fast-expanding, as Ambassador Mason just explained -- and it is subject to a review process, currently leading to the Second Review Conference of the Convention. The Preparatory Commission to this Review Conference, which met earlier this month, did little more than deal with procedural issues, but the Conference itself is likely to consider, among other issues, the scope of ENMOD in relation to the use of the Environment as a weapon of war in occupied Kuwait. Indeed, events in Kuwait will be our second subject this afternoon, to be presented by Mr. Paul Fauteux. The third presentation, on Satellite Observation, will be made by Dr. Peter Zimmerman and will take us into verification itself.

Given the wealth of expertise in the room today on science, technology, arms control and specifically verification, I will limit my own introduction to a few general reflections on the legal framework. After all, the law at its best should respond to actual practical needs. Also, it should be kept in mind that verification must be applied to compliance with specific legal obligations, or must be tailored to legal obligations that are themselves being developed.

I am not certain what the expression, "Arms Control," in the title of the Workshop is intended to cover, but I would hope its interpretation will not be too narrow. One of the difficulties of the subject is precisely that different kinds of law have developed in parallel, all affecting the protection of the Environment in time of armed conflict, without much of a common denominator: hard law and soft law, old law and new law, weapon-oriented law, human-oriented law, and even, occasionally, Environment-oriented law.

The degree of protection afforded to the Environment by such a crazy-quilt of provisions is difficult to assess. This very difficulty has led to suggestions that a brand new instrument should be developed, but we will see in the next couple of days that this approach is not without its own problems.

The impression of uncertainty as to the state of the law, which has emerged from the three expert conferences held in 1991 in London, Ottawa and Munich, is not

accidental. The way the United Nations General Assembly treated the subject at its 46th session also reflects considerable hesitations. The real interest a number of States had in the subject did not translate into major results. Upon the recommendation of its Second (Economic) Committee, the Assembly merely adopted a resolution which, basically, amounts to a request for assistance to States and the United Nations system in studying and mitigating the environmental deterioration of the Gulf region.

As for the Sixth (Legal) Committee, it could not even agree to develop a resolution and came up with a decision which originally simply reinscribed the item and asked the Secretary General to prepare a report on the basis of the 26th International Conference of the Red Cross and the Red Crescent, which was then to be held this year in Budapest. That Conference, having been cancelled for unrelated reasons, the Secretary General now has to report on "activities undertaken by the Red Cross with regard to that issue." The Secretary General's report will probably focus on a meeting of experts convened by the Red Cross on April 27-29. To my knowledge, the Red Cross itself seems to consider this meeting as an exploratory one, without preconceived ideas as to its outcome.

Old and new provisions applicable to Environment and War have been extensively reviewed in the past couple of years, and have not escaped criticism. Pre-1970 treaties focus on humans and their property. Nevertheless, some of their provisions are indirectly relevant to the environment: the principle that the right of belligerents to adopt means of injuring the enemy is not unlimited; the principle that destruction of property by an occupying power is prohibited except when such destruction is rendered absolutely necessary by military operations; the principle that military operations may only be directed against military objectives; and various provisions ranging from the principle of proportionality to restrictions on the use of asphyxiating gases.

The Martens clause in Hague Convention IV of 1907, later reproduced in modern treaties on humanitarian law, is also seen as an embryonic basis for environmental protection. It states:

> Until a more complete code of laws of war has been issued, the High Contracting Parties deem it expedient to declare that, in cases not included in the Regulations adopted by them, the inhabitants and the belligerents remain under the protection and the rule of the principles of the laws of actions, as they result from the usages established among civilized peoples, from the laws of humanity, and the dictates of the public conscience.

Despite their relevance, the generality and indirect applicability of such provisions makes them of uncertain -- and untested -- use. Lack of implementation mechanisms and dispute-settlement procedures is a compounding problem.

More recent instruments are more specific, but most have been deemed somewhat inadequate on various grounds: lack of authority, in the case of non-binding instruments; insufficient participation in certain treaties; lack of specificity of relevant applications and obligations; too many reservations by participating States, etc.

The ENMOD Convention itself is exclusively concerned with the Environment, but it has not been widely adhered to and it is highly unlikely to be considered as reflecting customary law. It is concerned entirely with "environmental modification

techniques," while substantial environmental degradation in wartime is almost always a collateral effect of military operations aimed at other objectives. A number of amendments have been suggested to ENMOD, including precise listing of prohibited environmental modification techniques; prohibition on research, development, production and possession of those techniques (in addition to their use); and elimination of the threshold of "widespread, long-lasting or severe effects" of those activities for the Convention to apply, even though this threshold is much lower, as seen below, than that set out in the other major instrument, the 1977 Protocol Additional to the Geneva Conventions of 1949, and Relating to the Protection of Victims of International Armed Conflict (Protocol I).

Protocol I has received more than 100 ratifications but lacks some key ones including France and the United States. It contains a number of articles that are relevant to the Environmental issue and deal with the intended or expected effect of certain actions. But, for the main provisions to apply, cumulative criteria of "widespread, long-term and severe damage to the natural environment" have to be met, and these criteria have been interpreted as imposing a very high threshold indeed. Other qualifiers apply to various provisions. The impact of those dealing with works and installations containing dangerous forces, for example, and those on the protection of foodstuffs, crops and certain agricultural areas, is restricted in practice by elements such as the military necessity exception, and the requirement of a link between damage to the natural environment and prejudice to the health or survival of the population.

These and other instruments, such as the 1980 Convention on Certain Conventional Weapons Which May be Deemed to be Excessively Injurious or to Have Indiscriminate Effects (Inhuman Weapons Convention) and the Geneva Protocol of 1925 Prohibiting the Use of Chemical Weapons and Bacteriological Weapons of Warfare, have been abundantly commented upon by different international lawyers and other experts. But this review has produced very different reactions.

A number of experts have concluded that existing instruments need to be supplemented and updated, but they differ on the method. Some have suggested that entirely new agreements are required, which would pick up elements of existing binding and non-binding instruments, consolidate and expand existing provisions of the law and add certain elements such as criminal responsibility and liability and verification. The suggestion for these additions is in some ways a natural consequence of Security Resolution 687 which, inter alia, established Iraq's responsibility for environmental damage and depletion of natural resources, and created the United Nations Special Commission (UNSCOM). The hope is to create a new treaty that would be binding but might attract wider participation because of the absence of certain controversial provisions in existing instruments, which so far have kept certain States away.

Others think the development of new treaties would be a lengthy and unpredictable procedure, and propose alternative approaches building on existing provisions and widening participation, until the time is ripe to conclude specific new agreements for areas of concern.

At the other end of the spectrum are those who consider that existing law is adequate; that, if there is a problem, it is basically one of adherence, implementation and compliance; that, in other words, what Iraq did in Kuwait is

already prohibited; that attempts to develop new rules would weaken the force of existing provisions; or, that new laws, even if justified by environmental considerations, would make no military sense and is, therefore, certain to be rejected or ignored by States that count.

There is, finally, another current: those who see little value in distinguishing between wartime and peacetime when it comes to protecting the Environment, and consider that the same principles should apply in all circumstances. This approach, however, probably runs into even more problems than the idea of developing new laws applicable to the protection of the Environment in time of armed conflict. One of the concluding paragraphs of the Chairman's summary of the Ottawa Conference is quite telling on this point: "At the outset, the view was clearly expressed that the law of armed conflict took precedence over the general law of the Environment during wartime."

As a non-expert in this area, all this leaves me with a number of questions, on which I hope the next few days will shed some light. I also hope we will be able to avoid the "last war" syndrome, expressed at the London Conference as follows:

> It is often said that Generals spend all their time fighting the last war. It is also true that pacifists spend most of their time opposing the last war. Lawyers, of course, legislate the last war.
>
> Let us hope we have enough non-lawyers in the room to avoid that fate.

INTERNATIONAL AGREEMENTS TO PROHIBIT OR CONTROL MODIFICATION OF THE ENVIRONMENT FOR MILITARY PURPOSES: AN HISTORICAL OVERVIEW AND COMMENTS ON CURRENT ISSUES

E.F. Roots
Science Advisor Emeritus
Environment Canada

Historical Setting

Deliberate changes or modification to the environment, or the unleashing of environmental forces to achieve a specific destructive objective, have been practices of humankind for as long as tribes or nations have quarrelled with one another. Environmental modification as a weapon of war is as old as mankind itself. The deliberate use of environmental forces for hostile purposes probably can be traced back to the time when an attacker or a defender rolled stones down a mountain slope to trap or destroy an enemy in a narrow pass, or set a grass fire to burn an enemy village. This has been the stuff of historical incidents, heroic tales, and novels from ancient Greece to the American Wild West.

Some notable incidents of deliberate environmental modification undertaken in the past, for military purposes, may be mentioned:

(a) About 2400 B.C., Entemenar, ruler of Sumer, had a canal dug to divert waters from the Tigris to the Euphrates watershed, thus making his country independent of the water supply from his rival kingdom Umma. This action brought victory and an end to what had been generations of war over water. The resultant rise in groundwater level in the desert soils caused, intentionally or not, rapid salinization of the border lands, impoverishing Umma and rendering it impotent as a military power. The scheme was successful, and resulted in dominance of the region by Sumer for a hundred years or so. Then it backfired, leading to the economic ruin and disappearance of Sumer itself through salt leaching of their own over-irrigated desert soils. By 2200 B.C. mighty Sumer was easy prey for upstart Babylon, which had less wealth and poorer technology but a clean environmental base.

(b) The most famous example of environmental modification for military purposes -- ENMOD for short -- was, if you take the Bible literally, about 1500 B.C. According to traditional accounts, which were written in the Old Testament, Moses (with Divine help) parted the waters of the Red Sea, just long enough for his people to escape from the pursuing Egyptian army. Then the sea came back and trapped the Egyptians. The mechanism by which Moses accomplished this rapid environmental modification is not clear to ordinary mortals today, but presumably he did it all by triggering tectonic movements. Certainly the geological structure and accumulated crustal stress in the Red Sea graben makes this a good potential location for ENMOD, if God is on your side.

(c) By the time of the Carthagenian (Punic) Wars, ENMOD was an established military practice. Around 205 B.C., local tribes are supposed to have set off avalanches and landslides, to block the Carthagenian army from

using the main travel routes in the Savoy Alps, forcing Hannibal and his elephants to make a spectacular crossing of the Alps farther north in order to attack Rome. In 146 B.C., at the close of the Third Punic War, victorious Rome plowed salt into the farm fields around Carthage, destroying for a long time the city's economic base. Carthage never recovered as a world power, and that part of North Africa never again became a centre of military force of any international consequence until the twentieth century activities of Col. Gadaffy. That action of the Roman army certainly was deliberate, long-lasting, widespread, and severe environmental modification for military purposes.

The Recognition of the Relation Between Military Activities and the Environment

In the modern context, concern over the effect on the environment of military activities, or the effect that environmental changes caused by military actions might have on non-combatting parties, is quite recent.

Until the present century, environmental destruction, even if quite severe, was an unfortunate consequence of warfare and military necessities, and if other countries or other parties were affected, that was simply too bad. The "all's fair in love and war" principle allowed protagonists or combatants to use the environment in any way they wished to achieve military objectives.

Some questions were raised in the British House of Commons during the Boer War 1899-1901 about the destruction of land as a military strategy as well as an incidental result of military operations. As a consequence, the field officers were instructed not to cause permanent damage to the countryside for which they were fighting. This may be an early expression of political concern to prevent environmental modification for military purposes. But there seems to be nothing in World War I or in the debates and resolutions of the League of Nations that recognized a responsibility to prevent deliberate environmental damage or modification.

The same appears to be true during World War II. There was a great increase of consciousness of the widespread and severe environmental damage and its consequences, but such damage, even if deliberate, was seen as the inevitable accompaniment of military action, and thus was an argument against war itself, rather than an environmental activity to be avoided. There do not seem to be any documented cases of deliberate changing or manipulating the environment for the purposes of war.

Interestingly, the first direct international action to recognize damage to the environment itself as a responsibility to be considered by those in charge of military activities came with the most modern of military weapons, the nuclear bomb. Awareness of the destructive effects that dispersed radioactivity would have on all living things, not only on humans, and that the effects of ionizing radiation, once released, could not be stopped, controlled, or removed by any known process, brought environment and military actions together in a quite new way. And when evidence began to accumulate that the testing of nuclear weapons in the atmosphere was having a measurable effect on the radioactive environment of the entire world, the realization emerged that a radioactively contaminated environment could itself be a weapon of military significance, as well as a

source of long-term damage both to combatants and non-combatants. The logic that there should be international control of military-related activities that could have far-reaching effects on the environment, so as to control the alteration of the environment itself as a possible military weapon, was indisputable.

The political result of this awareness and concern was the Nuclear Weapons Partial Test Ban Treaty of 1963, which prohibited nuclear test explosions in the atmosphere, outer space, or under water. Explosions in any other environment are permitted under the Treaty only if they do not cause radioactive debris to be present outside the territorial limits of the state under whose jurisdiction or control they are conducted. While the prime intent of this Treaty was to protect people from a contaminated environment, a secondary consideration was to discourage or prohibit use of the contaminated environment as a hostile threat or an agent of war.

This is the first international agreement recognizing that a nation must take responsibility for the environmental effects of its military activities. It was followed by others in the nuclear weapons field including the bilateral Threshold Test Ban Treaty (1974) and the Peaceful Nuclear Explosions Treaty (1976).

There are also now regional treaties prohibiting nuclear military activities in Antarctica, Latin America, the South Pacific and on the Moon. These treaties have environmental concerns as a basis, but only the Moon Treaty specifies directly the need to avoid damage to the environment. (Some may feel that this clause is a bit presumptuous given that we know very little about the environment of the Moon, or what would constitute damage to it.) Only a few of these treaties provide for means of verification, and none state criteria for recognition of environmental damage.

The Background to the ENMOD Convention

The ENMOD Convention itself, however, had a somewhat different, although parallel background. It had its beginnings in concerns about the consequences of modification of the environment for non-military purposes. The following outline touches on some of the key developments:

(a) In the late 1960's, the beginnings of ideas and actions about technological weather modification became widespread. (There have always of course been "rain-makers", and those whose business it was to influence natural powers to deliver rain to crops, bring on the monsoons or cause flood waters to recede; but these were in the realm of magic and intervention with the gods, not of technology.) The practical effectiveness of "seeding" clouds with chemical particles that act as condensation nuclei under certain favourable meterological conditions to cause precipitation grew quickly into a widespread practice. By 1978, seventy-four countries were using cloud seeding to increase precipitation or to suppress hail. Some important steps in this evolution may be noted:

i) Several states in the U.S. licensed professional cloud seeders. This led, inevitably, to legal actions where a farmer situated downwind from a cloud-seeding operation sued the upwind farmer, or

the rain-making company, for robbing him of rain that might otherwise have landed on his farm. The idea of responsibility for artificially changing someone else's "natural" environment thus entered the law courts and the statute books.

ii) In Canada, similar things were happening, although characteristically they took a less litigious route. Cloud seeding became a small industry, especially in southern Alberta and Saskatchewan. The Atmospheric Environment Service undertook a research programme on the use of artificial cloud seeding to cause rainfall to suppress forest fires. Many of the experiments were in northernmost Alberta and the Northwest Territories (east of Yellowknife), in part because it was a good place for the experiments, but also in part to lessen the risk of complications with agriculture, or other precipitation-sensitive private activities. The Alberta Research Council undertook a somewhat parallel programme to develop techniques for artificially reducing the severity of hailstorms.

iii) Hydro Quebec experimented extensively with the use of seeding to increase rainfall in catchment basins and thus help fill the hydroelectric reservoirs. Their experiments were followed on occasion or accompanied by such copious rainfall that the public protested. In 1964, after 69 consecutive days with rain, housewives in northwestern Quebec organized "Operation Umbrella" to protest Hydro Quebec's downpours. The Operation collected 61,000 signatures on a petition, set a "bounty" on captured rain-making equipment, thus causing some vandalism, and even successfully petitioned the government to issue free vitamin D tablets to school children deprived of sunshine! Whether the rainstorms that caused such a public outcry were caused, even in part, by the artificial seeding became lost in the furore, and the Government of Quebec ordered Hydro Quebec to abandon the experiments. One long-lasting result was the Quebec Weather Modification Act of 1970; the first of a number of Canadian provincial acts controlling the licensing and reporting of weather modification activities.

iv) Canada and the U.S. set up review committees to consider the various aspects -- scientific, legal, economic -- of weather modification, and to plan and review joint or co-ordinated research. Binational meetings were held between the U.S. Weather Modification Advisory Board, chaired by Dr. Harlan Cleveland, and the Canadian Working Committee on Weather Modification, chaired by the undersigned.

One result of this binational activity was signature in 1975 of the Canada-U.S. Memorandum of Understanding on Notification and Consultation Regarding Weather Modification Activities. The Memorandum commits authorities of each country to provide advance notification of any activities within 200 miles of the border on either side, that could affect the weather of the other country. This MOU has worked well for 15 years.

v) The World Meteorological Organization (WMO) also was active in the weather modification business. The Global Atmospheric Research Programme (GARP) (1968-79) outlined new possibilities and drew international attention to the idea that human activities could trigger large-scale weather changes. In 1978 it organized an international 5-year research experiment known as the Precipitation Enhancement Programme (PEP) in Spain, where various cloud-seeding techniques were applied on a test basin and the results compared, over a number of seasons, with adjacent areas in the same weather system left untreated. Canada and the U.S. collaborated in a similar large-scale experiment that extended from Wyoming to Saskatchewan. As a consequence of these and other similar activities, politicians and the public in several countries became used to the notion that, contrary to Mark Twain's famous remark, people were "doing something about the weather" (or at least were trying to) as well as talking about it; and furthermore that weather modification was a legitimate government concern.

(b) The U.N. Conference on the Human Environment (Stockholm, 1972) formalized the responsibility that activities carried out within a state should not adversely affect the environment of other states or of areas beyond national jurisdiction (Principle 21).

The principal actions focused upon at the Stockholm conference were acid rain and the spread of toxic pollutants in air, rivers and the oceans. At the time, concerns were raised that the atmospheric nuclear weapons testing would not only poison the atmosphere of a large part of the planet but might also affect the weather (in the early tests, considerable attention was given to the intensive lightning and local rainstorms that accompanied "mushroom clouds" at test sites). Furthermore, the WMO studies had shown that it would be difficult for any country to define any atmospheric or weather-related activity that did not affect the environment outside its borders. Some critics saw this as making Principle 21 impossible to apply; others saw it as making the Principle vitally necessary. Canada was a strong proponent of Principle 21.

(c) At about the same time as the GARP and the U.N. Stockholm conference, there occurred two environmental incidents of a different sort:

i) A destructive earthquake at Hogben, Montana was determined to have been triggered by the construction of a hydroelectric dam and the filling of the headpond.

ii) A series of snowslides in northern Italy, caused in part by road construction, splashed into a dammed lake, and generated a synchronous reverberating wave that overtopped and broke the dam, and the resulting flood caused severe loss of life.

These events further contributed, in a public already sensitized by weather modification activities and a then-current vogue for popular science and plausible science fiction by able writers such as Asimov, Clarke, and Sturgeon, who intrigued readers with visions of radically

changed future environments, to a fear that human actions or technology could or soon might be able to influence natural phenomena on a regional or global scale, with disastrous results for life or society.

(d) The potential military applications of these actions (influence on weather, triggering of earthquakes, or the setting in train of circumstances that could cause catastrophic floods) became apparent. The numerous "small" military conflicts throughout the world, as well as the continued superpower tensions seemed to offer temptations for the use of modern technology to bring about destructive changes in the environment for political or military ends. As a result of these concerns, in 1973 the U.S. Senate passed a resolution calling for an international agreement to "prohibit the use of any environmental or geophysical modification as a weapon of war."

(e) This same subject was on the agenda for the Nixon-Brezhnev (US-USSR) summit in 1974. The two leaders agreed that the USSR and the USA would undertake bilateral discussions to "prevent or overcome the dangers of the use of environmental modification techniques for military purposes."

The Development of ENMOD

Late in 1974 the USSR/USA bilateral discussions agreed upon at the Nixon-Brezhnev summit took place; and in 1975, at the UN Conference of the Committee on Disarmament (CCD), the U.S. and Soviet delegations tabled parallel, identical texts for a convention to prohibit or control deliberate modification of the environment for military or hostile purposes.

It was proposed that the convention should cover deliberate changes:

- to the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere, atmosphere or outer space;
- to weather patterns or climate, or in ocean currents;
- in the state of the stratospheric ozone layer or the ionosphere;
- that would result in any distinct upset in ecological balance.

This range of situations proposed to be covered by such a convention was so sweeping that if applied literally, many analysts feared it could claim to stop all military activities. As there was little likelihood that either of the proposing countries would allow all their military actions to be controlled by environmental considerations, there was widespread cynicism that the proposed convention would likely be anything more than an ineffective gesture on paper.

During 1976, discussions and negotiations were undertaken in the CCD to find a workable text that would be practical, given military and policy realities and the state of technology, and at the same time serve to prevent the environment from being used deliberately as a weapon of war.

Canada's response was to establish a small scientific group to examine and assess the plausibility and reality of the potential hostile uses of the environment. Our first objective was to attempt to determine what categories of deliberate environmental modification might be useful for military purposes, or

what modification techniques could potentially within a few decades become instruments of or accessories of warfare, and which ones were simply "science fiction". I was asked to chair this study, which was co-ordinated by the federal Department of the Environment.

The Canadian study looked at five main categories:

(a) environmental effects of nuclear warfare and of the production and deployment of nuclear weapons (both ionizing radiation and climatic effects);

(b) deliberate modification of the weather:

- to cause drought, forest fires, floods, avalanches, landslides,
- to cause severe weather (destructive hail, tornadoes, hurricanes),
- to create a hostile medium-term climate (i.e. one that might be favourable for the spread of crop blights, snow-blocked highways, etc.);

(c) modification of ecosystems:

- forest destruction
- introduced pests
- soil contamination;

(d) modification of geophysical processes:

- earthquakes, tsunamis,
- volcanoes,
- lightning at selected locations,
- significant changes in the electrical properties of ionosphere (causing, for example, breakdown of radiocommunications or disabling of navigation equipment);

(e) modification of ocean conditions:

- currents,
- persistent fog,
- sea ice.

For each of these categories of potential or imagined modification of the environment, we made a simple assessment or estimate of the likelihood of possible modification or control "on demand" by any present or scientifically plausible technology, the range of natural situations in which such modification might conceivably be successful, and what might be the consequences if such a modification were to be successful.

The Canadian analysis was tabled at the Conference of the Committee on Disarmament (CCD). It appeared to be well received as a constructive contribution of scientific opinion, to what had become a rather esoteric legal and political negotiation.

Soon after, the Netherlands government formed its own committee to examine the "Canadian analysis". They published their appraisal in the journal AMBIO, thus giving further international public exposure to Canada's contribution.

The text of the Convention developed by the CCD was adopted by the United Nations General Assembly in October 1976 by a vote of 96 to 8, with 30 abstentions. The draft convention, entitled a Convention on the Prohibition of Military or Other Hostile Use of Environmental Modification Techniques, and popularly called the ENMOD Convention, was referred to all nations for signature, and was to enter into force when ratified by 10 countries.

In May 1977, Canada and 33 other countries (including Iraq) signed the Convention. By 5 October 1978, 10 countries had ratified, and the Convention entered into force. The United States ratified on 5 January 1980, and on 6 November 1981, Canada ratified.

By September 1984, when the first Review Conference was held, 47 countries had ratified, and another 19 had signed the ENMOD Convention.

An Overview of The ENMOD Convention

The Convention has a simple text. There are 10 articles, four of which have supplementary explanatory "understandings". Some States have ratified the Convention while still expressing reservations about some of the "understandings".

Article I

Under this article, States parties undertake not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting, or severe effects as a means of destruction, damage or injury to any other state party.

Understanding to Article 1

The accompanying "understanding" paragraph simply provides definitions:

a) widespread - encompassing several hundred square kilometres.

b) long-lasting - a period of months, or approximately a season.

c) severe - serious or significant disruption or harm to human life, natural and economic resources or other assets.

Article II

Environmental modification techniques are stated to include any technique for changing, through deliberate manipulation of natural processes, the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere and outer space.

Understanding to Article II

This statement provides illustrative examples, including earthquakes; tsunamis; upset of ecological balance; changes in weather patters or ocean currents; changes in the state of the ozone layer; changes in the state of the ionosphere. The understanding recognizes that the list is not exhaustive. Other phenomena would be included provided that the criteria in Article I were met.

Article III

The Convention will not hinder the use of environmental modification techniques for peaceful purposes. States parties to the Convention undertake to exchange scientific and technological information.

Understanding to Article III

This Convention does not deal with whether or not peaceful modification of the environment is or is not in agreement with established international law. Thus, the Convention cannot be used in support of, or against, any legal action concerning environmental modification.

Article IV

Each state will use its laws and constitution to prohibit violation of the Convention.

Article V

States are required to consult and co-operate in the implementation of the Convention, through a UN Consultative Committee of Experts, and through UN Security Council. Thus, the entire United Nations system, and not a single designated body, is given responsibility for the Convention, and any UN body may be approached with regard to it. This arrangement has been considered by some to be a progressive forward step in international actions, but others have termed it "passive self-verification" and a recipe for inaction.

Article VI

This article deals with the procedure for amending. Amendments may be proposed by any State party, and will be adopted when all States parties have agreed. Thus, any signatory State has a veto on any amendment.

Article VII

The convention is of unlimited duration.

Article VIII

There is provision for a Review Conference after 5 years, and for subsequent reviews.

Understanding to Article VIII

This understanding states that a proposal to amend may be considered at any conference held under this Article, and gives a schedule for deposit in advance of notice of proposed amendments.

Article IX

The Convention will be permanently open to all States to accede. There is no specific provision through which a State may withdraw from the Convention.

Article X

The Secretary-General of the United Nations is the depository of the Convention. It may be significant that the ENMOD Convention is the first multilateral agreement in the field of arms limitation and military activities that has entrusted the functions of depository to the Secretary-General.

Subsequent Action

The First ENMOD Review Conference was held in September 1984, in Geneva. It was attended by delegations from 35 States parties, and 8 observer States. It was chaired by the Finnish ambassador to the UN. After clause-by-clause discussion and a review of world events, the Conference confirmed that Article I had been complied with by the parties. There was consensus that the Convention had been effective. The article-by-article debate found no need for change in the text of the Convention. It was also agreed that although the earlier "enthusiasm" for commercial weather modification had abated somewhat, peaceful uses of environmental modification techniques and exchanges have progressed, and that the Convention had not stood in the way of development of techniques for controlling or changing the environment for the common good.

The Present State of Knowledge of Environmental Modification Techniques That Could be Used for Hostile or Military Purposes

The techniques to which ENMOD applies must be those that result in environmental changes which are any or all of widespread, long-lasting or severe. To be useful to a protagonist or defender using them for hostile or military purposes, their initiation also must be controllable. At the very least, the technique must be one that can be applied with reason to expect that the environmental effect can be caused or turned on:

- at a time when it is useful to the originator;
- at a place where intended;
- at a scale intended.

It is also important that the effect will operate in such a way that more harm will be caused to the enemy than to the originator. In addition, it would be desirable, perhaps essential, that the environmental effect can be stopped when the cause is removed, or at least be of limited duration, when the operational goal is achieved.

These are not easy criteria to satisfy when one begins to play with Nature. Mother Nature sets her own rules, and does not easily take sides in the quarrels between humans.

The criteria set out in Article I imply that the Convention does not apply to local use of environmental forces e.g., causing avalanches. The same "widespread" criterion probably also puts most earthquakes outside the terms of the Convention, for the damaged area is rarely hundreds of square kilometres (except for the destruction caused by tsunamis). The "long-lasting" criterion would appear to exclude instantaneous or very short duration actions, such as an intense single-pulse distortions of the magnetic or ionospheric field with the intention of destroying regional electronic circuitry, thus causing failure of electronic navigational and guidance equipment, deranging automatic sensors, or causing computers to fail or jam. Although the military consequences might be severe and long-lasting, the environmental change would be brief. However, if the "any of the criteria" interpretation is followed, all of the above examples could "qualify".

It would appear that, seen from today's perspective, there are three main areas of potential environmental modification that might be subject to prohibition or control by the Convention:

(a) Changes that can be brought about quickly, and which can have both short-term and long-lasting effects on the environment.

The short-term effect may be desired for military actions in time of war, or to prevent an opponent from engaging in actions. The actions that had deliberate longer-term effects would be to damage or incapacitate the enemy. Some examples of environmental modifications of this type would be:

i) Large-scale, regional or repeated forest fires

The prime example of this technique that comes to mind is the campaign of drifting incendiary balloons launched from Japan during World War II to cause fires in British Columbia and the northwestern U.S. The scheme was quite successful in terms of environmental destruction — more successful, apparently, than the Japanese knew, owing to effective intelligence control by the Canadian and American military. Such environmental modification could have been an effective military action, at long-term cost to the Canadian environment, had it not been that brilliant geological analysis of the balloon ballast sand enabled the launching site to be pinpointed and put out of action by strategic Allied bombing.

The possibility of setting fires by triggering lightning discharges when meteorological conditions are favourable has received some speculation and attention. There are several possibilities, in locations mainly in the sub-tropics at certain times of the year, for modifying the conductivity and static friction of clouds in order to increase the incidence of lightning discharge and thus harass an opponent. I am not aware of any experiments since those of Benjamin Franklin two centuries ago, directed toward causing, as opposed to reducing the incidence of, lightening strikes.

ii) Large-scale oil spills

In selected areas, large oil spills can have both an immediate operational and long-lasting ecological effect. As tanker accidents in several parts of the world have shown, a supertanker can be an effective mobile environmental weapon. Pipelines and oil wells although not mobile, can also be effective at the right time and place. But the recent Persian Gulf experience has shown that those who would use such a weapon must know the oceanographic dynamics and local marine biology well, if they are to achieve maximum destructive effect. The psychological effect of deliberate oil spills may be greater than the absolute environmental effect; however, this may be counter-productive for the "spiller".

iii) Massive release of airborne pollutants or airborne particulate matter

Most of the scientific knowledge about large-scale environmental modification of this type comes through the mathematical modelling studies of the nuclear winter phenomenon, and from analysis of the ecological effects in 1816 ("The Year Without a Summer") of the dust cloud from the 1815 Mount Tamboro eruption. It is undoubted that a massive release of pollutants or particulates could "poison" plants and soils, and affect groundwater; it could cause changes in local or regional weather, and in precipitation. But to bring about such changes deliberately, for hostile purposes, would require a massive operation well planned in advance and the ability to "strike" only when natural conditions were favourable. And there would still be the problem of control, to ensure that damage was inflicted more on the enemy than on the perpetrator. A related effect, using environmental atmospheric change to incommode the enemy, might in some circumstances be achieved through fuel-air explosions. What would be the required scale of atmospheric explosion to have a regional environmental effect, how the explosive mixture could be transported and how far under what conditions, how it would be triggered, how the destructive force would be propagated and what will be the residual effect on vegetation, as distinct from the immediate effect on humans and structures is, at this time, fortunately only speculation.

iv) Triggering of tornadoes, hurricanes

Recent applied research has shown some success in diffusing and dispersing hurricanes and tornadoes in their early stages. We know of no research into the assisted generation of these violent phenomena. There is some evidence that local tornadoes can be set off when conditions are just right, by human-caused disturbances such as the vortex between two buses passing on a hot highway. But the idea of causing or intensifying a real hurricane or cyclone seems inconceivable at present. To bring such a disturbance about would require very special conditions, unlikely to occur just when needed in wartime, and the course such a phenomenon would take, is, at present, uncontrollable.

v) Earthquakes

Earthquakes are simple destructive environmental events whose mechanisms are well known. It may be tempting to try to use them for hostile purposes. The problems are: (1) as they only occur in certain places one must have the enemy in just the right place at the right time; and (2) one must be able to hold back the release and let the stresses that slowly build up between moving blocks of the Earth's crust accumulate until one is ready, then let them go. At present, the prospects for reducing the chances of damage from large earthquakes by "lubrication" of faults or setting off numerous small movements are better than for facilitating the accumulation of stress and then causing big ones.

Earthquakes occur only in geologically special, well-defined locations. The places where they are most likely to happen are well known, internationally. As it happens, however, a number of the "trouble spots" around the world where military tensions are high are also earthquake-prone, so the temptation to use the environmental destruction from a natural earthquake event, (and perhaps help its destruction a little by taking advantage of the havoc by setting incendiary fires or causing deliberate floods) cannot be discounted.

Some areas of military activity are in earthquake zones where it is conceivable that a well-placed bomb or two could release stresses already present and set off motions leading to considerable destruction. Examples of such places might be certain fault zones in Kurdistan, Armenia, Guatemala. To be of maximum effect, such activity would likely not be in the course of military operations, but ancillary to it, to disrupt the general operations of the enemy country (and its government or army) and make it more liable to military defeat. To be able to "use" potential earthquake stresses would require sophisticated on-site geophysical intelligence, and local preparations that may be conspicuous. There is also the handicap, from the "prosecution of the war" point of view, that at the present time the occurrence of an earthquake with attendant human suffering evokes a world-wide sympathetic response, which could interfere with or negate the ability of a protagonist to use it for strategic military purposes. At present, the potential for triggering earthquakes as a deliberate act of war seems very close to zero.

Tsunamis: As most of the regionally destructive tsunamis are caused by earthquakes on submerged ocean-basin faults, locations where they could be influenced by human interference are very few (there may be some places around the Pacific rim, on or near the Pacific and Indian Ocean islands, or the Azores). Even if they could be started by human action, tsunamis would be impossible to "steer", and at the present state of science, prediction of the course and magnitude of the destructive wave is not good. Despite their destructive potential, the possibility of deliberately using tsunamis as a tool of war or a military threat appears to belong to science fiction rather than to science speculation.

vi) Volcanic eruptions

Volcanoes, the most dramatic expressions of Nature's explosive forces, would, according to various generals since Hadrian (he was a junior

officer in a Roman army campaign that was stopped by a lava flow from Mt. Etna in Sicily), make effective weapons of war, if only one could command them and be sure whose side they were fighting on. From a military or hostile-use point of view, volcanoes have many of the same problems as earthquakes. They occur only in specialized locations, not subject to human choice, and they cannot be moved, although the locus of action may move apparently capriciously without warning. The timing and scale of their activity, likewise, is not subject to human influence, although humans are learning to protect lands from their action and to divert or direct the effects, on a small scale. The potential areas where volcanic action is most likely are well known. However, throughout history there have been some surprises where volcanoes or related phenomena erupted with little warning, in unexpected places.

The effects of volcanoes, as they may be important to military actions, are of two types:

- Lava eruptions are generally too small or local to come under the ENMOD Convention, although the Laki eruption in Iceland of 1784 or the incandescent clouds (nuees ardents) from the eruption in Martinique in 1905 certainly would have qualified had they been deliberately human-caused for hostile purposes.

- The gas and particulate matter emitted from a volcano can have widespread, long-lasting and severe environmental effects, but these are likely to affect both originator and the enemy. The severe effects that ingested volcanic dust can have on engines of jet aircraft, as shown by recent events in Alaska, demonstrate the modern potential for damage by this environmental phenomenon.

There do not seem to be any ideas for triggering or enhancing volcanic activity through deliberate human interference that can be taken seriously. It does not appear that in the foreseeable future, the ENMOD Convention could apply to volcanic eruptions themselves or to the lava, hot water or dust emitted. There still remains, however, as with earthquakes, the possibility that the Convention might by some people be considered to apply to hostile actions that take advantage of the environmental havoc caused by a volcanic eruption.

(b) Changes that can be brought about fairly quickly but whose effect on the environment is gradual or of intermediate term.

Changes of this kind as "the means of destruction, damage or injury to any other state party" will be ones whose direct effect (as an act of hostility) may be different and more immediate than the environmental consequences. Included are:

i) Scorched Earth actions of all types

- Carthage, as already noted, suffered effective deliberate environmental modification at the end of the Third Punic War. It seems that action, had it occurred today, could have been subject to the ENMOD Convention.

- A serious modern example is the extensive destruction of the forests and farm lands of Northern Finland and Norway, during the Second World War.

The environmental effects of these actions, which were intentional, have been long-lasting, widespread and severe. The environmental actions were deliberately hostile, but different from and perhaps incidental to the immediate military operational objectives. Just how the ENMOD Convention would apply would appear to depend upon an interpretation of how the changed environment was "used" for military purposes.

ii) Defoliation of forests

The most conspicuous examples of this type of environmental modification have been connected with U.S. army operations in Viet Nam 1960-1970, where various defoliants were sprayed on the forests in the course of offensive and defensive activities. The environmental effects seem to have ranged widely; some forest trees recovered within a season, while in other cases damage to the forest ecosystem or to agricultural crops has persisted for many years. Activities such as these should be considered with respect to the ENMOD Convention criteria.

iii) Airborne radioactivity

Although the Hiroshima and Nagasaki bombs drastically altered the local environment, there seems to be no evidence that deliberate modification of the environment was a factor in the military activities that brought about the end of the Second World War. The more widespread radioactive contamination of the atmospheric environment from military actions that resulted from nuclear bomb testing in the 1950's and 1960's was also incidental rather than deliberate environmental modification; but was an important factor in bringing about the Test Ban treaties as described above. The accident to the Chernobyl nuclear power station in Southern Ukraine in 1980 which resulted in severe environmental contamination over much of western U.S.S.R., Scandinavia and central Europe and which was detected around the world, had long-lasting environmental effects (sheep meat from some pastures in Norway is not expected to be fit for human consumption until at least 1993), and alerted governments and the public to the potential socioeconomic and political effect that could be caused by regional radioactive contamination of the environment.

Earlier studies and mathematical modelling of the environmental effect of nuclear war had emphasized the potential inadvertent indirect climatic effect ("nuclear winter") which was near-global in its ramifications, making deliberate environmental modification a very risky and probably counter-productive military exercise for anyone who attempted it. The Chernobyl experience, on the other hand, provided the first quantitative data on the biological as opposed to climatic effects of regional radioactive contamination, and has given information on the processes, rate and scale of impact, and consequences of such modification of the environment, by either

accidental or deliberate means. Such information may be useful should it become necessary to assess damage or verify compliance with the Convention.

iv) Seaborne radioactivity

Although laboratory experiments show that many marine organisms are sensitive to increased radioactivity, there is little direct evidence of the effect of small increases of ionizing radiation on marine ecosystems. The best-known example of rapid radioactive contamination of the sea is that connected with the accidental release of a considerable amount of radioactive material from the Windscale (later called Sellafield) nuclear fuel processing plant on the west coast of the island of Britain in 1974. Radioactivity from this incident was quickly incorporated into the bodies of marine organisms in the vicinity, and also dispersed to sea. After apparently having travelled from the Irish Sea and into the Arctic Ocean and out again, radioactive contaminants from this incident have been identified in the sea water of the Bay of Fundy on the east coast of Canada. It is not clear how deliberate "poisoning" of the sea by radioactivity as a hostile act could give a specific advantage to one protagonist during political tension or war; but it would be technically possible to render a harbour or a section of coastline less "safe" or perhaps unusable due to significant deliberate contamination. The strong public and political concern about dumping of radioactive wastes at sea, and about the fate of disabled nuclear-powered ships and submarines on the sea bed, show that there can be a strong psychological as well as physiological and environmental dimension to the possibility of radioactive modification of the ocean environment for military purposes.

v) Electrical changes in the upper atmosphere

Aeronomists and ionospheric physicists studying the upper atmosphere and near-space have in recent years learned much about the behaviour of the electromagnetic field surrounding planet Earth, and the possible effects of disturbances of that field. The introduction, by means of rockets, of small "charges" of barium and other selected materials to bring about changes in the local electromagnetic environment at heights of 50 to 200 kilometres has been able to produce artificial aurora, alter the conditions for radio signal propagation and reflection, and cause identified changes in earth current induction on an experimental basis. Some of these effects could have potential military application, but their control, to incommode the enemy and not the perpetrator, would obviously be a problem. During the Cold War, from time to time there appeared stories that one side or the other was developing or experimenting with methods of "beaming" massive amounts of electrical energy into the atmosphere of the other side, with the intention of disrupting the weather or changing the climate. None of these stories appear to have had any basis in fact.

vi) Chemical changes in the stratosphere or upper atmosphere

During early stages of the international concern over evidence that stratospheric ozone could be reduced or destroyed by the introduction of chemical nuclei from the exhausts of super-sonic aircraft, there was speculation that modification of the stratospheric environment, with its attendant cumulative effects on biosystems including humans, might itself become another weapon in the arsenal of hostile or warring states. While the possibility of deliberate "seeding" the stratosphere with ozone-destroying chemicals cannot be completely ruled out, any potential military benefit, other than psychological, seems impossible to identify. Any such action would be costly, and conspicuous to the world at large; it would: (1) affect both protagonists equally, as well as non-protagonists; and (2) take some time (a few years ?) to have an important effect on food crops or human health, and thus appear to be of no tactical or strategic importance.

(c) Changes that take some weeks or months to bring about, then can have long-lasting, widespread and severe effects.

There appear to be five major types of environmental modification of this type that could possibly be considered from their potential military value in a hostile and quarrelsome world, taking into account present scientific knowledge and technology:

i) Changes in precipitation

It was the widespread and growing practice of artificially-induced weather modification aimed at bringing about changes in precipitation during the 1970's that led to the international concerns that resulted in the ENMOD Convention. In the subsequent fifteen years, understanding of the meteorological processes concerned, and ability to determine and predict the stability or instability of the atmosphere (and thus be better able to judge the chances of success of any human perturbation) have continued to improve. There does not, however, appear to have been major changes or developments in precipitation-inducing technology. The techniques of "cloud seeding" from aircraft or ground projectiles were quite well developed by 1978. Perhaps because of lack of success in bringing rain to drought-plagued farmers, activity in precipitation enhancement is on the whole less today than it was two decades ago. The use of these techniques for hostile or military purposes does not appear to have received much attention, at least in actions accessible to the public, in recent years.

The practice of local "rain-making" could in principle be used to enhance rainfall or snowfall in selected areas of accumulation, to increase the chance of avalanches or major floods in "enemy" territory, thus hampering or causing damage to an opponent. The areas where such a stratagem might be used in an operational sense are limited, and to a first approximation fairly easily identified, but quite widely scattered around the world. However, it would require detailed regional meteorological information, and the ability to "seed" clouds

when conditions are favourable without hinderance, for such a scheme to work in an operational sense; and such situations are not likely at a time of hostilities. The technique could possibly have some potential use in special situations where there is long-standing animosity across an undisputed border, where the upstream or up-wind protagonist could increase precipitation in its own territory to cause floods which could harass or devastate the downstream opponent. Possible examples of such situations might be found in a region such as Georgia/Armenia/Azerbaijan/Turkey/Iraq, where the complex geography, hydrology, and weather systems could allow one country to modify its own local environment to increase its capacity to cause damage to another. But the situations where such conditions exist are rare and special, and would need long-standing or permanent hostility, sophisticated meteorological knowledge, constraint and patience, and stand-by resources to be developed as a military stratagem.

Other developments in precipitation control -- reduction of hailstorms, suppression of forest fires by enhanced rainshower activity, "de-fusing" of embryonic hurricanes -- appear, at the present state of the art, to have little application to military activities or goals.

There has been some speculation whether present or recent human activities have had an influence on the course and timing of monsoon storms in sub-tropical Asia. Model analyses of the meteorological and climatic effect of the oil fires in Kuwait and Iraq in 1991 seem to indicate a possible influence on the monsoon of that year (Blanchet, this symposium). Such evidence inevitably leads to speculation as to the type of atmospheric perturbation that would be needed deliberately to "steer", block, or dissipate a monsoon. Any such action, even if it altered the monsoon only by a small amount, could have large socioeconomic consequences and thus affect a country's ability in war or international conflict. At the present state of knowledge and atmospheric modification technology, it would appear that the magnitude of energy transfers causing and accompanying a monsoon are so enormous, compared to any conceivable local human influence, that all such speculation appears to be in the realm of science fiction. But perhaps there has been, already and in a small way, some influence on the monsoon as a result of the deliberate environmental modification during the Iraq-Kuwait War. One characteristic of the 1991 monsoon season was a lack of rain in the horn of Africa, contributing to the tragic drought in Somalia in 1992. If a connection with military disturbance of the environment could be established, would the ENMOD Convention apply in such a case?

ii) Changes in atmospheric chemistry

The public, and government authorities, are familiar with the hazards and insidious damages to the environment from human-caused inadvertent changes in atmospheric chemistry, in the form of acid precipitation, long-range dispersion of toxic chemicals, or chemicals that destroy the stratospheric ozone layer. Whether such changes, or related modifications in the atmospheric environment could be deliberately

intensified or focused as a hostile act to give a military advantage in time of conflict, is not clear. The possibility seems remote at best.

For purposes of applying the ENMOD Convention, it would appear necessary to distinguish between modifying the chemistry of the regional environment (as in acid rain), and using the environment as a medium to transport and deliver a foreign chemical for military purposes (as in the use of poison gas in the First World War or in the 1980's in Kurdistan). It may be necessary to examine Article II of the Convention critically to make this distinction.

iii) Alteration of natural ecosystems

The natural environment includes living components; and deliberate modification of the natural environment for military purposes includes, inter alia, causing deliberate changes in the living component of the environment, with hostile intent. The number and variety of such actions, or opportunities for causing military damage through deliberate changes in the biosystem, is almost unlimited, and a favourite topic of legends and novels. An important aspect of this subject is the whole topic of biological warfare, at least part of which includes modifying the natural environment on a large scale for military purposes. Other examples of human-influenced biological threats or nuisances today, which could conceivably be enhanced or used for military purposes if a protagonist were so inclined, are:

- "killer" bees;
- introduced bee parasites, which could devastate bee populations in an area and prevent pollination of vital crops;
- "red tide" toxic algae that can cause damage to local coastal ecosystems;
- zebra mussels, which, if introduced into previously mussel-free waters, can quickly clog water intakes and filtering systems;
- "mnemiopsis": the predatory sponge from the Atlantic coast of North America, inadvertently introduced into the Black Sea through bilge waters discharged from American or Canadian ships, and presently playing havoc with local marine ecosystems.

None of these incidents has had a deliberate hostile intent, but they show the range of some recent human-influenced biological modifications of the environment, that conceivably could have variations which in times of hostility could have military importance. There have been times in the past when introduction of a pest or virus has influenced a military outcome (the devastation of North American Indians by European smallpox during the struggle between the Europeans and the Indians in eastern North America in the 18th century is a well-documented but seldom-admitted example); but these events have been generally considered to be accidental modification of health rather than of deliberate alteration of the natural environment. Consideration of the future applicability of the ENMOD Convention may have to give consideration to such distinctions.

iv) Changes in climate patterns

Although human activities as a whole are with little doubt altering both regional climate and global energy balance, and thus helping to bring about significant changes in global climate patterns, the ability to affect, in a deliberate or planned fashion, any changes in climate in such a way that one could gain an advantage over one's opponent in war would appear to be remote. The military use of global change processes appears most likely, therefore, to be strategic rather than operational. The most successful military strategy would appear to be not to attempt to modify the environment for hostile purposes, but to use knowledge of different aspects of human-enhanced global change to identify areas of increasing or impending environmental stress; for example, desiccation, vulnerability to fire, insects infestation, flooding,etc., and to make use of that information in planning campaigns, harassing the enemy populace, and so on. The applicability of the ENMOD Convention to such activities may have to be considered. Is deliberate use, for hostile purposes, of the results of human-caused modification of the environment distinctly separate from deliberate modification of the environment?

v) Changes in ocean currents, and in marine conditions

Changes in the pattern and strength of ocean currents is an integral part of global change. There is reason to expect, in the next few decades, that there will be distinct changes in oceanic characteristics and circulation in response to the global warming, changed precipitation and river runoff, and different wind patterns that are being brought about by human actions. Some of the most obvious oceanic effects to be expected have been thought to be changes in the continuity and strength of the Gulf Stream in the North Atlantic Ocean, and in the ice conditions and drift patterns in the waters east of Greenland, in Baffin Bay and Labrador Sea, and north of Russia. The operational significance of these environmental changes, from a military point of view, are likely to be considerable. But whether any of the changes themselves can be brought about or influenced deliberately for hostile purposes seems very doubtful.

Schemes for changing ocean conditions as part of modern technological warfare: continuous acoustic jamming, electromagnetic blanketing, massive discharges of icebergs, etc.; all seem technically fanciful, or to require so much energy and continued application as to make them quite impractical for military purposes. Quite different, of course, is the well-developed military technique of selective local "jamming" for tactical purposes.

At this stage of the art of warfare, it does not seem likely that large-scale deliberate changes in natural ocean currents or conditions, to which the ENMOD Convention would apply, can be envisioned.

Problems and Future Considerations

Some of the issues that should be addressed in reviewing the future applicability of the ENMOD Convention and related international agreements respecting arms control and the environment, touched upon in the above review, may be listed as follows:

(a) Consensus on criteria

The "criteria" of ENMOD - **widespread**, and/or **long-lasting**, and/or **severe**, make the whole Convention conditional on consensual agreement about when it should or should not apply. Verification of whether the obligations have been met by the States parties is therefore dependent on prior consensus of what shall be the quantitative criteria.

(b) Deliberate versus incidentally-on-purpose modification

Application of the Convention requires distinction between:

i) deliberate modification of the existing biological, physical or chemical characteristics of the environment with the intent to gain an advantage over the opponent as a consequence of the induced changes in the environment, and,

ii) deliberate action as an act of war that incidentally results in widespread, long-lasting, and severe changes in the environment, which may or may not disadvantage the opponent.

The distinction, after the event, may be more social or political than environmental, for the environmental result may in each case be about the same.

(c) Deliberate modification as an act of military preparedness

Will the ENMOD Convention be applicable to deliberate environmental modification as a result of actions connected with military preparedness or weapons development, even though these are not part of openly declared "hostilities"? Some nuclear bomb testing has deliberately modified the environment; so has, apparently, the transmission of strong very low frequency electromagnetic waves.

(d) Strategic use of environmental modification

Will ENMOD apply to deliberate modification of the regional environment, or the environment of others, or the threat of such modification, as a strategic weapon? Environmental security can be used in the same way as military security, or threats to that security, to achieve national ends. A case in point at the present time, which may be far-fetched but is introduced for discussion, is in China. That country has the potential to hold the developed world as an "environmental hostage" to obtain massive funding for industrial

development by threatening to base its own economic development on large-scale increases in the burning of soft coal, which could accelerate undesirable global change and world-wide pollution. While such a development is not connected with international conflict, could it be considered to be a deliberate threat of environmental modification that could have widespread, long-lasting and severe results? Under what conditions would such a threat become a hostile act? If and when such a development was considered hostile, would the ENMOD Convention apply?

(e) Verification

Modern developments of environmental modification will call for very sophisticated methods of verification. For example, to apply the Convention to some of the situations noted above, it would be necessary to be able, inter alia:

- to recognize deliberately caused weather disturbances, and distinguish them from natural or inadvertent changes;

- to monitor human-induced changes in biological productivity, emergence of destructive new species, etc. and identify them as having been caused deliberately as an hostile act; and

- to recognize extreme environmental events as being the result of hostile actions.

Such a list could be very long, and involve the frontiers of science and technology in many fields. It would seem that attempts to verify whether a given environmental change is the result of a deliberate hostile action are rarely likely to be successful. Surveillance and verification will have, therefore, for the most part to be directed toward identifying the activity that sets in motion the environmental change -- cloud seeding, breeding of killer bees, etc.

The Lasting Value of the ENMOD Convention

The range of activities through which the environment may be deliberately modified is limited only by scientific imagination. Surveillance or detection of acts causing such modification for hostile purposes will need a full panoply of sophisticated satellite and remote sensing technologies, model forecasting and hindcasting facilities, genetic analyses, geophysical and oceanographic monitoring techniques, etc. The enormity of the surveillance and detection task, the difficulty of distinguishing "deliberate" acts and of applying the criteria, means that the ENMOD Convention will likely have its greatest effect, not through threat of detection and exposure, but through the restraint that arises from the public international commitments that signatory countries have entered into. And surely that restraint is its greatest strength, and the most promising contribution that ENMOD Convention is making toward achieving widespread, long-lasting and effective protection of our dynamically changing environment. In so doing, it will also contribute to the reduction of open conflict and the growth of collective responsibility for the future.

THE USE OF THE ENVIRONMENT AS AN INSTRUMENT OF WAR IN OCCUPIED KUWAIT[1]

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Introduction

As its title indicates, this paper is concerned with the use of the environment as a weapon, as opposed to the impact of weapons on the environment. We shall therefore not deal with:

- indirect damage to the environment caused by war and war preparations, including specifically the problem of the physical aftermath of war, which is the subject of a number of conventional[3] and other[4] documents;

- the destruction of Iraqi nuclear installations[5] and cultural property[6] by coalition forces, which might also lead to the application of treaty provisions and of resolutions of international organizations; and

- problems of liability, except to note that in accepting Security Council Resolution 687 Iraq acknowledged that it is "liable under international law for any direct loss [and] damage, including environmental damage and the depletion of natural resources" as a result of its unlawful invasion and occupation of Kuwait.[7]

The Facts

A. Oil Spills

On 21 January the United States army accused Iraq of having two days earlier deliberately opened the floodgates of the Sea Island terminal off Kuwait City, where were anchored three tankers full of Iraqi and Kuwaiti crude oil, loaded before the imposition of the embargo which followed the invasion.[8] If we add the capacity of the terminal tanks to the capacity of the three tankers, we are talking initially about 1.5 million tonnes of oil released into the Gulf waters.[9]

On 31 January the BBC announced and the British army confirmed that a day earlier the Iraqis had created another oil slick by opening the floodgates of their offshore Mina Al-Bakr terminal, located northeast of the Kuwaiti island of Boubian. The magnitude of this second spill was not stated, but the Coast Guard captain directing the American crew sent to Saudi Arabia to combat the first one called it the biggest oil spill in history.[10]

On 1 February, relying on photographs from the Soviet space station Mir, the "Centre de documentation, de recherche et d'expérimentation sur les pollutions accidentelles" (CEDRE) estimated the total volume of the first oil spill at 500,000 tonnes, more than twice the size of the Amoco Cadiz spill off the coast of Britanny in 1978, and stated that half of this light oil had evaporated in the first ten days. CEDRE estimated the second oil spill at about 100,000 tonnes.[11]

At the end of the war on 27 February it was observed that the "oil spill of the century" had not happened. About fifty kilometres of Saudi coasts were in fact soaked in oil, the origin of which is not known with certainty, but no major seawater desalination plant was threatened and fishing was still permitted everywhere in the Gulf where it normally is at that time of year. There were 25,000 to 35,000 dead birds on the northeast coast of Saudi Arabia but the number of "victims" was otherwise small: fish, pearl oysters and shrimp were apparently intact.[12]

Where did the millions of tonnes of oil initially announced go? Some argued that the magnitude of the problem had been deliberately exaggerated by "military disinformation" in order to stifle the pacifist opposition which was developing in a number of coalition countries.[13] On the other hand, a United Nations report estimated that the volume of the first oil slick, which was 50 kilometres long and 8 kilometres wide on 25 January, could have amounted to 13 million barrels,[14] which is a little more than 1.8 million tonnes or 0.3 million tonnes more than the first figure released by the United States army. In any event it is clear that, thanks to favourable weather, nature did its job and largely limited the damage.[15] After confirming the opinion of CEDRE that about 50% of the spill had rapidly evaporated, the same UN report added that the rest had decreased in volume under the effects of climate and decomposition. It then broke up into small slicks which moved toward the Saudi coast, where they amounted to no more than about 1 million barrels[16] or less than 150,000 tonnes.

The effects of the oil spills on the Gulf ecosystem are mostly unknown, both because of the very large number of variables to be taken into account and because of significant gaps in the available biological data base.[17] These effects could bear on the primary production of phytoplancton, macrophytes such as zostera, coral reefs and the vast intertidal zone covered in blue-green algae which comprises the base of the food chains for many fish and crustaceans and the feeding ground for many species of wading birds.[18] Four months after the "disaster", quantitative data on the contamination of the marine environment were still not available. United Nations experts had gone to the site to try to ascertain the damage but their investigation was inhibited by the presence of mines, barbed wire and other obstacles on the beaches and off the coast of Kuwait, as well as by the general absence of scientific infrastructure and resources.[19]

B. Sabotage of oil installations

Iraq's aim in invading Kuwait on 2 August 1990 was to take control of its oilfields. As the deadline of the ultimatum given by the Security Council approached, there was concern about the risk that if it were compelled to withdraw from this prize Iraq would first try to destroy the Kuwaiti oil installations, which it was suspected of having mined.[20] This risk became reality on 22 January when the American command announced that the Iraqi army had blown up the oil wells and storage tanks at Al Wafrah. The real extent of the damage and Iraq's objective in this remained unclear at that time.[21]

On 12 February a Pentagon spokesperson announced that about fifty wells spread over all of the Kuwaiti oilfields had been burning for a week.[22] The Iraqis started setting fire to more than a hundred additional wells, along with oil installations, on 22 February.[23] On 28 February there were reports that nearly 600 wells had been set afire.[24] On 14 March, when the Emir of Kuwait returned after seven months in

exile, the KOC estimated that out of the thousand wells surveyed in the Burgan region alone, eight hundred had exploded and about five hundred were still ablaze.[25]

And so this time there was a true disaster, beyond anything the oil industry had experienced in the hundred and thirty years of its existence[26] and posing an unprecedented environmental problem.[27] At the end of the war the burning wells, storage tanks and refineries were consuming more than 5 million barrels of oil and more than 70 million cubic metres of gas per day, pouring out an enormous amount of smoke, sulfur dioxide and other pollutants, which could have as yet unknown effects on human health in the region and affect the atmosphere at great distances from the site of the fires.[28] Contrary to what was feared by some, however, it would seem that the impact of this pollution on world temperatures and precipitation was negligible.[29]

At the beginning of May 1991, the World Meteorological Organization (WMO) estimated that more than 40,000 tonnes of sulfur dioxide, 3,000 tonnes of nitrous oxide, a half million tonnes of carbon dioxide and various other pollutants were being emitted every day. The quantity of sulfur dioxide exceeded the total daily emissions of France, Germany and the United Kingdom put together. Emissions of fine particles from the burning oil wells and installations were estimated at about 18 million tonnes per year, equalling or exceeding total annual world emissions of such particles in automobile exhaust. After a year, emissions of soot attributable to the fires would have doubled the concentration of these particles in the atmosphere.[30]

In addition to these world-wide effects, there were obviously effects on human health and the environment in Kuwait. People living there suffered from respiratory problems, allergies, asthma, migraines and persistent coughs. Their eyes, noses, throats and lungs were irritated and they were often short of breath.[31] The smoke was so thick in March that Kuwait City was plunged into darkness two days out of three,[32] which could not help but have a psychological impact on its inhabitants.

Pollution affected not only the air but also water and soil, since toxic gases concentrated and fell on the surface in the form of acid rain, which was as black as oil. This rain polluted vegetation as well as underground water.[33] The soil was destroyed by thousands of tonnes of oil gushing from erupting wells which had been set afire by the Iraqis and subsequently extinguished, part of which could also penetrate into underground water and make it unusable for irrigation and human consumption.[34] The portion remaining on the surface grew daily and created vast oil lakes. Torrents of crude oil, which were quite deep and reached up to 70 metres wide, blocked roads. Since drainage flows naturally toward the coast, earth dams were built in the valleys to create new oil lakes and thereby inhibit the flow onto roads and the creation of a new oil spill.[35]

International Reaction

It is ironic that Saddam Hussein turned Kuwait's oil, the very object of his desire, into a weapon of war by spilling it into the sea and setting it on fire. These tragic events were doubly unusual: first, they were the result of a deliberate act, a form of ecological aggression, as opposed to an accident, a natural disaster or even collateral damage caused by military action; second, the fires, as opposed to the oil spills, were of an unprecedented order of magnitude. For this reason, some observers wrote that the Gulf war was the first conflict in which "ecoterrorism" played a major role in the belligerents' battle plan and that, even though combat lasted only 42 days, it might be the most ecologically destructive conflict in the

history of war.[34] One thing for certain is that, largely because of the omnipresence of the American Cable News Network (CNN) on television screens and the resulting conversion of the war into a "live" media event, it was the first time that the environmental ravages of war were broadcast on such a large scale.

Given the enormity of the toll taken by Saddam Hussein on the environment in Kuwait, there was no shortage of qualifications of his actions, frequently formulated in legal or quasi-legal terms. Thus, the day after the first oil spill, President Bush called this an act of ecological terrorism, which did not have the slightest military value.[35] As we shall see, this last statement is of some consequence in terms of international law.

After the second oil spill, the Environment Ministers of the member countries of the Organization for Economic Cooperation and Development (OECD), meeting in Paris, stated that this act constituted "a violation of international law". The vagueness of this formulation will be noted. Was it a violation of conventional or customary international law? Of the law applicable in peacetime or wartime? What exactly was the legal rule which had been violated? Perhaps seeking to make up for this vagueness and reinforce their denunciation of this act, the Ministers then called it a "crime against the Environment" and demanded that Iraq "cease using the destruction of the environment as a weapon".[36]

As to the oil fires, which were expected to take at least a year to put out[37] and which had been described as the greatest disaster of all time after Chernobyl,[38] the Kuwaiti authorities tried at first to have them declared a war crime[39] and then a crime against humanity.[40] They also stressed the need for an international convention prohibiting such behaviour, in the same way as chemical weapons had been excluded as means of warfare.[41]

The legal questions raised by these statements, particularly the OECD Environment Ministers' press release, explain the structure of the following analysis of the relevant norms of international law. First, we shall examine the rules of environmental law which apply in time of peace and how they apply in time of war. Second, we shall consider the law of war, both conventional and customary. Finally, the opinion we will have formed in the process as to the legality of Iraq's attacks on the environment in Kuwait will lead us to comment on the adequacy of existing international law for contemporary needs and on the possible outcome of these events in legal terms.

The Law: Environmental Law[42]

(i) General rules concerning environmental protection in time of peace

While international environmental law is relatively new, a fundamental principle flows from certain traditional rules of international law: the duty of each State not to cause significant damage to the environment of other States. This prohibition also applies to areas which are outside the limits of a State's jurisdiction. In addition, there is the as yet incomplete emergence of a broader rule, requiring respect for the environment in general, regardless of its geographic location or legal regime.

(a) The obligation not to cause significant damage to the environment outside the limits of the territorial jurisdiction of the State

The obligation of States not to cause significant damage to the environment outside the limits of their territorial jurisdiction flows from traditional principles which are solidly established in public international law. The principle of the non-damaging use of territory has been set out in a number of decisions by courts and arbitral tribunals relating to the general duty not to violate the rights, and particularly the territorial rights, of other States. Thus, the arbitral award in the Island of Palmas case, involving a dispute between the United States and the Netherlands concerning sovereignty over that island, stated:

> Territorial sovereignty (...) involves the exclusive right to display the activities of a State. This right has as corollary a duty: the obligation to protect within the territory the rights of other States, in particular their right to integrity and inviolability in peace and in war, together with the rights which each State may claim for its nationals in foreign territory.[43]

The decision of the International Court of Justice in the Corfu Channel case, which concerned damage to British warships caused by mines placed in Albanian territorial waters, also recalled:

> every State's obligation not to allow knowingly its territory to be used for acts contrary to the rights of other States.[44]

This obligation is also at the root of the arbitral decision in the Trail Smelter case, dealing with cross-border pollution caused in the United States by emissions from a smelter located in Canada, which stated that:

> under the principles of international law (...) no State has the right to use or permit the use of its territory in such a manner as to cause injury by fumes in or to the territory of another or the properties or persons therein, when the case is of serious consequence and the injury is established by clear and convincing evidence.[45]

This same obligation also flows from a more general principle, which is the prohibition against abuse of right. This principle is reaffirmed by, inter alia, the Convention on the Law of the Sea, according to which States Parties:

> shall fulfil in good faith the obligations assumed under this Convention and shall exercise the rights, jurisdiction and freedoms recognized in this Convention in a manner which would not constitute an abuse of right.[46]

Stated in this general form, the principle does not simply prohibit the violation of the territorial rights of other States but also provides protection for areas which do not fall within the territorial jurisdiction of the State where pollution originates. Causing significant damage to the environment located outside the limits of a State's territorial jurisdiction is therefore prohibited. This principle has been reaffirmed in fairly specific terms in several international conventions.[47]

However, a number of conventions expand this obligation to areas under the sovereignty of the State itself. The most important of these, in terms of both geographic scope and number of signatories, is the Convention on the Law of the Sea, which provides that "States have the obligation to protect and preserve the marine environment".[48] This general obligation not to pollute the marine environment, irrespective of its legal status, had been regularly laid down by multilateral treaties prior to the Convention.[49]

Moreover, partly as a result of the efforts of the United Nations Environment Program (UNEP), a number of regional convention systems came into being, mostly comprising a plan of action, a framework convention and additional protocols. In each such system there is set out a general obligation not to damage the marine environment through pollution.[50] Iraq and Kuwait are both parties to one of these regional conventions, under which:

> The Contracting States shall, individually and/or jointly, take all appropriate measures in accordance with the present Convention and those protocols in force to which they are party to prevent, abate and combat pollution of the marine environment in the Sea Area.[51]

The obligation of States not to damage the environment outside the limits of their territorial jurisdiction is also confirmed in several non treaty instruments. The fundamental document in this area is principle 21 of the Stockholm Declaration:

> States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.[52]

This principle is restated word for word in a large number of international treaties[53] and other instruments.[54] It is generally acknowledged at present as the expression of a rule which has become the customary basis of international environmental law.[55]

The practice described above leads us to conclude that the obligation of States not to cause significant damage to the environment beyond the limits of their territorial jurisdiction is a positive rule of customary international law. There follows from this rule a duty of abstention, that is the duty of States to abstain from causing significant damage to the environment outside their territorial jurisdiction, and a duty of prevention, which is the duty of States to take care that no significant damage to the environment outside the limits of their territorial jurisdiction is caused by sources under their control.

(b) The obligation to respect the environment in general

A broader rule may be considered in this context: the obligation of States to respect the environment in general, regardless of whether the legal regime governing it is that of the State itself, of another State or of no State. As we have seen, this general rule is implied in the conventions previously referred to relating to protection of the marine environment, which contain an obligation not to cause damage

not only to the environment beyond the territorial jurisdiction of States (particularly beyond the limit of territorial waters and the exclusive economic zone), but also to the marine environment within the areas which are exclusively subject to national jurisdiction.

An obligation to respect the environment in general is also laid down in conventions relating to other areas. There are a number of treaties, for example in respect of watercourses and lakes, which are for the most part bilateral and which contain an undertaking by the parties not to degrade the quality of the water covered by the treaty, including water which is under their sole jurisdiction.[56] Equivalent obligations appear in a number of other conventions dealing with air pollution,[57] world heritage protection,[58] the moon and other celestial bodies[59] and the deep seabed.[60] In addition to this practice, which has created rules which are, if not identical, at least consistent, there is also a large body of non-treaty instruments adopted since the beginning of the 1970s.[61]

Finally, the domestic practice of States confirms the recognition of their duty to protect the environment. All legislation which is designed to protect the environment derives from the conviction that such a duty exists, although its precise nature is not always stated. A number of States have provided an even stronger basis for this duty by entrenching it in their constitution.[62]

However, there remains the question as to whether the cumulative adoption of conventions, resolutions and constitutional provisions has already resulted in the creation of a rule of customary international law. Is there an obligation on States to respect and protect the environment as such? The elements of practice we have described may provide a basis for contradictory conclusions, particularly concerning the effect of accumulated conventional provisions. On the one hand, the inter alios acta rule, which is confirmed by the Vienna Convention on the Law of Treaties,[63] prohibits extrapolations in principle. Similarly, it can be said that the adoption of a conventional rule shows the opinion of the States Parties that such a rule does not otherwise exist. On the other hand, it can be argued that the growing number of similar clauses in various treaties is a manifestation of a general practice accepted as law, in other words that it amounts to the creation of a rule of customary law within the meaning of the Statute of the International Court of Justice.[64]

Without trying here to resolve this fundamental debate, we might simply note that the growing number of treaty rules, international resolutions and constitutional provisions laying down the obligation of the State to protect the environment demonstrates, at the very least, that there is a general recognition of a need, in the sense of the subjective element of international custom (opinio juris sive necessitatis). One may therefore consider that if it is not a rule of positive law, the rule which demands protection of and respect for the environment in general is at the very least a customary rule in statu nascendi.

(ii) Applicability of these rules in time of war

Among the legal consequences which result from a state of international armed conflict, the distinction between belligerent and non belligerent States is fundamental. In their relations with those in the second category, States in the first are not relieved, by virtue of the state of war, of their obligation not to cause significant damage to the environment outside the limits of their territorial jurisdiction.

State practice during the Second World War confirms this, particularly in respect of damage to the territory of Switzerland, a neutral country surrounded by belligerent countries, as a result of incidents such as airplane crashes, barrage balloon landings and the dropping of fuel reservoirs and bombs. Some of this damage had been caused by allied bombing of targets situated on German territory but so close to the border that the blast had hit and damaged property on the Swiss side. These incidents were the basis of negotiations between Switzerland and the States in question, which all recognized in principle their obligation to compensate for breaches of Swiss neutrality, including in cases of transborder damages.[65]

These examples show that, even in wartime, the obligation of parties to a conflict not to damage the environment of third States and of areas which are not under any national jurisdiction persists and that it is in the nature of an obligation of result as opposed to means. In other words, the mere occurrence of damage amounts to a violation of the obligation. The State which has caused the damage will therefore incur liability regardless of any precautions it may have taken to avoid it.

The same is not true of relations between belligerents, which suffer considerable legal disruption. When hostilities break out, normal relations between the parties are broken off and replaced by relations of belligerence. These relations are essentially governed by the law of international armed conflict, which constitutes an exceptional regime vis-à-vis the law of peacetime.[66] Some elements of that law will continue to apply between the parties, for example in the area of human rights.[67] However, these elements of the ordinary regime survive as exceptions. They must be considered on a case by case basis and their existence does not invalidate the rule that normally the legality of the conduct of the parties to the conflict towards each other must be examined in light of jus in bello.

This rule is particularly applicable in relation to the environment, since it is in the very nature of war to destroy life and property.[68] Just as it has been written that the essence of war is doing the impossible so that pieces of iron will enter living flesh,[69] it must be recognized that in this context many pieces of iron, large and small, inevitably enter the environment. For this reason, the general rules concerning environmental protection in time of peace no longer apply between belligerents in time of armed conflict. This is also the reason why we must now turn to the law of war to examine the legality of the use of the environment as an instrument of war in occupied Kuwait.

The Law: The Law of War

(i) Conventional law

(a) The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques[70]

1. Background

Since ancient times, environmental damage, both accidental and deliberate, has been an integral part of war. From the sacking of Rome by the Vandals in 455 to the nuclear destruction of Hiroshima and Nagasaki in 1945, between which we find the devastation of the German states during the Thirty Years War from 1618 to 1648, the

scorched earth policies used by the Russians against Napoleon in 1812 and by the Chinese against the Tai Ping revolt from 1850 to 1864, and the use of chemical weapons during the First World War, there has been a long list of conflicts during which the protagonists tried to destroy the enemy by attacking the environment.[71]

What distinguishes recent times in this respect is a realization of the seriousness of conduct that damages the environment and, at the same time, an increasing appreciation of the need to protect the environment in wartime and in relation to military activities. This is a consequence of the unprecedented destructiveness of military techniques and technologies, as well as an expression of a developing consciousness of environmental values and of the fact that we ignore these values at our peril.[72]

All these factors played a role in the political impetus which led in the early 1970s to the negotiation of the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD).[73] At the time there was growing concern about the environment in general and, more specifically, the possible future development of environmental modification techniques. The large-scale use of various methods of destroying forests and crops by the United States in Vietnam had been sharply criticized. In July 1972 the American press published detailed reports on secret attempts by the United States to manipulate the climate in Indochina, particularly in order to swamp or flood the roads from North to South Vietnam.[74] Faced with these reports, the United States Senate concluded that this kind of activity could only lead to the development of much more dangerous environmental modification techniques, which might cause irreparable damage to the world environment. The Senate consequently adopted a resolution on 11 July 1973 asking the Administration to enter into a treaty prohibiting any environmental or geophysical modification as a weapon of war.[75]

At the 1974 Moscow Summit, the United States and the USSR agreed to discuss the dangers of what was later called environmental war.[76] The following year, the Americans and the Soviets introduced two identical draft conventions at the Geneva Conference of the Committee on Disarmament (CCD). Negotiations were undertaken and in 1976 the CCD transmitted a revised text of the draft convention to the United Nations General Assembly (UNGA), together with a set of draft interpretive agreements relating to Articles I, II, III and VIII. These agreements were dropped, however, from the text referred to States by the UNGA for consideration,[77] signature and ratification on 10 December 1976. They are accordingly of limited value as a means of interpreting the Convention.[78]

2. Analysis of principal provisions

2.1 General scope

The general scope of the Convention is defined in Article I, paragraph 1, which reads as follows:

> Each State Party to this Convention undertakes not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party.

As observed at the time by some negotiators and subsequently by most commentators, this scope is very narrowly defined. The Mexican delegation to the CCD demonstrated this reductio ab absurdum by proposing the following reading of the above-quoted provision:

> Each State Party to this Convention shall be entitled to use environmental modification techniques for military or other hostile purposes as the means of destruction, damage or injury to another State Party, provided that such techniques do not have widespread, long-lasting or severe effects.[79]

The American delegate to the CCD had justified this restrictive formulation by asserting the need to ensure respect for the Convention and to avoid frictions and controversies over insignificant questions arising from complaints about violations which would be impossible to verify.[80] The Netherlands delegate had replied, in our view correctly, that the more conditional the prohibition, the greater the risk of violations and disputes, since a country could always claim that the conditions under which the prohibition applied had not been fulfilled.[81]

2.2 Prohibited activities

The same restrictive approach prevailed in determining the activities prohibited by the Convention, limited by paragraph 1 of Article I to the use, under certain conditions, of environmental modification techniques, to which paragraph 2 adds assisting, encouraging or inducing another State, group of States or international organization to engage in prohibited activities. The Convention thus does not prohibit either research into such techniques or the threat of their use.[82] It relates only to use, and then only under certain conditions.

2.3 Techniques covered

Article II of the Convention provides that:

> As used in article I, the term "environmental modification techniques" refers to any technique for changing — through the deliberate manipulation of natural processes — the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space.

The terms used seem at first glance to be very comprehensive, but enough questions were raised during the course of the negotiation as to their meaning that a need was felt to provide a list of examples in an interpretive agreement:

> earthquakes; tsunamis; an upset in the ecological balance of a region; changes in weather patterns (clouds, precipitation, cyclones of various types and tornadic storms); changes in climate patterns; changes in ocean currents; changes in the state of the ozone layer; and changes in the state of the ionosphere.[83]

Although the agreement provided that this list was not exhaustive,[84] it was also criticized as being restrictive, inappropriate and ambiguous. On reading the debates provoked by the list, it is clear why the interpretive agreement in question

was not approved by the UNGA along with the Convention.[85] The dominant impression which emerges is two-fold: first, this was an area which had barely been explored and where the international community was still feeling its way around;[86] second, the Convention seemed designed to apply to techniques which were unusable given the current state of scientific knowledge and technological developments, and so to a danger that was virtually non-existent[87] at the time the Convention was negotiated and remains so today. Agreement in respect of the Convention was undoubtedly facilitated by the apparent conclusion of the United States Department of Defense that environmental modification was not promising from a military point of view and by the fact that the legal undertaking contained in the Convention was worded so as to avoid casting doubt on the legality of environmentally damaging means and methods of warfare which had seemed militarily useful during the Vietnam war.[88]

The result is nonetheless a relatively complex text capable of supporting various interpretations, especially given the weakness of its provisions concerning dispute settlement.[89] On the other hand, Article II clearly establishes at least one thing: the Convention does not apply to environmental modification which occurs incidentally, indirectly or as a corollary of conventional means of warfare or weapons of mass destruction, i.e. by methods or means of warfare which do not have as their primary objective environmental modification by deliberate manipulation of natural processes.[90]

2.4 Element of intent

The prohibition set out in Article I deals only with "military or any other hostile use". It is accordingly subordinated to intention, a subjective criterion if ever there was one. Moreover, the phrase modifying the prohibition is written in a way that is not consistent with the normal meaning of its terms, all military purposes not being by definition hostile.[91] Finally, the use of environmental modification techniques for non-hostile purposes falls completely outside the prohibition, even if such use produces widespread, long-lasting or severe effects.[92]

2.5 Threshold of severity

Not all environmental modification techniques are prohibited, but only those "having widespread, long-lasting or severe effects". These three conditions have been the object of particular criticism because they make the Convention a threshold agreement, establishing only a partial prohibition. In fact, as it is worded the Convention permits the hostile use of environmental modification techniques the effects of which are destructive but not "widespread, long-lasting or severe".[93]

These conditions are expressed in terms which are so vague that they had made necessary an interpretive agreement under which the expression "widespread" meant encompassing an area on the scale of several hundred square kilometres; "long-lasting" meant lasting for a period of months, or approximately a season; "severe" meant involving serious or significant disruption or harm to human life, natural and economic resources or other assets.[94] These definitions were in turn criticized by numerous delegations, who noted that they were subjective and incomplete and showed that they meant one thing for the great powers and another for small States and developing countries.[95] This kind of criticism explains why the draft interpretive agreement was rejected by the UNGA and disappeared in the final version of the Convention to which States were invited to become parties.

2.6 Bilateral character

The conditions examined above are necessary but not sufficient for the prohibition provided in the Convention to apply to a particular environmental modification technique. The technique must also be used "as the means of destruction, damage or injury to any other State Party". Some delegations had pointed out at the time that the terms "destruction", "damage" and "injury" were ambiguous. Even more had sought to have the word "Party" removed, being of the view that the Convention had to apply erga omnes and not only to States Parties.[96] The retention of this limitation was apparently the result of a desire to prevent States which had not adhered to the Convention from benefiting from it, and thus to encourage adherence.[97]

3. Application to the Gulf War

3.1 Form

This last hope was not realized, the numerous lacunae in the Convention perhaps explaining its low number of States Parties, which currently stands at 55. Among these one finds in particular Kuwait, the United States, the United Kingdom and Canada. Iraq is not a Party, having signed the Convention on 5 August 1977 but never having ratified it. The last of the previously mentioned restrictions on the prohibition provided by the Convention, i.e. that it only applies between States Parties, consequently has the effect of removing from the purview of the Convention the destruction inflicted by Iraq on the environment in Kuwait.

It could perhaps be considered that this destruction constitutes an act which defeats the object and purpose of the Convention within the meaning of the Vienna Convention on the Law of Treaties, which provides that:

> A State is obliged to refrain from acts which would defeat the object and purpose of a treaty when:
>
> a) it has signed the treaty or has exchanged instruments constituting the treaty subject to ratification, acceptance or approval, until it shall have made its intention clear not to become a party to the treaty (...).[98]

This argument does not appear convincing for three reasons. First, although it was opened for signature on 23 May 1969, the Vienna Convention only entered into force on 27 January 1980, after Iraq's signature of the ENMOD Convention. Second, it is generally recognized that Article 18 of the Vienna Convention is new law and therefore that, contrary to certain of its other provisions, it does not codify a rule of customary law that existed before the Convention entered into force.[99] Third, Iraq is not a party to the Vienna Convention and accordingly is not bound by the new rules it creates (at least as long as those new rules have not acquired a customary character, which does not seem today to be the case of Article 18).

3.2 Substance

One may nevertheless ask whether, by acting as it did in occupied Kuwait, Iraq would have violated the obligations the ENMOD Convention entails if it had ratified

the Convention. The question then arises of whether the deliberate release of oil into the sea and the sabotage of oil wells and related facilities, of which Saddam Hussein apparently wanted to make "military or any other hostile use" within the meaning of Article I of the Convention, constitute "environmental modification techniques" as defined in Article II. In our view, the answer with respect to the oil spills is clearly negative. As we have seen,[100] and despite the uncertainty surrounding effects on the Gulf ecosystem, it is clear that thanks to favourable weather, nature largely limited the damage by promoting the rapid evaporation of about 50% of the oil spills and the subsequent decomposition and dispersal of the rest. The oil spills can therefore not be considered an "environmental modification technique" in respect of the Gulf, particularly since that body of water has for a long time frequently experienced and absorbed such spills.

The Persian Gulf has about 800 operating offshore oil wells and about 25 major terminals from which oil is shipped to the main consumer regions of Europe and the Far East, as well as more than 25,000 tanker crossings per year through the Strait of Hormuz. In view of its relatively small size, there is probably more oil spilled into the sea in that region as a result of these activities than anywhere else in the world. In recent years, military activities have exacerbated the problem. As a result of repeated spills, most of the beaches in the region are severely contaminated by tar: concentrations of 1 to 30 kilograms per metre of beach are common. Nonetheless, the levels of petroleum hydrocarbons in sediment and biota are not exceptionally high, probably because of rapid breakdown and the effect of the climate,[101] or in other words of the absorptive capacity of the marine environment of the Gulf.

The answer is not so clear with respect to the sabotage of oilwells and installations, the impact of which on the Kuwaiti environment has been much more significant.[102] However, it seems difficult to argue that this was a "manipulation of natural processes". While oil formation is the result of a natural process, it only flows naturally from the ground in exceptional circumstances. Oil extraction therefore depends on human intervention, a fortiori storage and processing of the oil.

Even if we admit that this first obstacle can be overcome, this "manipulation" would still have to have as its objective the modification of the "dynamics, composition or structure of the Earth", which in our view goes well beyond the objectives pursued by Saddam Hussein in undertaking the sabotage in question. This conclusion is supported by the fact that none of the examples listed in the draft interpretive agreement relating to Article II developed by the CCD[103] or cited during the negotiations[104] corresponds to what happened in Kuwait. Given this situation, it is not necessary to ask whether the effects of the sabotage on the Kuwaiti environment were "widespread, long-lasting or severe" within the meaning of the Convention.

For the foregoing reasons, we are of the opinion that, even if Iraq had been a party to the ENMOD Convention, it would not have violated it by its use of the environment as an instrument of war in occupied Kuwait. However, there is another law of war treaty, negotiated during the same period as the Convention, in light of which Iraqi actions must be now examined.

(b) Protocol I to the Geneva Conventions

1. Background

In the context of the international law of environmental protection, like the Convention analyzed above, Protocol I of 1977 to the 1949 Geneva Conventions[105] was a reaction to the excesses of the Vietnam War.[106] This reaction was at the root of the discussions which resulted in the ENMOD Convention[107] and so, during the preparatory discussions to the Diplomatic Conference at which the two 1977 Protocols were negotiated,[108] neither the International Committee of the Red Cross (ICRC) nor the Western delegations initially proposed any provision dealing with environmental protection.[109] In 1972, at the second session of the Conference of government experts, the Eastern European delegations had made proposals referring, for example, to "methods and means of warfare which destroy the natural human environmental condition" but no paragraph of this nature appeared in Article 33 or in Part IV of the draft of Protocol I presented by the ICRC to the Diplomatic Conference.[110]

When the Conference itself opened in 1974, the problem was raised again and various proposals were tabled. Committee III set up an unofficial working group, known as the "Group Biotope", within which two points of view emerged concerning the fundamental reasons for environmental protection in wartime. Some delegations were of the opinion that this was an end in itself, while others considered that its objective was to guarantee the survival of the civilian population. The first approach supported inclusion of a paragraph on the environment in Article 35, which already contained provisions relating to certain methods and means of warfare. The second argued in favour of a separate article in Chapter III of Part IV, which dealt with protection of civilian objects. The Group Biotope recommended accommodating both approaches and at its second session Committee III adopted the two corresponding proposals, which became Article 35, paragraph 3, and Article 55 in the final text of Protocol I.[111]

It should be noted that, at the time the problem was being debated at the Diplomatic Conference in the spring of 1975, the CCD, which was also sitting in Geneva, was considering the US-USSR draft of what was to become the ENMOD Convention.[112] That Convention was then signed only 10 days before the Diplomatic Conference in plenary session adopted Article 55 of the Protocol.[113] As we shall see, the simultaneous nature of these two legislative processes explains certain relationships between the texts which they produced.

2. Analysis of principal provisions

2.1 Article 35, paragraph 3

The first of the two relevant provisions of Protocol I appears in the first Article, entitled "Basic Rules", of Section I of Part III, dealing with "Methods and Means of Warfare". Article 35(3) reads as follows:

> It is prohibited to employ methods or means of warfare which are intended, or may be expected, to cause widespread, long-term and severe damage to the natural environment.

The resemblance to the wording of Article I, paragraph 1, of the ENMOD Convention is striking -- but it is a resemblance, and not a mirror image, on several points.

2.1.1 Threshold of severity

First, while the Convention refers to "widespread, long-lasting or severe" effects, the Protocol deals with "widespread, long-term and severe" damage. The alternative nature of the first list and the cumulative character of the second results in differences in the scope of the two provisions, that of the Protocol being clearly more limited.

Second, words do not necessarily have the same meaning in the two formulations. The first indication of this lies in the fact that the word "durable" used in the French text of both the Convention and the Protocol corresponds to the English words "long-lasting" in the first case and "long-term" in the second. This is not an accidental difference, since the preparatory work shows that the negotiators of these two instruments did not have the same time-frame in mind. According to the Rapporteur of Committee III, although "it is impossible to say with certainty what period of time might be involved", the debates at the Diplomatic Conference clearly indicated that time was to be measured in decades and not in months, as the CCD was doing in its parallel work.[114]

The Convention negotiators, aware of this problem, had also tried to avoid having the interpretation of the terms "widespread, long-lasting or severe" applied automatically to the Protocol, by stating in the draft interpretive accord relating to Article I that:

> It is further understood that the interpretation set forth above[115] is intended exclusively for this Convention and is not intended to prejudice the interpretation of the same or similar terms if used in connection with any other international agreement.[116]

For greater certainty and in the opposite direction, when Article 35, paragraph 3 of the Protocol was adopted by consensus in plenary session, several delegations, in particular those which had opposed including the words "widespread, long-lasting or severe" in Article I, paragraph 1 of the Convention, made a point of stating that these words did not have the same effect in the two instruments and that their approval of the one did not prejudice their ultimate approval of the other.[117]

2.1.2 Element of intent

Nor is intent the same in the two relevant provisions. Article 35(3) of the Protocol refers to methods or means of warfare "which are intended, or may be expected, to cause" damage to the natural environment. This is an alternative test, which may be subjective ("intended to cause") or objective ("may be expected to cause"), while the test in the Convention is exclusively subjective (only "military or any other hostile use" of environmental modification techniques is prohibited). Unlike the threshold of severity, the Protocol is therefore less restrictive than the Convention in terms of the element of intent. The Rapporteur of Committee III explained the inclusion in Article 35(3) of the two expressions cited above by an abundance of caution. The first alluded to a deliberate attack directed against the natural environment as a method or means of warfare, such as the destruction of natural resources, while the second implied an objective standard concerning what the State or individual involved considers or should consider as likely to result in the effects described.[118]

2.1.3 Unilateral character

The prohibition with which States agree to comply in Article 35(3) is formulated in general terms ("It is prohibited to employ"). This is an obligation that is unilaterally assumed by each State Party to the Protocol, the fulfilment of which does not require that the other States Parties to the international armed conflict in the context of which the problem of protecting the natural environment arises also be Parties to the Protocol.

This unilateralism contrasts with the bilateral character of the obligation assumed by States Parties to the ENMOD Convention. The latter are prohibited from causing damage or injury, by the use of environmental modification techniques, only to other States Parties to the same Convention and remain free to cause such damage or injury to third States. On this point, as with the element of intent, the Protocol is less restrictive and accordingly likely to ensure better protection of the natural environment.

2.1.4 General scope

The prohibition set out in Article 35(3) is not designed to protect the natural environment against the use of weapons or techniques directed expressly against the environment, nor to protect the population and the combatants exclusively. It is clearly intended to protect the natural environment *per se*[119] and is therefore an important innovation in the law of war, which traditionally provided such protection only by implication and indirectly in the form of protection of civilian property.[120]

The qualifier "natural" attached to the environment in Article 35(3) is of some importance, since it distinguishes the natural environment from the human environment and concerns "conditions and influences which affect the life, development and survival of the civilian population and living organisms".[121] It is thus the system of inextricable interrelations between living organisms and their inanimate environment[122] which is meant in the Protocol by the term "natural environment", the kind of permanent or transient equilibrium depending on the situation, though always relatively fragile, of forces which keep each other in balance and condition the life of biological groups.[123] The ENMOD Convention prohibits the use of modification techniques affecting the environment in general, including the human environment, for the purpose of causing harm to the military forces and civilian population of another State Party to the Convention, to its cities, industries, agriculture, transportation and communications systems and its natural resources and assets.[124]

Unlike the Convention, which covers only the deliberate use of environmental modification techniques as weapons, Article 35(3) applies to all methods or means of war "which are intended, or may be expected, to cause" damage to the natural environment. As such it also covers the objectively foreseeable collateral effects of the methods and means in question.[125] Thus in this respect, as in all others examined above with the exception of the threshold of severity, the Protocol has a broader scope than the Convention, although it is clear that in some circumstances the two instruments may apply simultaneously and the Protocol may supplement the Convention.[126]

This overlap can only exist in the context of an international armed conflict, the context in which the Protocol applies. In that case, the two instruments jointly prohibit:

- any direct action on natural phenomena of which the effects would last more than three months or a season for one or other of the Parties to the Convention, even if this Party is not a Party to the conflict;

- any direct action on natural phenomena of which the effects would be widespread or severe (...), regardless of the duration, affecting one or other of the Parties to the Convention, even if it is not a Party to the conflict;

- any method of conventional or unconventional warfare which, by collateral effects, would cause widespread and severe damage to the natural environment as such, whenever this may occur over a period of decades.[127]

On the other hand, the ENMOD Convention applies even in the absence of a declaration of war and the use of any other weapon.[128] On this point it accordingly has a broader scope than the Protocol.

The commentary on the 1977 Protocols summarizes as follows the complex relationship between Article 35(3) and the ENMOD Convention:

> Geophysical war and ecological war are two aspects of the same subject. They are dealt with in two separate juridical instruments and form the object of provisions which are sometimes couched in similar terms, underlining their kinship, though this should not lead to confusion.
>
> For example, geophysical war might be aimed at changing the weather or the climate, or triggering off earthquakes. It is prohibited by the United Nations Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, vis-à-vis any State Party to the Convention. This concerns a measure of arms control which applies in time of peace, as in time of war. The threshold of applicability of this prohibition is determined with reference to the extent of the damage, to the period during which the damage is caused, or to its severity. The order of magnitude is in terms of some hundreds of square kilometres with regard to the extent, several months or one season with regard to the duration, and the serious disruption of human life and natural or other resources with regard to the severity.
>
> Ecological warfare refers to the serious disruption of the natural equilibrium permitting life and the development of man and all living organisms, a disruption of which the effects may be felt for one or more decades. The paragraph under consideration here prohibits this, whether it is committed intentionally or not, for example, by the deliberate use of the tools of chemical warfare, or whether it is simply the result of the use of weapons which inevitably have the same effect on vast stretches of land, whether these are populated or not. Because of the transnational aspect of this problem in particular, the prohibition is absolute; it even continues to apply in the absence of any direct threat to the population or to the flora and fauna of the enemy State. It is the natural environment itself that is protected. It is common property, and should be retained for everyone's use and be preserved.[129]

2.2 Article 55

The second provision of Protocol I which is relevant for the purpose of this study is found in Part IV ("Civilian Population"), Section I ("General Protection Against Effects of Hostilities"), Chapter III ("Civilian Objects"). It is Article 55, entitled "Protection of the natural environment", which reads as follows:

> 1. Care shall be taken in warfare to protect the natural environment against widespread, long-term and severe damage. This protection includes a prohibition of the use of methods or means of warfare which are intended or may be expected to cause such damage to the natural environment and thereby to prejudice the health or survival of the population.
>
> 2. Attacks against the natural environment by way of reprisals are prohibited.

The concepts conveyed by this Article are very similar, although not identical on all points, to those in Article 35(3): "natural environment", "widespread, long-term and severe damage", and "methods or means of warfare which are intended or may be expected to cause". The foregoing observations relating to the threshold of severity, the element of intent, the unilateral character and general scope of the latter therefore apply to the former. We shall consequently limit our discussion here to a few comments on the elements which distinguish them, on the relationship between the two articles taken together and on their combined effect.

First, we would note that, unlike Article 35(3), Article 55 starts with the formula "care shall be taken in warfare to protect the natural environment". Although it might be suggested that the expression "care shall be taken" weakens the text by leaving a margin for interpretation, the second sentence of the same paragraph speaks explicitly of prohibition, which reinforces the provision and to some extent compensates for the effect of the above-noted expression. It also has the advantage of emphasizing the duty of care incumbent upon all Parties.[130]

Unlike numerous other articles of the Protocol, Article 55 refers to the population without prefacing it with the adjective "civilian". This omission is intentional and is designed to point out that damage to the natural environment may extend over time and indiscriminately affect the entire population, both civilian and military.[131]

The reference to the "health or survival of the population" also differentiates Article 55 from Article 35(3). The use of the word "health" further distinguishes it from Article 54, which concerns the protection of objects indispensable to the survival of the civilian population, and indicates that it is concerned not only with acts which threaten that survival but also with those which could seriously prejudice health, such as congenital defects, degenerations or deformities. Temporary or short-term effects on health are not, however, taken into account by Article 55[132] which, like Article 35(3), concerns only "long-term"[133] damage.

The prohibition of attacks against the natural environment by way of reprisals set out in paragraph 2 of Article 55 is another distinctive element. The issue of reprisals in general was one of the most controversial questions during the Diplomatic Conference and an analysis of that debate would take us away from our subject matter. We would simply recall that, in the context of the law of war, reprisals are coercive measures constituting an exception to the ordinary rules of

that law, taken by a belligerent in response to unlawful acts committed against it by another belligerent, with the intention of compelling the latter, by injuring it, to observe the law.[134] Article 55(2) accordingly has the effect of preventing attacks on the natural environment from being permitted in response to a violation of other rules of the law of war.

During the Diplomatic Conference, the question was raised as to whether Articles 35(3) and 55, which are very similar in substance, did not amount to a duplication. This issue was examined by the Group Biotope, which attempted to incorporate Article 35(3) within Article 55. It finally decided that the two provisions should remain separate, since the second related to the protection of the population while the first concerned the prohibition of unnecessary injury. This judgment was endorsed by the Conference as a whole, which concluded that Article 35(3), falling within the ambit of methods of combat, had a broader scope, while the objective of Article 55 was to ensure the survival or health of the population living in a wartime environment.[135]

Finally, it seems generally acknowledged, in light of the work of the Diplomatic Conference, that Articles 35(3) and 55 do not impose any significant restriction on combatants waging conventional warfare. Some representatives referred to the destruction of battlefields in France during the First World War as being outside the scope of the prohibition and there was a generally held opinion that damage to battlefields by conventional warfare would not normally be prohibited. The Group Biotope report stated that "Acts of warfare which cause short-term damage to the natural environment, such as artillery bombardment, are not intended to be prohibited"[136] by these articles. They are rather directed to high level policy makers and would affect unconventional means of warfare such as the massive use of herbicides or chemical agents producing widespread, long-term and severe damage to the natural environment.[137]

3. Application to the Gulf War

3.1 Form

Iraq is not a party to Protocol I, nor has it signed it. As noted earlier,[138] this instrument is the first in the law of war to include provisions specifically designed to protect the environment. One can therefore not consider Articles 35(3) and 55 as a codification of pre-existing rules of customary international law which would be binding on Iraq independently of any convention.

This is apparently also the opinion of the ICRC, as set out in a Memorandum on the applicability of international humanitarian law sent to the 164 States Parties to the 1949 Geneva Conventions pursuant to the adoption of Security Council Resolution 678 (1990). In its Memorandum the ICRC noted that, in addition to these Conventions:

> The parties to an armed conflict must also observe a number of rules on the conduct of hostilities. These rules are, in particular, laid down in the Hague Conventions of 1899 and 1907, most of which have become part of customary law.
>
> These rules have been reaffirmed, and in some cases supplemented, in 1977 Protocol I additional to the Geneva Conventions.[139]

The ICRC then listed the general rules it felt are "recognized as binding on any party to an armed conflict" and added further that:

> The ICRC invites States which are not party to 1977 Protocol I to respect, in the event of armed conflict, the following articles of the Protocol, which stem from the basic principle of civilian immunity from attack:
>
> - (...);
> - Article 55: protection of the natural environment;
> - (...).[140]

The juxtaposition of rules which are "recognized as binding on any party to an armed conflict" and those which the ICRC "invites States which are not party to 1977 Protocol I to respect" confirms that the latter rules, including those set out in Article 55 relating to protection of the natural environment, have not acquired the status of rules of customary international law. The very cautious formula used by the ICRC, to the effect that article and the others for which it hopes to encourage respect "stem from the basic principle of civilian immunity from attack", is undoubtedly an attempt to promote acquisition of such status by the rules in question, but at the same time a tacit admission of the fact that this has not yet happened.

3.2 Substance

As was done earlier for the ENMOD Convention,[141] it might be interesting to consider the question of whether, had Iraq been a party to Protocol I, that instrument would have branded as unlawful its conduct in occupied Kuwait. To this end, we must examine whether the acts of releasing oil into the sea and sabotaging oil wells and related installations were intended or could have been expected to cause "widespread, long-term and severe" damage to the natural environment. As noted previously,[142] these criteria are cumulative in Protocol I and not alternative as in the ENMOD Convention. In other words, if the relevant facts meet only one or two of these tests, but not all three, there will be no violation of the Protocol.

The three criteria in question are very subjective because they are very imprecise. If these expressions are given their "ordinary meaning", according to the general rule of interpretation in the Vienna Convention on the Law of Treaties,[143] we find that "widespread" means "widely disseminated or distributed",[144] "long-term" means "occurring in or relating to a long period of time"[145] and "severe" refers to something "violent, vehement, extreme".[146] That does not tell us how great the extent of the damage must be, how long it must last and how serious must be its consequences in order for it to meet the threshold established by the Protocol. Criteria worded in such general terms must necessarily be interpreted in light of the specific circumstances of each case and therefore leave a wide margin for interpretation.

Undoubtedly having such terms, inter alia, in mind, the drafters of the general rule of interpretation referred to above provided that "A special meaning shall be given to a term if it is established that the parties so intended".[147] As seen earlier,[148] while the preparatory work[149] for the Protocol tells us little about the meaning that the parties intended to assign to the terms "widespread" and

"severe", it is quite clear as to their intention in respect of the expression "long-term": the damage must be measured in decades, not months or even years, to meet this test within the meaning of Articles 35(3) and 55 of the Protocol.[150]

Will the effects of the attacks by Saddam Hussein on the environment in Kuwait be felt for so long? Surely not with respect to the oil spills, for the reasons discussed earlier.[151] Once again, however, the answer is less obvious in relation to the sabotage of oilwells and related installations. These were extinguished after less than eight months,[152] but how long will the natural environment feel the effects of the oil deposits which entered it by air and by land? The following extract from the previously quoted United Nations report gives a good idea of the scope of the work that will be necessary to repair the damage and indirectly of the time needed to complete that task:

> The oil on the land will have to be taken off most areas by pumping, scooping or other means and retained in special oil-holding areas until suitable disposal can be arranged. Rehabilitation treatment of the remaining oil-soaked areas is still uncertain. Proposals under consideration include plowing or harrowing to mix the oil layer with sub-surface soil and sand. It is not known how successful such measures may be and the future of these oil-soaked lands will be one of Kuwait's more obvious environmental problems arising from the occupation.[153]

If it cannot be predicted with certainty that it will be possible to rehabilitate some of these oil-soaked areas, it is safe to say that it will be at least ten years, if ever, before all the damage to the natural environment caused by Iraq in Kuwait is repaired.[154] It is accordingly possible to conclude that the Iraqi sabotage of the oil wells and related installations in Kuwait was indeed a method of warfare causing "long-term" damage to the natural environment within the meaning of Articles 35(3) and 55 of Protocol I. It remains to be seen whether this damage was also "widespread" and "severe".

With respect to the criterion of extent, the greater part of Kuwaiti territory, which amounts to about 18,000 square kilometres,[155] was affected by the emissions of gas and particulates from the burning wells,[156] not counting the vast areas of sea onto which these particulates were deposited.[157] If we add to this the worldwide effects of this atmospheric pollution,[158] which caused damage to the natural environment up to 3,000 kilometres from its source,[159] we can conclude that the damage it caused to the environment was "widespread" within the meaning of the Protocol.

The severity of the damage flows naturally from the two preceding criteria. How could damage which will take at least 10 years to reverse, which directly affects an area of several thousand square kilometres and the effects of which will be felt thousands of kilometres away not be considered "severe"? To this we must add the effects on human health, both physiological and psychological, in Kuwait.[160] All of these factors taken together enable us to conclude that the damage caused by Iraq to the natural environment in Kuwait was "severe" within the meaning of Articles 35(3) and 55 of Protocol I.

It follows that, if these provisions had been binding on Iraq, it would have been in violation of both of them when it sabotaged oil installations in Kuwait, because this was a method of warfare which was intended or might have been expected to cause widespread, long-term and severe damage to the natural environment, thereby jeopardizing the health of the Kuwaiti population.

(ii) Customary law

(a) Applicability

While Iraq is a party to neither Protocol I nor the ENMOD Convention, is it nonetheless bound by certain rules of customary international law which may assist in determining whether its use of the environment as a weapon in occupied Kuwait was lawful? Protocol I itself answers the first part of this question in the affirmative. According to paragraph 2 of Article 1 of the Protocol, entitled "General principles and scope of application",

> In cases not covered by this Protocol or by other international agreements, civilians and combatants remain under the protection and authority of the principles of international law derived from established custom, from the principles of humanity and from the dictates of public conscience.

This is a modern version of the Martens clause, which appears in the preamble to the Fourth Hague Convention of 1907 and which reads as follows:

> Until a more complete code of the laws of war can be drawn up, the High Contracting Parties deem it expedient to declare that, in cases not covered by the rules adopted by them, the inhabitants and the belligerents remain under the protection and governance of the principles of the law of nations, derived from the usages established among civilized people, from the laws of humanity, and from the dictates of the public conscience.[161]

These provisions mean that the rules of the customary law of international armed conflict continue to exist in parallel to more recent conventional rules, as well as general principles of law within the meaning of Article 38 of the Statute of the ICJ,[162] which are often the last bulwark against immoderate action by belligerents.[163] These rules and principles apply both to belligerent practices not covered by conventional rules and to States which are not bound by those rules.[164]

(b) Content

1. The St. Petersburg Declaration

Efforts undertaken during the second half of the 19th century and in the early 20th century to develop humanitarian law through codification were based on normative concepts which are still accepted today. Among the leading documents resulting from this process, the St. Petersburg Declaration[165] was considered by the principal European powers to be a binding international agreement, despite being entitled a Declaration.[166] It was the first formal intergovernmental attempt to limit the methods and means of warfare. The Declaration is of interest not so much because of its normative content as of its underlying assumptions. It shows, above all, a relatively clear vision of the goal of military operations: to weaken the enemy's

military forces. Based on this concept, the Declaration entrenches the principle of the prohibition of weapons which would cause unnecessary suffering to men put out of combat or would make their death inevitable, on the grounds that putting them out of combat is sufficient.[167]

The Declaration is of interest for two additional reasons. First, it subordinates and restricts claims based on military necessity in respect of a particular category of weapons. In so doing it demonstrates that, right from the outset of the modern law of war, absolute claims of military necessity have been rejected. Second, it establishes the fundamental concept that a means of warfare must bear a direct relationship to a military objective. This concept implies the illegality of vindictive and punitive destruction, including at least implicitly deliberate damage to the environment and natural resources.[168]

2. The Hague Convention

The St. Petersburg Declaration was followed by other instruments formulated by the Hague Peace Conferences of 1899 and 1907. The 1907 Conference adopted, inter alia, Convention No. IV, referred to above,[169] to which were annexed "Regulations respecting the Laws and Customs of War on Land". The Regulations contain two provisions which are of particular interest to us, especially the first which establishes the cardinal principle governing the conduct of hostilities,[170] since they have often been invoked against military extremism:[171]

Article 22

> Belligerents have not got an unlimited right as to the choice of means of injuring the enemy.

Article 23

> In addition to the prohibitions provided by special Conventions, it is particularly forbidden:
> (...)
> (g) To destroy or seize enemy property, unless such destruction or seizure be imperatively demanded by the necessities of war (...).

We would note that the fundamental rule set out in Article 22 of the Hague Convention was restated in Article 35, paragraph 1 of Protocol I, which provides that:

> In any armed conflict, the right of the Parties to the conflict to choose methods or means of warfare is not unlimited.

3. The Nürnberg Principles

The Nürnberg Tribunal, which was assigned the task of trying the major German war criminals, was created by an agreement among the four victorious powers at the end of the Second World War.[172] It was made up of four judges and four alternates appointed by those powers; it held its first session in Berlin in October 1945 and subsequently transferred its sittings to Nürnberg, the cradle of Nazism. From 20 November 1945 to 30 August 1946, it held 403 public hearings. Its judgment, rendered on 1 October 1946, contained 19 death or imprisonment sentences and 2 acquittals.[173]

The UNGA gave the principles set out in the Charter (annexed to the aforementioned agreement) and the judgment of the Nürnberg Tribunal the status of customary norms of international law. It had entrusted to the International Law Commission (ILC) "the formulation of the principles of international law recognized in the Charter of the Nürnberg Tribunal and in the judgment of the Tribunal".[174] During the course of the ILC's work, the question arose as to whether or not it should decide the extent to which the principles set out in the Charter and the judgment constituted principles of international law. The ILC came to the conclusion that, since the Nürnberg principles had been "unanimously affirmed" by the UNGA,[175] its task did not consist in passing judgment as to whether these principles were principles of international law, but simply in formulating them.[176] In 1950 the ILC established a formulation of the Principles of International Law Recognized in the Charter of the Nürnberg Tribunal and in the Judgment of the Tribunal,[177] which it presented with its comments to the UNGA. The latter invited the governments of Member States to furnish their observations on this formulation and requested the ILC to take account of them in preparing the draft code of offenses against the peace and security of mankind.[178]

The sixth of these Principles, of which there are seven, lists crimes which are punishable as crimes under international law, divided into three categories: crimes against peace, war crimes and crimes against humanity. At the end of the list of war crimes in paragraph (b) appears "wanton destruction of cities, towns or villages, or devastation not justified by military necessity." In its comments the ILC noted that the Nürnberg Tribunal had pointed out that the war crimes defined in Article 6(b) of its Charter were already recognized as war crimes under international law.[179] This was because the rules set out in the Hague Convention,[180] particularly Article 23(g) thereof which prohibits destruction which is not "imperatively demanded by the necessities of war", had in 1939 acquired the status of customary rules of international law.[181]

(c) Application to the Gulf war

Can it be considered that the oil spills deliberately instigated by Iraq and its sabotage of oil installations in Kuwait were imperatively demanded by the necessities of war? Some might be tempted to say so, on the ground that the oil spills were intended to impede any eventual landing by sea, that the installations in question were legitimate military objectives within the meaning of Article 52, paragraph 2 of Protocol I[182] and accordingly objects of destruction, and finally that the smoke caused by this destruction was intended to provide protection for Iraqi forces and to obscure the vision of enemy forces.[183]

We do not share this view. With respect to the spilling of oil into the sea, as noted previously President Bush stated that it did not have the slightest military value.[184] Admiral Lanxade, then President Mitterrand's personal Chief of Staff, expressed a similar opinion when he stated that this ecological catastrophe would not impede an Allied landing, even though it would not make it easier.[185] Ultimately, the fact that such a landing never happened took away any opportunity Saddam Hussein might have had to justify his action on the basis of a hypothetical military advantage he might have hoped to obtain.

It is also far from clear that the destruction of oil installations by Iraq, "in the circumstances ruling at the time, [offered] a definite military advantage" within the meaning of Article 52(2) of Protocol I.[186] While oil refineries make "an effective contribution to military action" by producing the fuel needed for military

vehicles, the same cannot be said of wells and storage tanks which contain only crude oil. Moreover, coalition forces in no way depended for their fuel needs on Kuwaiti refineries, which consequently made no contribution to their military action. Even though there were initially contradictory statements by American spokespersons as to the impact which the smoke from the oil fires might have on military operations,[187] no significant impact was observed in fact and Iraq therefore derived no real military advantage. Moreover, it is obvious that the quantity of smoke produced, its extent and its persistence were entirely disproportionate to the military objective sought, even admitting that such an objective existed.

This reference to proportionality brings us back to the principle of necessity, of which it is in a way the corollary. It has been said that the concept of military necessity has been interpreted subjectively in wartime and that it has thereby prevailed in practice over the principles of discrimination, proportionality and humanity which are the other three cornerstones of international humanitarian law.[188] Nevertheless, and contrary to what such criticisms might suggest, this concept is not infinitely extendible. Its limits have been judicially defined, inter alia by the Nürnberg Tribunal in Case No 47, known as the Hostages Trial.

The following extract from the judgment of the Court in that case is extremely clear as to the meaning and limits of military necessity. The Court stated that it:

> permits the destruction of life of armed enemies and other persons whose destruction is incidentally unavoidable by the armed conflicts of war; it allows the capturing of armed enemies and others of peculiar danger, but it does not permit the killing of innocent inhabitants for purposes of revenge or the satisfaction of a lust to kill. The destruction of property to be lawful must be imperatively demanded by the necessities of war. Destruction as an end in itself is a violation of international law. There must be some reasonable connection between the destruction of property and the overcoming of the enemy forces. It is lawful to destroy railways, lines of communication, or any other property that might be utilized by the enemy. Private homes and churches even may be destroyed if necessary for military operations. It does not admit the wanton devastation of a district or the wilful infliction of suffering upon its inhabitants for the sake of suffering alone.[189]

In light of the facts examined earlier and the conditions established by the Nürnberg Tribunal for invoking military necessity, which distinguish it from simple military "expediency", we do not believe that there was a reasonable connection between the sabotaging of oil installations in Kuwait and the victory sought by Iraq over coalition forces nor, a fortiori, that these acts of destruction were imperatively demanded by the necessities of war. On the contrary, like the deliberate spilling of oil into the sea, these acts fall into the category of "wanton devastation", of "destruction as an end in itself", which military necessity does not allow and which international law condemns.

Conclusions

The deliberate instigating of oil spills and sabotaging of oil installations in Kuwait clearly violate the prohibition of "devastation not justified by military necessity" within the meaning of the sixth principle of international law recognized in the Charter of the Nürnberg Tribunal and in the judgment of the Tribunal. Despite the generality of their press release[190] the OECD Environment Ministers were therefore correct: there was in fact a violation of international law, more

specifically of a rule of customary international law which had been "unanimously affirmed" by the UNGA, as noted by the ILC.[191]

This conclusion will perhaps reassure those, both in the legal community and in the general public, who had been deeply shocked by the attacks on the environment carried out by Iraq in Kuwait and who had felt that, if such actions were not already prohibited by international law, they clearly should be. The legal situation it reflects is not, however, entirely satisfactory, because of the weaknesses inherent in reliance on the norms of customary international law to uphold humanitarian principles. Three such weaknesses deserve to be highlighted.

First, such norms are formulated in general and abstract terms and are thus open to subjective interpretation and selective application. President Bush's use of the expression "ecological terrorism" to describe the first oil spill instigated by Iraq[192] in part reflected the absence of a set of precise rules directly applicable to facts of this type. Second, the general and abstract character of customary norms undermines the educational and preventive functions of the law of war, in other words its ability to provide clear rules to political leaders and military commanders and to guide public opinion and legal commentators accordingly. Third, there is the absence of procedures for implementing customary norms, particularly in terms of objectively determining their violation and of settling disputes arising as a result.[193]

However, as seen in our examination of the ENMOD Convention and Protocol I, the contractual approach also has its limitations, the most significant of which is that treaty rules do not apply if States parties to a conflict are not also parties to the treaties in which the rules are set out. This limitation is not peculiar to environmental protection in time of armed conflict. Its general applicability was implicit in, inter alia, resolution 687 of the Security Council, according to which it

> Invites Iraq to reaffirm unconditionally its obligations under the Geneva Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare, signed at Geneva on 17 June 1925, and to ratify the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction, of 10 April 1972 (...).[194]

Had it been concerned about the need to prevent Iraq from once again using the environment as a weapon (and committing other violations of humanitarian law), the Security Council could have "invited" Iraq to adhere to Protocol I as well, particularly since, unlike some of the rules set out in that instrument, the aforementioned Protocol and Convention were not violated during the Gulf war. In addition to declaring that Iraq was responsible for damage to the environment caused by its unlawful invasion and occupation of Kuwait,[195] the Security Council could also have condemned the destructive acts which caused that damage as war crimes within the meaning of the Nürnberg Principles.

In any event, the "invitation" issued to Iraq is a reminder that it is easier to encourage States to accept conventional rules than customary ones.[196] This is why questions are currently being raised about the possibility of developing conventional humanitarian law concerning environmental protection in time of armed conflict. These questions arise from the fact that we are currently in one of those "legislative moments" when advances in the law are possible in the wake of a conflict

during which the belligerent practices of the losing side did not correspond to the concept of military necessity held by the victors.[197]

By way of illustration, Austria, Finland, Italy, Sweden and Switzerland had the Governing Council of UNEP adopt a resolution on the environmental effects of warfare,[198] which invites States to consider identifying weapons, hostile devices and ways of using such techniques that would cause particularly serious effects on the environment and to consider strengthening international law prohibiting them. Similarly, a Round Table Conference was organized by the London School of Economics, Greenpeace and the Centre for Defence Studies on a 'Fifth Geneva' Convention on the Protection of the Environment in Time of Armed Conflict.[199] Canada, in cooperation with the United Nations, hosted a Conference of Experts on the Use of the Environment as a Tool of Conventional Warfare, to examine the existing rules of international law in this area and see whether they should be strengthened or supplemented.[200] Jordan added to the agenda of the last UNGA session an item concerning protection of the environment in time of armed conflict, on which an initial discussion was held in the Sixth (Legal) Committee.[201] Although it is still too early to predict their outcome, it is not impossible that ultimately one of these initiatives or another similar one will lead to an international convention prohibiting the techniques used by Iraq, in accordance with the wish expressed by the Kuwaiti authorities.[202]

It is true that victors' actions harmful to the environment have traditionally been almost impossible to stigmatize in a legally meaningful manner.[203] The present "legislative moment" does not seem to be an exception to that rule and it is therefore unlikely that coalition practices during the Gulf war, such as the destruction of Iraqi nuclear installations,[204] will be called into question. However, these practices appear to have been less harmful to the environment than those of Saddam Hussein. Even if it was politically possible to condemn only the conduct of the losing side, that in itself would already represent significant progress for protection of the environment in time of armed conflict.

References

1. This paper grew out of an address to a symposium organized by the "Centre de droit international de Nanterre" in Paris on 8 June 1991. An earlier version was published under the title "L'utilisation de l'environnement comme instrument de guerre au Koweit occupé" in "Les aspects juridiques de la crise et de la guerre du Golfe", Montchretien (1991) 227-286.

2. The author was in charge of environmental law from 1983 to 1985 and Head of the UN, Human Rights, Peace and Security Section in 1987 and 1988 in the Legal Operations Division of the Department of External Affairs. The opinions expressed here are however his own and do not necessarily reflect those of the Government of Canada.

3. Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May be Deemed to Be Excessively Injurious or to Have Indiscriminate Effects, Protocol on Prohibitions or Restrictions on the Use of Mines, Booby Traps and Other Devices (Protocol II), done at Geneva on 10 October 1980, in force on 2 December 1983, Doc A/CONF/95/15 and Corr 1 to 5.

4. Security Council Resolution 686 of 2 March 1991, para 3(d), and General Assembly Resolution 37/215 of 20 December 1982.

5. Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts (hereinafter referred to as Protocol I), done at Geneva on 8 June 1977, in force on 7 December 1978, Canada Treaty Series (CTS) 1991/2, Article 56; Resolutions of the International Atomic Energy Agency General Conference GC (XXVII)/RES/407 of 14 October 1983, GC (XXVIII)/RES/425 of 28 September 1984, GC (XXIX)/RES/444 of 27 September 1985, GC(XXXI)/RES/475 of 25 September 1987 and GC(XXXIV)/RES/533 of 24 September 1990. These instruments were adopted, inter alia, because of the severe losses in the civilian population (and implicitly because of damage to the environment) which may be caused by the release of "dangerous forces", that is, ionizing radiation, as a result of attacks on nuclear installations.

6. Convention for the Protection of Cultural Property in the Event of Armed Conflict, done at The Hague on 14 May 1954, in force on 7 August 1956, 249 United Nations Treaty Series (UNTS) 215; Protocol I, supra note 3, Article 53. The question of whether cultural property must be considered as included in the general concept of the environment, as opposed to the natural environment, is the subject of a debate on which we shall not voice an opinion here.

7. Resolution 687 of 3 April 1991, para 16. Iraq's agreement is set out in a letter dated 6 April 1991 reproduced in document S/22456 of the same date.

8. Maurus and Rebeyrol, La marée noire pourrait menacer l'alimentation en eau potable des populations côtières, Le Monde, 27-28 January 1991, p 4; Chipaux, F 111 contre marée noire, Le Monde, 29 January 1991, p 1. The facts concerning this first deliberately created oil slick in occupied Kuwait are still not perfectly clear and may never be. For example, a report of the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization states that the first slick started on January 19, when Iraq began to pump oil from the 5 (not 3) tankers anchored off the Sea Island terminal. See Lidén and Jernelöw, Report of the IOC Mission to the ROPME Sea Area, April-May 1991, Doc IOC/WGOCR-1/Inf.2 of 4 June 1991 (hereinafter referred to as the IOC Mission Report), p 2.

9. Rebeyrol, Les nappes de pétrole risquent de rester bloquées dans les eaux saoudiennes, Le Monde, 3-4 March 1991, p 6. Other oilspills occurred in the Gulf during the war but it was not suggested that they were deliberately caused. On this point, see IOC Mission Report, op cit supra note 6, p 3.

10. Rebeyrol, Une deuxième marée noire aurait commencé, Le Monde, 1 February 1991, p 36.

11. Des experts occidentaux se mobilisent pour lutter contre la marée noire, Le Monde, 5 February 1991, p 6; Rebeyrol, op cit supra note 7.

12. Maurus, La 'marée noire du siècle' n'a eu que des effets très limités, Le Monde, 27 March 1991, p 7. This observation must, however, be tempered by the fact that fishing activities had been interrupted during the war. IOC Mission Report, op cit supra note 6, p 5.

13. Maurus, op cit supra note 10.

14. Report presented to the Secretary General by a United Nations mission led by Abdulrahim A Farah, former Under-Secretary-General, to assess the scope and nature of damage inflicted on Kuwait's infrastructure during the Iraqi occupation of the country from 2 August 1990 to 27 February 1991 (hereinafter referred to as the Farah Report), document S/22535 of 29 April 1991, para 161.

15. Maurus, op cit supra note 10.

16. Farah Report, op cit supra note 12, para 162.

17. Sheppard and Price, Will marine life survive the Gulf War?, New Scientist, 9 March 1991, p 40.

18. Farah Report, op cit supra note 12, paras 163-166.

19. IOC Mission Report, op cit supra note 6, p 6 and 9.

20. See, for example, Rebeyrol, Les installations pétrolières dans le Golfe sont inégalement vulnérables, Le Monde, 20 October 1990, p 30.

21. Maurus, Le sabotage par l'Irak des installations koweitiennes n'aura aucun effet sur l'approvisionnement pétrolier international, Le Monde, 24 January 1991, p 31.

22. Des dizaines de puits de pétrole sont en flammes au Koweit, Le Monde, 14 February 1991, p 3.

23. Rebeyrol, Les dégâts seront longs à réparer, Le Monde, 24-25 February 1991, p 5.

24. Id, 363 puits 'actifs', Le Monde, 28 February 1991, p 8.

25. Maurus, Au Koweit, l'industrie pétrolière est dévastée, Le Monde, 15 March 1991, p 1 and 24.

26. Ibid.

27. Farah Report, op cit supra note 12, para 137.

28. World Meteorological Organization, WMO to Assess Impact of Kuwaiti Oil Fires, WMO Press Release No 465, 1 May 1991 (hereinafter referred to as WMO Press Release).

29. Id. To the same effect, see Simmonds, Kuwait Oil Fires Said to Pose Little Risk to World Climate, International Herald Tribune, 17 April 1991, p 7.

30. WMO Press Release, op cit supra note 26.

31. Rebeyrol, Koweit: Comment le désert s'embrasa, Le Monde, 17 April 1991, p 13-14; Maurus, Sous un soleil noir, id, p 14.

32. Ambroise-Rendi, Une antenne française d'assistance écologique est en place au Koweit, Le Monde, 29 March 1991, p 4.

33. Maurus, Le Koweit lance un appel à l'ONU et à une conférence internationale pour lutter contre les incendies des puits de pétrole, Le Monde, 14 March 1991, p 4.

34. Ambroise-Rendi, op cit supra note 30.

35. Farah Report, op cit supra note 12, para 152.

34. Elmer-Dewitt, A Man-Made Hell on Earth, Time, 18 March 1991, p 23. However, see infra section IV A (ii).

35. Krauze, La 'stupéfaction' du président Bush, Le Monde, 27-28 January 1991, p 1.

36. OECD, Environment Ministers' Statement on the Environmental Situation in the Gulf, Press Release SG/PRESS(91)8, 30 January 1991.

37. Gueyras, L'extinction des puits de pétrole: une tâche ardue et hasardeuse ..., Le Monde, 3 May 1991, p 3. Some experts believed that this job would take about two years. See Intergovernmental Oceanographic Commission, Executive Summary of the Report of the WHO Meeting of Experts on the Atmospheric Part of the Joint UN Response to the Kuwait Oilfield Fires, Geneva, 20-30 April 1991, Doc IOC/WGOCR-I/Inf.12 of 4 June 1991, p 1. In fact it was completed in less than eight months. See Rebeyrol, Le Koweit ne brûle plus, Le Monde, 6 November 1991, p 1 and 12.

38. Jean-Marie Cavada, host of the French television program "La marche du siècle", in a debate broadcast by FR3 on 15 May 1991.

39. Maurus, op cit supra note 23.

40. Ambroise-Rendi, op cit supra note 30.

41. Id. The use of chemical weapons in war was prohibited by the Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or other Gases, and of Bacteriological Methods of Warfare, done at Geneva on 17 June 1925, in force on 8 February 1928, CTS 1930/3. However, the Protocol does not prohibit developing, producing, acquiring, stockpiling, retaining or transferring such weapons, and in acceding to the Protocol some States made reservations designed to limit their obligations only to those States which are parties to the Protocol and to reserve the right to use such weapons in reprisal against States which used the same weapons against them or whose allies used the same weapons against them. Negotiations are ongoing at the Conference on Disarmament concerning a draft Convention on chemical weapons.

42. This section is based largely on a report presented in 1985 by a study group composed of professors Michael Bothe, Antonio Cassese, Frits Kalshoven, Alexandre Kiss, Jean Salmon and Kenneth R Simmonds. This group of specialists in humanitarian and environmental law had been established in 1983 by Karl-Heinz Narjes, a member of the Commission of the European Communities, to study the problems arising out of the prevention and reparation of damages that actions of war might cause to the environment, highlighted at the time by the Iran-Iraq war. Its report, entitled "La protection de l'environnement en temps de conflit armé" and published as document SJ/110/85, reflected the opinion of the group and was in no way binding on the Commission. Similarly, this section reflects the opinion of the author and is in no way binding on the members of the group on whose work he has drawn and to whom he wishes to acknowledge his indebtedness.

43. Max Huber, Tribunal of Arbitration, 4 April 1928, II Reports of International Arbitration Awards (RIAA) 839.

44. International Court of Justice (ICJ), Decision of 9 April 1949, Merits, 1949 Reports, p 22.

45. 11 March 1940, III RIAA 1965.

46. United Nations Convention on the Law of the Sea, done at Montego Bay on 10 December 1982, Doc A/CONF.62/122, Article 300.

47. See for example the Convention on the Law of the Sea, Article 194, para 2, and the preamble to the Convention on Long-Range Transboundary Air Pollution, done at Geneva on 13 November 1979, in force on 16 March 1980, CTS 1983/34.

48. Supra note 46, Article 192. The other provisions of Part XII of the Convention provide further clarification as to the content of this general obligation.

49. See for example the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters, done at London, Mexico City, Moscow and Washington on 29 December 1972, in force on 30 August 1975, CTS 1979/36, Article 1; the Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft, done at Oslo on 15 February 1972, in force on 7 April 1974, Alexandre Kiss (ed), Selected Multilateral Treaties in the Field of the Environment (1980) 405, Article 1; and the Convention for the Prevention of Marine Pollution from Land-Based Sources, done at Paris on 4 June 1974, in force on 6 May 1978, ibid, p 430, Article 1.

50. See, inter alia, the Convention on the Protection of the Marine Environment of the Baltic Sea Area, done at Helsinki on 22 March 1974, in force on 3 May 1980, Kiss, op cit supra note 49, p 405, Article 3; the Convention for the Protection of the Mediterranean Sea Against Pollution, done at Barcelona on 16 February 1976, in force on 27 September 1978, ibid, p 448, Article 4; the Convention for the Protection and Development of the Marine Environment of the West and Central African Region, done at Abidjan on 23 March 1981, in force on 5 August 1984, Doc UNEP/IG/22/7, International Legal Materials (hereinafter referred to as ILM) 1981, p 746, Article 4; the Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment, done at Jeddah on 14 February 1982, in force on 20 August 1985, Doc UNEP GC.15/INF.2, W E Burhenne (ed), International Environmental Law, Multilateral Agreements, Beiträge zur Umweltgestaltung B7, No 982:13/1, Article 4; and the Convention on the Protection and Development of the Marine Environment of the Wider Caribbean Region, done at Cartagena on 24 March 1983, in force on 11 October 1986, ILM 1983, p 221, Article 4.

51. Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution, done at Kuwait on 24 April 1978, in force on 1 July 1979, Kiss, op cit supra note 49, p 486, Article 3, para a). In addition to Iraq and Kuwait, Bahrain, Iran, Oman, Qatar, Saudia Arabia and the United Arab Emirates are also party to this Convention.

52. Declaration of the Stockholm Conference on the Human Environment, adopted on 16 June 1972, ILM 1972, p 1416.

53. See for example the conventions cited supra in notes 49 to 51.

54. See in particular the Charter of Economic Rights and Duties of States, annexed to resolution 3281 (XXIX) of the United Nations General Assembly (UNGA) of 12 December 1974; the Final Act of the Conference on Security and Co-operation in Europe, adopted at Helsinki on 1 August 1975, IIM 1975, p 1292; and Article II of the resolution of the Institute of International Law on Pollution of Rivers and Lakes, adopted at Athens in September 1979, 58 Yearbook of the Institute of International Law, Part II (1979) 198.

55. Alexandre Kiss, Droit international de l'environnement (1989) 34.

56. J G Lammers, Pollution of International Watercourses (1984) 98-147.

57. Supra note 47, Article 2.

58. Convention concerning the Protection of World Cultural and Natural Heritage, done at Paris on 23 November 1972, in force on 17 December 1975, CTS 1976/45, Article 4.

59. Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, done at New York on 5 December 1979,in force on 11 July 1984, appended to UNGA resolution 34/68, Article 7.

60. Convention on the Law of the Sea, supra note 46, Article 145.

61. See for example the Stockholm Declaration, supra note 52, principles 2, 3, 5, 6 and 7; UNGA resolution 35/8 of 30 October 1980 on the Historical Responsibility of States for the Preservation of Nature for Present and Future Generations; and the World Charter of Nature, annexed to UNGA resolution 37/7 of 28 October 1982.

62. See, inter alia, Article 24, para 1, of the Greek Constitution, in force on 11 June 1975.

63. Done at Vienna on 29 May 1969, in force on 27 January 1980, CTS 1980/37, Article 34: "A treaty does not create either obligations or rights for a third State without its consent."

64. Annexed to the Charter of the United Nations, done at San Francisco on 26 June 1945, in force on 24 October 1945, CTS 1945/7, Article 38, para 1 b).

65. Jaccard, Uber Neutralitätsverletzungsschäden in der Schweiz während des zweiten Weltkrieges, 87 Revue de la Société des juristes bernois (1951) 225-251.

66. Nguyen Quoc Dinh, Patrick Daillier, Allain Pellet, Droit international public (1987) 840. These authors state that relations between belligerents are wholly governed by the law of international armed conflict, which we believe to be an overstatement.

67. Article 4, para 2 of the International Covenant on Civil and Political Rights (done at New York on 16 December 1966, in force on 23 March 1976, CTS 1976/47) provides that no derogation may be made from articles 6 (right to life), 7 (prohibition of torture), 8 paras 1 and 2 (prohibition of slavery and servitude), 11 (prohibition of imprisonment for failure to fulfil a contractual obligation), 15 (prohibition of retroactive prosecution and retroactive increase in sentence), 16 (recognition as a person before the law) and 18 (freedom of thought, conscience and religion), even "in time of public emergency which threatens the life of the nation" such as, for example, in time of armed conflict.

68. Mallisson, The Laws of War and the Juridical Control of Weapons of Mass Destruction in General and Limited Wars, 36 George Washington Law Review (1967) 308-309. For a review of the environmental damage caused by all the great battles of the twentieth century, see Cans, La guerre, fauteur de crimes écologiques, Le Monde, 30 January 1991, p 4.

69. André Malraux, L'espoir (1937) 109.

70. This Convention is an arms control agreement, which applies both in time of peace and in time of war, and so could be considered not to be a part of the law of war stricto sensu, although, as Nguyen, Daillier and Pellet (op cit supra note 66, p 838) note, since arms control agreements have an effect on the conduct of conflicts, the boundary between the law of arms control and the law of war is far from obvious. Nonetheless, for purposes of convenience we shall deal with the ENMOD Convention under the latter heading, as opposed here to environmental law.

71. Stockholm International Peace Research Institute (SIPRI), Warfare in a Fragile World: Military Impact on the Human Environment (1980) 15-19.

72. Falk, The Environmental Law of War: an Introduction, in Glen Plant (ed), Environmental Protection and the Law of War (1991) 78.

73. Done at New York on 10 December 1976, in force on 5 October 1978, CTS 1981/40.

74. SIPRI, Ecological Consequences of the Second Indochina War (1976) 55.

75. United States Senate, Prohibiting Environmental Modification as a Weapon of War, Senate Report No 270, 93rd Congress, 1st Session (1973) 1 and 5.

76. Doc A/31/27, 1976, p iii.

77. The representative of Finland in the First Committee observed that the use of this term was unprecedented in earlier resolutions by which the UNGA commended draft treaties negotiated in the CCD to signature and ratification by States. As the record of discussions makes clear, this was a reflection of the reluctance expressed by a number of delegations in respect of the Convention. Doc A/C.1/31/ PV.50 of 2 December 1976.

78. Fischer, La Convention sur l'interdiction d'utiliser des techniques de modification de l'environnement à des fins hostiles, 23 Annuaire français de droit international (1977) 825. See contra Goldblat, The Environmental Warfare Convention, 6 Ambio No 4, 216, based on the fact that, in one of the preambular paragraphs of its resolution of 10 December 1976, the UNGA was "bearing in mind all relevant documents and negotiating records of the [CCD] on the discussion of the draft Convention". This argument appears less convincing that the one put forward by Fischer, who notes that the substance of the same resolution refers to States only the Convention "which is annexed to the present resolution" and that the documents and minutes of the CCD show that some of its members considered the interpretive agreements to be entirely unsatisfactory and unacceptable.

79. Doc CCD/PV.724 of 26 August 1976 and CCD/516 of 1 September 1976.

80. Doc CCD/PV.691 of 4 March 1976.

81. Doc CCD/PV.692 of 9 March 1976.

82. Proposals to prohibit each of these activities were made but rejected during the negotiation of the Convention. See Fischer, op cit supra note 78, 826-827.

83. Doc A/31/27, 1976, p 92.

84. Id. The representative of the USSR at the UNGA also gave an indicative list of the activities his government intended to prohibit, which overlapped with but did not correspond exactly to the previously quoted list: activities intended to influence weather and geophysical processes; cause fire storms (a kind of atmospheric fiery cyclone); create windows in the ozone shield of the earth in order to allow increased penetration of the hard ultra-violet radiation to selected parts of our planet; create extensive ultra and infra-acoustic fields on the sea or the ocean surface to combat individual ships or whole flotillas; melt the ice caps of the Arctic or of the Antarctic for the purpose of delivering a totally annihilating blow against a potential enemy;

cause tidal waves, tsunamis and earthquakes, etc. Doc A/AC.1/PV.1998 of 21 October 1974.

85. Fischer, op cit supra note 78, 828.

86. Ibid, 821.

87. Ibid, 835.

88. Falk, op cit supra note 72, 90.

89. Article V contains an undertaking by the States Parties "to consult one another and to co-operate in solving any problems which may arise in relation to the objectives of, or in the application of the provisions of, the Convention" (para 1). A consultative committee of experts is created (para 2) "to make appropriate findings of fact and provide expert views" (Annex to the Convention), but it can neither make a judgment as to a violation of the Convention, nor assign responsibility, nor even present recommendations. A violation of the Convention may be the subject of a complaint to the UN Security Council (para 3), which may, but is not required to, initiate an investigation "in accordance with the provisions of the Charter of the United Nations" (para 4) and therefore subject to the exercise of the veto of the five permanent members of the Council.

90. Fischer, op cit supra note 78, 828.

91. Ibid.

92. Goldblat, The Mitigation of Environmental Disruption by War: Legal Approaches, in A. Westing (ed), Environmental Hazards of War (1990) 51.

93. Ibid.

94. Doc A/31/27, 1976, p 91.

95. Doc CCD/PV.692 of 9 March 1976 (Netherlands); 703 of 20 April 1976 (Romania); 724 of 26 August 1976 (Mexico); A/C.1/31/PV.20 of 1 November 1976 (Mexico).

96. Doc CCD/PV.692 of 9 March 1976 (Netherlands); 697 of 25 March 1976 (Iran); 701 of 8 April 1976 (Egypt and Yugoslavia); 724 of 26 August 1976 (Mexico).

97. Doc CCD/PV.698 of 30 March 1976 (USSR); United States Senate, Prohibiting Hostile Use of Environmental Modification Techniques, Hearing before the Subcommittee on Ocean and International Environment of the Senate Committee on Foreign Relations, January 1976, p 17.

98. Supra note 63, Article 18.

99. Customary rules in this area are less than perfectly clear. A State which has signed a treaty subject to ratification incurs an obligation of good faith to refrain from acts calculated to frustrate the object of treaty. While it could not amount to a breach of a conventional undertaking, since no such undertaking yet exists, such an act would entail international responsibility. The exact scope of this obligation of conduct, established by international custom on the basis of the principle of good faith, is not easy to determine. Reuter, Introduction au droit des traités (1972) 77. In the Certain German Interests in Polish Upper Silesia case (PCIJ, Series A, No. 7, Judgement of 25 May 1926, Merits, p. 30), the Permanent Court of International Justice recognized to a certain extent that abuse of right or a breach of the principle of good faith by the signatory State of a treaty in the period preceding its ratification may constitute a violation of the treaty. Although the preceding elements are not wholly conclusive, there consequently seems to exist a customary rule to the effect that a State limits its freedom of action during the interval between signature and ratification. However, Article 18 a) of the Vienna Convention goes further than customary international law since it requires the State to refrain from acts which would defeat the object and purpose of the treaty as long as it has not made clear its intention not to become a party to it. This article is at once more rigid than the customary rule of good faith, since it omits the relevance of circumstances, and more relaxed in that it limits the scope of the obligation to the object and purpose as opposed to the treaty as a whole. O'Connell, International Law (1970) 222-224.

100. Supra section II A.

101. Lindén et al, State of the marine environment in the ROPME Sea Area, UNEP Regional Seas Reports and Studies No 112 Rev 1 (1990) 30.

102. Supra section II B.

103. See supra the list accompanying note 83.

104. See the list cited supra note 84.

105. Supra note 3.

106. Aldrich, Some Reflections on the Origins of the 1977 Geneva Protocols, in C Swinarski (ed), Studies and Essays on International Humanitarian Law and Red Cross Principles (1984) 129-31; H Levine, Protection of War Victims: Protocol I to the 1949 Geneva Conventions (1979) 259-60; Mallison & Mallison, The Juridical Status of Privileged Combatants Under the Geneva Protocol of 1977 Concerning International Conflicts, 42 Law and Contemporary Problems (1978) 6; SIPRI, op cit supra note 74, p 88. Among the American means and methods of warfare which SIPRI considered disproportionate in relation to the military benefits obtained were the widespread use of heavy artillery, tanks, incendiary bombs and herbicides; the use of climate modification techniques and antipersonnel chemicals; and the bombing of dams and dikes. According to SIPRI, all these practices caused and continue to cause severe ecological problems which hinder reconstruction efforts in Indochina.

107. See supra text accompanying notes 73 to 78.

108. The Diplomatic Conference on the Reaffirmation and Development of International Humanitarian Law Applicable in Armed Conflict was held in Geneva from 20 February 1974 to 10 June 1977.

109. Bothe, Partsch and Solf, New Rules for Victims of Armed Conflicts (1982) 344.

110. Ibid.

111. Id, 345.

112. Sandoz, Swinarsky and Zimmermann (eds), Commentary on the Additional Protocols of 8 June 1977 to the Geneva Conventions of 12 August 1949 (1987) 413.

113. Bothe, Partsch and Solf, op cit supra note 109, p 347.

114. Sandoz, Swinarsky and Zimmermann, op cit supra note 112, p 417.

115. Cited supra in text accompanying note 94.

116. Doc A/31/27, 1976, p 91.

117. Sandoz, Swinarsky and Zimmermann, op cit supra note 112, p 419-420 and footnotes 128-130.

118. Id, p 419, footnote 127.

119. Id, p 410.

120. In this sense the ENMOD Convention, concluded the preceding year, was also a precedent. However, see supra note 70.

121. Sandoz, Swinarsky and Zimmermann, op cit supra note 112, p 415 and footnote 110.

122. Id and footnote 112.

123. Ib, p 415.

124. Doc cited supra note 94, p 82.

125. Bothe, Partsch and Solf, op cit supra note 109, p 347.

126. Sandoz, Swinarsky and Zimmermann, op cit supra note 112, p 416.

127. Ibid.

128. Doc cited supra note 94, p 73.

129. Sandoz, Swinarsky and Zimmermann, op cit supra note 112, p 420.

130. Id, p 661. While it does not appear in Article 35(3), the expression "care shall be taken" appears in Article 57(1) of Protocol I, relating to precautions in attack.

131. Id, p 662-664.

132. Id, p 663-664.

133. With respect to the meaning attributed to this word by the negotiators of the Protocol, see supra section 2.1.1.

134. With respect to the problem of reprisals in Protocol I, see Sandoz, Swinarsky and Zimmermann, op cit supra note 112, para 3424 to 3459.

135. Id, p 414. At the end of the debate, the delegation of the United Kingdom was apparently the only one which continued to consider Article 35(3) to be a useless repetition of Article 55. Id, p 420 and footnote 131.

136. Id, p 417.

137. Bothe, Partsch and Solf, op cit supra note 109, p 348.

138. See supra text accompanying note 120.

139. ICRC, Note verbale and memorandum of 14 December 1990, International Review of the Red Cross, January-February 1991, No 787, p 24.

140. Id, p 25.

141. See supra section 3.2.

142. See supra section 2.1.1.

143. Supra note 63, Article 31, para 1: "A treaty shall be interpreted in good faith in accordance with the ordinary meaning to be given to the terms of the treaty in their context and in the light of its object and purpose."

144. The Concise Oxford Dictionary (1976) 1333.

145. Id, p 642.

146. Id, p 1043.

147. Vienna Convention on the Law of Treaties, supra note 63, Article 31, para 4.

148. See supra text accompanying note 114.

149. The preparatory work is a supplementary means of interpretation that can serve to determine the meaning of terms used in a treaty when application of the general rule of interpretation leaves the meaning ambiguous or obscure. Vienna Convention on the Law of Treaties, supra note 63, Article 32.

150. This intention is confirmed by the generally held opinion referred to in the text accompanying note 136 according to which destructions caused to battlefields by conventional war would not be covered by the prohibitions set out in the Protocol. On the other hand it is probably exaggerated by the statements referred to in the same text tending to exclude in particular those caused in France during the First World War. These destructions left scars in the French countryside which are still visible today, three quarters of a century later. In Champagne and Lorraine "artillery preparations" transformed thousands of hectares of fields and prairies into wasteland, unfit for farming for decades. In the most seriously affected departments, such as the Marne and the Meuse, entire cantons were left fallow because agriculture was no longer possible: arable soil had vanished, the limestone subsoil was exposed, the land was battered and strewn with shell splinters, etc. In the ten departments invaded by the Germans, more than 3 million hectares of agricultural or forested land were temporarily sterilized. In 1923, 5 years after the end of the war, there were still 288,000 hectares in need of rehabilitation. Cans, op cit supra note 68. While the statements referred to earlier do not necessarily reflect the views of all States participating in the Diplomatic Conference, they nevertheless tend to reinforce the idea that these States had in mind, in the words of the Rapporteur, "such damage as would be likely to prejudice, over a long term, the continued survival of the civilian population or would risk causing it major health problems". Sandoz, Swinarsky and Zimmermann, op cit supra note 112, p 417.

151. See supra text accompanying notes 100 and 101.

152. See supra note 37 and accompanying text.

153. Farah Report, op cit supra note 12, p 47.

154. Telephone conversation on 2 July 1991 with Dr Ruben Bojkov, Head of the Environment Division of the World Meteorological Organization. This is the scale on which ecological catastrophes are measured. For example, at the time of the Amoco Cadiz disaster, when 220,000 tonnes of oil were spilled off the coasts of Brittany in 1978, it was estimated that it would take five to ten years for the equilibrium of the ecological systems on the shore to recover, in other words for the flora and fauna to return to their former level of existence. Sandoz, Swinarsky and Zimmermann, op cit supra footnote 112, note 120.

155. Although the negotiators of Protocol I and of the ENMOD Convention clearly sought to prevent the meaning of the words "widespread", "long-lasting"/"long-term" and "severe" as used in the two instruments to be interpreted in the same way (see supra section 2.1.1), it should be recalled that, according to the draft interpretive agreement relating to Article I of the Convention, "widespread" was to be taken to mean effects encompassing an area on the scale of several hundred square kilometres (see supra text accompanying note 94).

156. Conversation with Dr Bojkov, supra note 154.

157. Farah Report, op cit supra note 12, p 46.

158. See supra text accompanying notes 26 to 28.

159. Conversation with Dr Bojkov, supra note 154.

160. See supra text accompanying notes 29 and 30. With the same reservation as stated supra note 155, it should be recalled that, according to the draft interpretive agreement relating to Article I of the ENMOD Convention, "severe" meant "involving serious or significant disruption or harm to human life, natural and economic resources or other assets" (see supra text accompanying note 94).

161. Convention concerning the Laws and Customs of War on Land (Convention No IV), done at The Hague on 18 October 1907, in force on 26 January 1910, British Treaty Series 1910/9.

162. Supra note 64, Article 38, para 1 c).

163. Nguyen, Daillier and Pellet, op cit supra note 66, p 836.

164. Falk, op cit supra note 72, p 84.

165. Declaration renouncing the Use, in time of War, of Explosive Projectiles under 400 Grammes Weight, done at St Petersburg on 11 December 1868, in force between 29 November and 11 December 1868, British and Foreign State Papers 58/16.

166. Falk, op cit supra note 72, p 83.

167. Sandoz, Swinarsky and Zimmerman, op cit supra note 112, p 403.

168. Falk, op cit supra note 72, p 83.

169. See supra text accompanying note 161.

170. Nguyen, Daillier and Pellet, op cit supra note 66, p 840.

171. Falk, op cit supra note 72, p 83.

172. Agreement for the Prosecution and Punishment of the Major War Criminals of the European Axis, with the Charter of the International Military Tribunal as an Annex, done at London on 8 August 1945, in force on the same day, 82 UNTS 279. This agreement, concluded between the United States, France, the United Kingdom and the USSR, was subsequently adhered to by 18 other States.

173. Nguyen, Daillier and Pellet, op cit supra note 66, p 585.

174. Resolution 177(II) of 21 November 1947.

175. In Resolution 95(1) of 11 December 1946. This resolution, entitled "Affirmation of the Principles of International Law recognized by the Charter of the Nürnberg Tribunal", is rather peculiar in that, after affirming in the first paragraph the principles recognized by both the Charter and the judgment, in the second paragraph the UNGA directs the ILC to formulate the principles it has just affirmed. Resolution 177(II), entitled "Formulation of the principles recognized in the Charter of the Nürnberg Tribunal and in the judgment of the Tribunal", is also peculiar in that it simply reiterates the mandate already given by Resolution 95(I), as if the UNGA were afraid that the ILC had not properly understood what was expected of it. These peculiarities are undoubtedly attributable to the breaking in process of the UNGA, which had only recently been established, and to the fact that the ILC, having been created in 1947 and its first members elected in 1948, only started its work in 1949.

176. United Nations, The Work of the International Law Commission (1988) 28.

177. Id, Annex IV, p 141.

178. Resolution 488(V) of 12 December 1950.

179. Yearbook of the International Law Commission, vol II, p 194.

180. See supra section 2.

181. International Military Tribunal (Nuremberg), Judgment and Sentences, October 1946, Judgment, 4 American Journal of International Law (1947) 248-249.

182. "(...) military objectives are limited to those objects which by their nature, location, purpose or use make an effective contribution to military action and whose total or partial destruction, capture or neutralization, in the circumstances ruling at the time, offers a definite military advantage."

183. On this point, see Green, The Environment and the Law of Conventional Warfare, Paper presented to a Conference of Experts on the Use of the Environment as a Tool of Conventional Warfare, Ottawa, 10-12 July 1991, p 11-13, to be published in the Canadian Yearbook of International Law.

184. Supra note 35.

185. La chute du régime irakien n'est pas le but politique de la France, Le Monde, 29 January 1991, p 4.

186. Supra note 182. Emphasis added.

187. Supra note 20.

188. Falk, op cit supra note 72, p 80.

189. Case No 47, The Hostages Trial, Trial of Wilhelm List and Others, United States Military Tribunal, Nuremberg, 8th July, 1947, to 19th February, 1948, US Government Printing Office, 11 Trials of War Criminals Before the Nuremberg Military Tribunals Under International Law No 10 (1947) 1253. Emphasis added.

190. See supra text accompanying note 36.

191. See supra text accompanying note 175.

192. See supra text accompanying note 35.

193. Falk, op cit supra note 72, p 85-86.

194. Resolution 687 of 3 April 1991, para 7. This "invitation" is remarkably respectful of Iraq's sovereignty and, particularly concerning the Convention of 10 April 1972, of the rule that, like any other State, Iraq is not bound by a rule of conventional law as long as it has not expressed its agreement to be so bound. It contrasts with the terms of paragraphs 8 and 10 of the same resolution, according to which the Security Council "Decides that Iraq shall unconditionally accept the destruction, removal, or rendering harmless, under international supervision, of: (a) All chemical and biological weapons and all stocks of agents and all related subsystems and components and research, development, support and manufacturing facilities" and "unconditionally undertake not to use, develop, construct or acquire any of the items specified

in paragraphs 8 and 9". Nevertheless, these obligations were imposed on Iraq by the Security Council and were not incumbent upon it as a result of a treaty to which it was not a party.

195. See supra text accompanying note 5.

196. However, just as a horse can be brought to water but cannot be made to drink, treaties can be written but States cannot be forced to become parties to them.

197. Falk, op cit supra note 72, p 81.

198. Doc UNEP/GC 16/L.53 of 31 May 1991, section B, para 2.

199. See supra note 72.

200. See supra note 183.

201. See Doc A/46/693 of 27 November 1991 and UNGA Decision A/46/417 of 19 December 1991.

202. See supra text accompanying note 41.

203. Falk, op cit supra note 72, p 81.

204. On this point see the instruments cited supra note 3.

SESSION 1: DISCUSSION

The discussion ensuing from Session I dealt mainly with the interpretation of the wording of the ENMOD Convention, which significantly limits the impact of the Convention. For example, the wording of Article I specifies that an environmental modification technique must have "widespread, long-lasting or severe" effects to be prohibited. This vague and imprecise phrasing allows for divergent interpretations of very important aspects of the Convention.

The Convention also specifies the words "deliberate manipulation of natural processes". It was suggested that this has the effect of diluting the impact of the purpose of the Treaty. Take an oil spill for example. Because oil spills constitute deliberate actions on a human process and not a natural process as defined by the Treaty, this would not constitute a violation.

Specific examples of "non-deliberate" methods of manipulating the environment were suggested, for instance, the spread of zebra mussels and water diversion plans by Syria and Turkey.

Another point of discussion was whether any one of the criteria (i.e. "widespread, long-lasting or severe") would constitute a basis for non-compliance.

SESSION 2

KUWAIT: A REVIEW OF WHAT HAPPENED AND THE SCIENTIFIC EVIDENCE

Chairperson: Fred Roots

THE KUWAIT OIL FIRES AND THEIR ENVIRONMENTAL EFFECTS

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That Saddam Hussein should have ordered the destruction of Kuwait's oil producing capacity should have come as no surprise to anybody. What the oil fires symbolize, together with the releases of oil into the Gulf, is just how much environmental and ecological damage can be caused by one man in our increasingly crowded and technological world. I personally fault many countries for not having taken prudent action to rein in the Iraqi regime many years earlier. In November of 1979, when the Iranian Revolutionary Guard took over the American embassy in Teheran, and subsequently in 1980, when Saddam Hussein invaded Iran, everybody was violently opposed to Ayatollah Khomeini. While I held no brief for the Ayatollah, I was receiving a great deal of flak for suggesting that if I were forced to make a choice, I would prefer to live in Khomeini's Iran rather than in Saddam Hussein's Iraq governed, as it was and still is, by a bunch of thugs from Takrit, who eliminate their political opponents by any means possible, including poisoning by thallium, a particularly unpleasant form of slow death.

The Iraqis seem to have adopted a potential scorched-earth policy from the day they set foot in Kuwait. Kuwait is one of the major oil producers of the world with proven reserves before the Gulf War of 97 billion barrels. Oil was produced from many fields (Figure 1)[1] including the al-Burgan field some 50 km south of Kuwait City. This is the world's second largest oil-field after the al-Ghawar field in Saudi Arabia. The area just east of the al-Wafrah field, some 40 km further south, was an irrigated prime agricultural region before the outbreak of war. At the time of the Iraqi invasion, about 858 of Kuwait's 1,386 wells were producing oil[2]. This included wells in the Kuwaiti-administered portion of the Neutral zone between Kuwait and Saudi Arabia.

Shortly after the invasion, after studying detailed maps of captured oil-fields, the Iraqi occupation troops, supervised by petroleum engineers, packed almost every wellhead with 15-20 kg of Russian-made C-4 plastic explosive, using electric detonation systems backed up by non-electric detonators[3]. During December 1990, Iraqi troops experimented in igniting small basins of oil and six oil wells in the Kuwaiti fields to determine the best method for destroying the wells. The Iraqis found that maximum destruction was most likely to occur if they put sandbags on top of each charge to direct the blast downwards[4]. During February 1991, the Iraqis sabotaged more and more wells, and by February 24, over 600 wells were burning, over 300 of them in the greater al-Burgan field. Most of the sabotaged well heads were blown open at the base, with surface casings also damaged. The exact number appears to be slightly uncertain, with figures of 732-749 wells damaged[5], with 610-650 set on fire[6] and the rest just flowing freely, creating huge basins of spilled oil; beneath these oil basins, crude pockets of gas accumulated. In addition to the wells, a number of oil storage tanks and refinery facilities were damaged. For instance, more than 20 of 26 gathering centres that separate the oil, gas and water recovered from the underground reservoirs were destroyed and the remainder damaged. Each of these gathering centres served 30-40 wells, and must be rebuilt before production can begin again[7]. Adding to this damage is the fact that much of the documentary information (such as well depth, pressure, etc.) was also destroyed.

The fires were a spectacle. The burning oil wells put out a deafening roar that could be heard for miles; there was a fine mist of unburnt oil particles, both from the burning wells and from gushers. The unburnt oil formed a number of large oil lakes around and between some oil wells. Some of these oil lakes were up to 5 km long and 1.5 m deep[8]. At the end of the war, the first thought was how to extinguish the fires and cap the damaged wells as quickly as possible. The problem was exacerbated by two factors. First, many of the wells were surrounded by minefields; as mines these days are plastic and can be set to go off with a very small disturbance, they are hard to clear. Second, the pressure of many of Kuwait's oil deposits is very high, as much as 15,000 psi, which is over 1,000 bar pressure. Actually, some wells sunk in the 1940s still flow from natural pressure, which is remarkable.

The spectacle of the burning oil wells raised many fears. Many dire predictions were made at that time as to the potential environmental effects. These included:

1) Global cooling via the nuclear winter hypothesis; this was quickly laid to rest.

2) Modification of global and regional weather patterns, including interruption of the Indian monsoon.

3) Regional cooling and heating.

4) Regional precipitation modifications, including precipitation amounts, acid rain and black rain.

5) A large increase in the release of greenhouse gases.

Other concerns included:

1) Health effects on local populations and animals, both from the emission and subsequent inhalation of toxic gases, together with the respiratory threat from high concentrations of submicron-sized particles, especially carbon particles resulting from incomplete combustion (which might have toxic metal species bonded to their surface) and also salt particles from the brine in the oil fields.

2) Potential ground-water contamination from the huge oil lakes around some of the wells.

3) The deposition on land and sea of large soot particles and unburned oil droplets, coating and possibly killing food-chain elements and also, possibly, depositing toxic amounts of metal species, particularly those containing nickel and vanadium.

What are the facts? I must emphasize here that many of the following results are preliminary.

It was initially thought that fires would take up to two years to extinguish, even longer according to Red Adair in April 1991. In fact, there seems to have been

quite a steep learning curve among the 80% of the world's fire-fighting teams, together with some friendly competition using new technologies including jet engines mounted on tanks to blow the fires out, and liquid nitrogen to displace oxygen, suffocating the flames. The result was that the rate at which the fires were extinguished climbed from one every few days in the early weeks to seven a day by October[9]. The fires were all put out in just over eight months, with the last well being capped on November 6th, 1991[10].

Initially, the wells were spewing oil at a rate of about 4.4 $\pm$ 0.6 million bbl/day[11-15], close to the daily imports of the USA (slightly greater than 5 million bbl/day), together with 35-50 million m^3 natural gas/day (1.3-1.8 bcf/day). Over the eight and a half month period of the fires, an estimated 90 million bbl were burned or spilled onto the land (this is about what the USA uses in 50 days)[16]. Early estimates of the amount of oil being lost were about 2.5 million bbl/day[17]. These estimates were based on the production capacity of the wells, and were almost certainly too low as they are based on the production capacity after the oil has been valved through the tree at the well head, thus reducing the pressure, and most of the trees were blown off. The long-term uncontrolled flow of oil from the wells may have caused considerable damage to the reservoirs and certainly has caused some. One problem is the loss of pressure in many of the fields, due to the loss of natural gas; this constitutes an economic loss since it will necessitate more pumping in the future. Some of the wells were observed spewing steam, suggesting that formation-water and/or ground-water was mixing with the oil; this is most probably due to water coning in the vicinity of the well (in most formations, there is a bottom layer of water, then a layer of oil, and then a gas layer which serves to pressurize the reservoir). These effects, together with gas migration, relative permeability reduction, and other irreversible petrophysical effects within the reservoir could have the result that a significant portion of proved reserves may become unrecoverable.

The amount of carbon dioxide (CO_2) being formed in the early months was about 1.8-1.9 million tonnes/day, which is about 2.4% of daily worldwide emissions of carbon dioxide from fossil fuel and biomass burning[12,13].

There were, and are, two major environmental concerns:

1) the effects of the smoke, with all the combustion products from the oil; and

2) the effects of the oil droplets from unburnt oil which coated the land, creating large oil lakes close to the fields and resulting in a fair amount of oil being deposited further afield, in southern Kuwait, northern Saudi Arabia and the Gulf itself, adding to the effects of the deliberate oil spills; the total amount of oil deposited this way could be as high as 90 million bbl.

Let's look at the smoke in a little more detail. Initially, there was some worry that the smoke might rise to the tropopause (which over Kuwait is at about 13,000 m) and thus enter the stratosphere. This would have led to a stratospheric dispersal around the globe. These fears proved unfounded as the smoke was never detected above 6,000 m and was generally confined to the well-mixed boundary layer with a maximum height of around 4,000 m (Figure 2)[18]. Some small amounts of smoke

were observed in the upper troposphere as far away as Hawaii and Wyoming, but this was not significant[19-21]. During the first few minutes of emission, material in a smoke plume rises rapidly, driven mainly by the heat in the burning oil. Assuming that each burning well is a heat source of 500 MW[22] (the actual value of each burning well as a heat source was probably only half this on an average basis), it can be calculated that the plume should reach a height of 1-2 km under stable winter conditions and a height of 3 km in the summer[22]. After the initial rise of the plumes, they spread out and merge. The smoke generally had a southerly drift due to the Shamal, a north-westerly wind which blows for most of the late spring and summer. This had the effect of protecting Kuwait City from much of the smoke, since the majority of the burning wells, particularly those which produce hydrogen sulfide (H_2S) were south of the city.

Returning to the smoke plumes, a further slow rise, termed "self-lofting," can and does occur through solar heating[22], as the smoke is an efficient absorber of short-wave visible radiation, although the smoke was optically far whiter than expected (albedo 0.5-0.6 cf. JP-4 fuel pool fires with albedo = 0.3)[21]. The predicted and actual rise of the smoke remained low compared with the typical height of the tropopause over Kuwait, with most smoke remaining below 3 km. A small fraction lofted as high as 6 km in 24 hrs, but no smoke was seen to go higher after 48 hours[21]. Often, a marked vertical wind shear was observed with, for example, the lower part of the plume being transported south-east down the Gulf, with the upper part moving over Iran[11]. One result of solar heating of the plume is that the plume is warmed. This has two effects: first, that the plume tends to remain concentrated as winds converge on the plume while it is rising and, second, the surface is cooled under the plume. Surface temperatures were depressed by up to 10°C beneath high smoke concentrations within about 200 km of the source, and by as much as 20°C under the plume close to the wells[11]. In fact, Bahrain had its coolest May in 35 years, about 4°C below normal. Sunlight was reduced to near night-time levels when thick smoke was overhead. The irrigated agricultural region around the village of Al-Wafrah, close to the southern border, which had previously produced an abundance of vegetables and fruits, including cucumbers for export to Paris, has been declared dead for three reasons:

1) because the village lost its water supply;

2) there was sufficient lack of light from the smoke plume to almost totally curtain photosynthesis on many days; and

3) the produce outside greenhouses was coated with oil drops[14].

How big were the fires? The heat release has been calculated by Lawrence Radke of NCAR and Peter Hobbs of Washington University to be about 5×10^{14} Joules per hour[21]. This is about half the heat release sustained for more than 30 days by the forest fires in Yellowstone National Park a few years ago.

From March to August, various aircraft sampled the plume at various distances from the source. They found the following:

1) Ninety-five percent of the carbon emitted by the fires was in the form of carbon dioxide together with 1% carbon monoxide (CO), 2.4% non-methane organic vapours, 0.35% methane (CH_4), 0.45% soot, and approximately 0.65%

as organic particles[23]. The low soot content of about 2,500 tonnes/day (Peter Hobbs suggests about 3,500 tonnes /day[12,21]) was much less than expected and is due to the high efficiency of combustion of the oil because of its gas content. The low percentages of methane and carbon monoxide are also a result of the efficiency of combustion in a process that visually appears to be a rather inefficient one.

2) About 2% of the mass of the fuel burned is emitted as sulfur (in the form of sulfur dioxide [SO_2]); however, aircraft measurements of both sulfur dioxide and nitrogen oxides (NO_x = NO + NO_2) showed that they were both rapidly lost in the plume (about 50%/hr for the first few hours of plume travel)[12,21,23]. These gases are presumably scavenged primarily by the soot, with the sulfur dioxide being subsequently converted to sulphate. These oxides, when dissolved in water, are the cause of acid rain; some episodes of rain up to ten times more acid than usual were observed in Saudi Arabia; however, the rain was fairly benign compared with acid rain episodes in parts of central Europe and the USA and is not expected to cause any problems. Very little hydrogen sulfide, which is found in the natural gas and which is more poisonous than hydrogen cyanide (HCN), was found, again due to the efficiency of combustion of the oil.

3) The hydrocarbon vapours appeared to be similar in composition to the oil itself, suggesting that the majority of these hydrocarbons came from oil drops in the plume[23]. The concentration of polycyclic aromatic hydrocarbons, many of which are known carcinogens, was very small.

4) The smoke particles in the composite plume were composed mainly of salt, soot, sulfate and heavy hydrocarbons in comparable amounts[23]. The salt and sulfate precipitated quite rapidly, but a proportion of the soot, consisting of very small inhalable particles was dispersed only slowly, and some episodes of black rain were observed as far away as Turkey and Pakistan. Contrary to some predictions, the smoke particles were found to be very effective cloud condensation nuclei (presumably because of the metal species and salt adsorbed on the surface of the particles); this obviously acts to reduce the tropospheric lifetime of the smoke. The generation of convection clouds was observed close to the plume, which indicates that at least some of the smoke was being scavenged fairly quickly.

5) Peak concentrations of carbon monoxide, sulfur dioxide, nitrogen oxides and ozone (O_3) in the smoke plume at 130 km from the fires were everywhere less than the U.S. national ambient air-quality standards, with the exception of sulfur dioxide which occasionally exceeded the standards. Now, while these observations are dependent on meteorological conditions (primarily wind speed and mixing), they clearly provide an indication that beyond the local region, these pollutants do not constitute a hazard, even if the elevated smoke plume is lowered to the surface[12,21,23].

Interestingly enough, airborne measurements in the densest part of the smoke plume at about 120 km from the burning wells in late March 1991, showed typical particulate mass densities of 500-1,000 $\mu g\ m^{-3}$ [11]; by comparison, particulate mass densities, mainly soot with adsorbed sulfuric acid (H_2SO_4), reached a continuous

maximum at ground level of over 1,600 $\mu g\ m^{-3}$ for three consecutive days during the December, 1952, smog episode in London[24], with a one hour maximum of over 4,400 $\mu g\ m^{-3}$ [25]. Mixing ratios of 100-500 parts per billion by volume (ppb_v) of sulfur dioxide were also found in the plume, with a maximum concentration of 1,000 ppb_v being observed on one occasion 15 km south of the Burgan field[12]. This is rather less than the concentration of over 700 ppb_v observed over two days, with a peak one hour concentration of 1,300 ppb_v in the same 1952 London smog episode[24]. It should be pointed out that the four-day smog in London in December of 1952 resulted in over 4,000 excess deaths[24].

It seems reasonable to conclude that regional environmental effects of the burning oil wells, while detectable, are marginal in terms of environmental damage. But what about local effects in Kuwait and northern Saudi Arabia? These have been, and some will continue to be, quite severe. Kuwait City itself seems to have escaped the worst of the airborne pollution because of the Shamal winds. From May through July, the concentrations of total particulate mass in Kuwait City did not exceed local historical levels, but did exceed the U.S. ambient air-quality 24 hr standard[26]. The fraction of particulate mass due to the fires is not known. The ground-level concentrations of sulfur dioxide, nitrogen oxides, carbon monoxide, and ozone did not exceed U.S. ambient air-quality standards over the same time period[27]. The atmospheric particles had concentrations of polycyclic aromatic hydrocarbons and metal species containing nickel, chromium and vanadium that compare to urban-industrial areas in the USA, Europe and Japan. Tests have shown that the particles were not very mutagenic[27].

To the east and south of Kuwait City it is a different story. In this region, in addition to the black smoke, there was a continuous fall-out of oil droplets within 50 km or so of the wells. In fact, as an example, those persons remaining in the oil company town of Al-Ahmadi on the east of the Al-Maqwa field were constantly coated in a film of grimy oil every time they ventured outside[14]. Crops, grass and palm trees were covered with a thick film of oil, and this (coupled with the lack of light) caused many of the plants to wither. We do not know whether toxic metals in the oil will cause even more damage. Many animals died from a combination of eating oil-coated plant life together with general environmental stress, such as the loss of sunlight. Chickens, because of the lack of light and general environmental stress, would not lay eggs. There were a number of short term episodes of very high sulfur dioxide concentrations reported when the plume happened to touch the ground. For instance, Mina Saud in northern Saudi Arabia reached a maximum one-hour level of 1.03 ppm_v[28], which is nearly four times the allowable limit.

The major environmental damage is likely to come from the vast oil lakes. During 1991, tens of millions of barrels of oil flowed like black satin, releasing gases, including a fairly large amount of hydrogen sulfide. These oil lakes swallowed plants, lizards, gheckos, insects and small mammals. Tens of thousands of migrating birds, particularly cormorants, mistook the oil for water, especially in the low light. These lakes do not seem to have been a high priority for the Kuwaitis. Much of this oil could have been sucked up in the early days and processed, albeit at an economic cost; but now the more volatile fractions have evaporated, leaving behind a thick goo containing all the toxic residues such as heavy metal species. Even if this is ploughed into the desert, this land may remain toxic, because of heavy-metal contamination, for many generations. There is also the possibility that airborne metal species settling on the ground have contaminated both

soil and vegetation. Sheep, goats and camels grazing on the land will accumulate these metals, thus eventually affecting the human population. Ground water contamination may also prove to be a problem in some areas.

One other environmental problem that may be important is that where no roads existed thousands of vehicles during the war loosened the desert's thin protective crust, the armour of pebbles over naturally compacted sand. This may result in intensified sandstorms, whipped up by the Shamal winds in spring and summer, leading to the formation of shifting dunes that could block roads and airports and engulf farms[29]. Paradoxically, where the Kuwaiti smoke cloud hung over the desert, falling oil and soot have congealed with the sand to form a brittle crust.

In summary, while global environmental effects are negligible and regional environmental effects small, local effects may prove severe for years to come.

References

1. "The Environmental Aftermath of the Gulf War." Report of the Senate Committee on Environment and Public Works, Gulf Pollution Task Force (Senators Q.L. Burdick, J.I. Lieberman and J.L. Chafee). Prepared by the Congressional Research Service, Environment and Natural Resources Policy Division, American Law Division and Science Policy Research Division in support of the Gulf Pollution Task Force. p.CRS-29, March 4, 1992.

2. Ibid p.CRS-5.

3. Id.

4. Id.

5. The figure of 732 wells damaged is given in the report of the Senate Committee on Environment and Public Works: Gulf Pollution Task Force entitled "The Environmental Aftermath of the Gulf War. Executive Summary and Recommendations" by Senators Q.L. Burdick, J.I. Lieberman and J.L. Chafee. March 5, 1992. The figure of 749 is given on p. 14 of the Report to Congress, United States Environmental Technical Assistance from January 27 - July 31, 1991, p. 14, prepared under public law 102-27, Section 309, by the Environmental Protection Agency in conjunction with ten other U.S. government agencies. The difference between the two numbers appears to be that 732 wells were damaged sufficiently to flow freely or be on fire, and the remaining 17 had leaky well-heads.

6. The figure of 610 wells set ablaze is given on p. 14 of the Report to Congress cited in note 5. A figure of 613 was quoted in the Gulf Times in November 1991 (Dr. Amin Meshal, personal communication). A figure of 625 is given in a draft paper prepared by MEPA and KFUPM (see note 17). The figure of 650 is given on p. 2 of the executive summary of the report of the Senate Committee on Environment and Public Works: Gulf Pollution Task Force (see note 5).

7. Report of the Senate Committee on Environment and Public Works: Gulf Pollution Task Force, op cit supra note 1 p.CRS-5.

8. Personal communication, Dr. Peter C. Hill, Assistant Director, National Oceanic and Atmospheric Administration, Office of the Chief Scientist, Gulf Program Office, Washington, D.C.

9. "Environmental Crisis in the Gulf: The U.S. Response" pp. 4-5, by the U.S. Gulf Task Force.

10. Parmelee, J., "Kuwaiti Emir Snuffs Out Last Iraqi-Lit Oil Fire," Washington Post, Nov. 7, 1991, at A1.

11. Johnson, D.W., C.G. Kilsby, D.S. McKenna, R.W. Saunders, G.J. Jenkins, F.B. Smith and J.S. Foot, "Airborne Observations of the Physical and Chemical Characteristics of the Kuwait Oil Smoke Plume," Nature 353, 617-621 (17 Oct. 1991).

12. Hobbs, P.V. and L.F. Radke, "Airborne Studies of the Smoke from the Kuwait Oil Fires," Science 256, 987-991 (15 May 1992).

13. Earle, S.A., "Assessing the Damage One Year Later," National Geographic 181, No. 2, 122-134 (Feb. 1992).

14. Canby, T.Y., "After the Storm," National Geographic 181, No. 2, 2-35 (Aug. 1991).

15. Report of the Senate Committee on Environment and Public Works: Gulf Pollution Task Force, op cit supra note 1 p.CRS-6.

16. "Environmental Crisis in the Gulf: The U.S. Response," p. 4 by the U.S. Gulf Task Force.

17. "Environmental and Health Impact of Oil Burning in the Kuwaiti Oil Fields: Preliminary Assessment," Draft paper prepared by the Meteorological and Environmental Protection Administration (MEPA) of Saudi Arabia and the Research Institute, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia, and presented at the first meeting of the working group on oceanic cooperation in the ROPME sea area organized by the Inter-governmental Oceanic Commission of UNESCO (Paris, 12-14 June 1991).

18. Report to Congress, United States Environmental Technical Assistance from January 27 - July 31, 1991, p. 23, prepared under public law 102-17, Section 309, by the Environmental Protection Agency in conjunction with ten other U.S. government agencies.

19. "Why the Hush-Hush on War's Environmental Effects," Houston Post, 21 May 1991, p.9.

20. See note 23 in Hobbs, P.V. and L.F. Radke, "Airborne Studies of the Smoke from the Kuwait Oil Fires," Science 256, 987-991 (15 May 1992).

21. Radke, L.F. and P.V. Hobbs, "An Updated Briefing on the Kuwaiti Oil Fire Smoke Experiment," A part of Gulf Regional Air Monitoring Program, July, 1991.

22. Browning, K.A. et al., "Effects from Burning Oil-wells in Kuwait," Nature 251, 363-367 (30 May 1991).

23. "Answers to Some Commonly Asked Questions About the Kuwaiti Oil Fire Smoke," draft paper from the Office of the Chief Scientist, NOAA, 25 September 1991.

24. Williamson, S.J. Fundamentals of Air Pollution, pp. 265-269, Addison Wesley Publishing Co., 1973.

25. Waller, R.E. and B.T. Cummins, "Episodes of High Pollution in London 1952-66," in International Clean Air Congress Proceedings I, 228-231 (1966), London, England.

26. Report to Congress, op cit supra note 18, p.A-2.

27. Report to Congress, op cit supra note 18, p.A-3.

28. National Report on Oil and Air Pollution presented by the Kingdom of Saudi Arabia to an extraordinary Session of ROPME Council, Nairobi, Kenya, May 1991.

29. Holden, C., "Kuwait's Unjust Deserts: Damage to its Deserts," Science 251, 1175 (8 March 1991).

Figure 1. Kuwait Oil Infrastructure
(Source: United Nations)

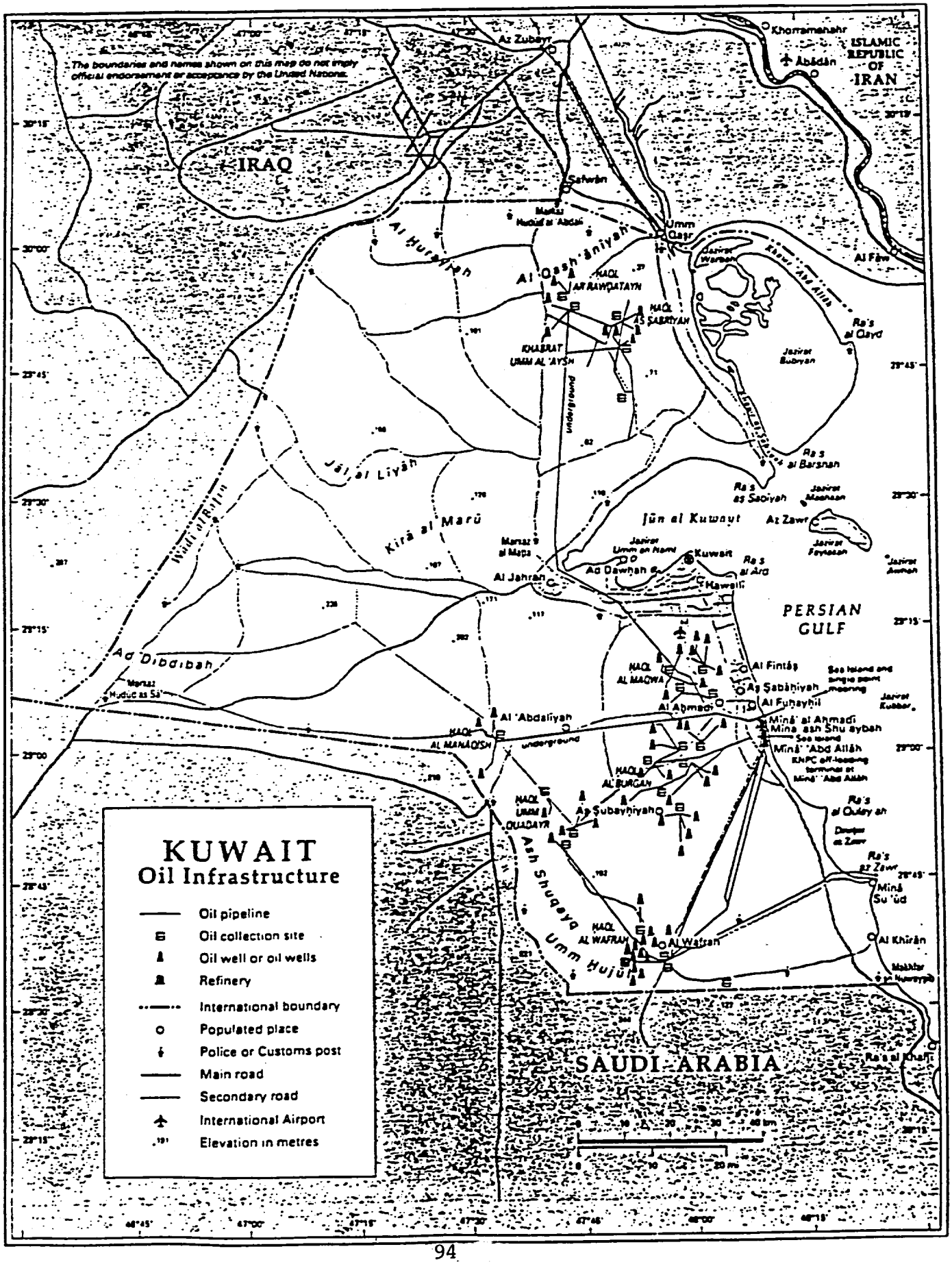
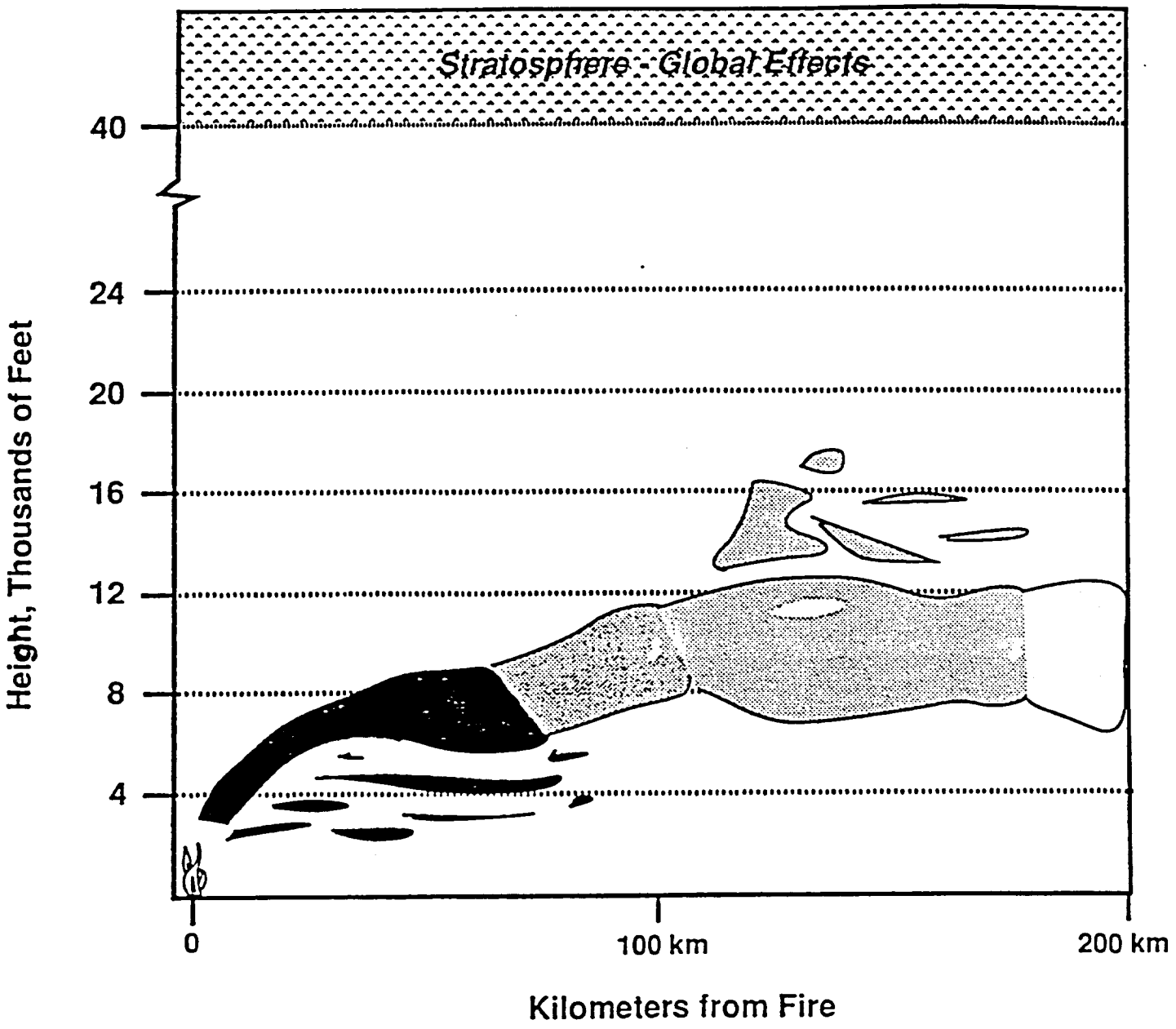


Figure 2:

Oil Fire Plumes



Observations:

- The plume does not rise into the stratosphere and therefore, global effects are not likely.
- The smoke plume is generally at heights between 1,500 feet and 13,000 feet.
- The smoke plume dissipates as it travels from the source.

Graphic: U.S. EPA

Data Source: NSF

ATMOSPHERIC MODELLING OF POLLUTION IN THE GULF AREA

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Introduction

In a large pollution event like the smoke produced by the oil fires in Kuwait, the use of mathematical models for forecast and assessment are important tools for scientists and decision makers in emergency planning. This presentation reviews three aspects of this issue. First, a general overview of the modelling basis and objectives is presented; second, the types of models available for application in such a situation are reviewed; and thirdly, an illustration of the results obtained with the Canadian Climate Centre/Global Climate Model (CCC/GCM) is given.

Modelling of Environmental Changes

Essentially, a mathematical model is a digital replica of physical, chemical or biological processes. Ideally, it should rely on fundamental laws of nature to reproduce the behaviour of evolving systems. In practice, some processes are often replaced by parametric formulations. Those greatly simplified treatments should be designed to reproduce faithfully the detailed process within the range of application. Unfortunately, some model elements may be poorly understood and yet need to be accounted for in the system to model. This situation creates weak links between processes within the model system.

For instance, a climate model brings together at least three fundamental processes:

1) electromagnetic radiation which is the ultimate source and sink of the climate system; it is also the aspect that is first altered by anthropogenic activities;

2) thermodynamics which describes the transformation of radiative energy into various forms of heat; and

3) dynamics which provide rules for the dynamics of the atmosphere or the ocean.

The early models had only loose connections between those three processes. Energy Balance Models (EBM) essentially describe the heat budget at the Earth's surface with very crude radiation. One-dimensional Radiative-Convective (1D-RC) models further allow for the evolution of the vertical structure of the atmospheric temperature. General Circulation Models, resolving many features of the Earth's surface and atmosphere, permit realistic simulation of most aspects of the atmosphere's meteorology and the Earth's climate. As the resolution of these models increases, the link between processes becomes tightly interlaced, providing a rapid response and better simulations of the atmosphere.

The numerical modelling activity is a direct result of advancing computer technology. A continuing improvement of computational speed and storage permits finer treatment of evolving processes. Computer power has been regularly improving at a rate of about 100-fold per decade. Although a new computer, installed in Montreal, permits calculations reaching 23 billion floating point operations per second, it is still insufficient to simulate global climate at a resolution better than 100,000 km^2. An alternative to that problem is the nesting of models operating at various spatial scales.

The main difficulty of merging different systems is due to large differences in the characteristic response of individual systems. For instance, the processes involved in large oil fires, such as in Kuwait, are mostly acting at the micro-scale level; ranging from seconds to hours. On the other hand, the atmosphere responds on a larger time scale from about half an hour to many months; and ocean response ranges from a month to thousands of years. Each of those time scales has corresponding spacial scales that are linked by the characteristic velocity of the transport within the fluid.

An atmospheric model of the GCM type may be viewed as a grid of points covering the region of interest. Each grid point represents some treatment of the surface energy fluxes determining the ground temperature and water budget. A column of atmosphere with a prescribed vertical resolution gives computational points in the vertical direction and treats radiation, vertical diffusion of tracers, clouds, temperature, and moisture. By connecting all columns with three-dimensional dynamics of the flow, those columns become a prognostic system where the evolution of the state can be studied and predicted.

Within each of those grid points, a parametric treatment of the unresolved processes is performed. If the cell is a land point then the ground is represented by several soil layers containing heat and moisture, and the appropriate fluxes. Snow can accumulate or melt, depending on conditions. A realistic topography affects the atmospheric flow. A vegetated canopy, with primary and secondary types of vegetation and corresponding soil characteristics, influences the moisture and the heat balance of the surface. The excess of surface water is carried in the runoff flow. Sensible and latent heat are computed through the surface boundary layer. If it is an ocean grid point, the current version assumes a shallow mixed layer (about 50m deep) where ice may form at the freezing point. In the atmosphere, cloud and precipitation may form. Radiative transfer accounts for absorption and scattering by air, H_2O, CO_2, O_3, CH_4, N_2O, CFCs, aerosols and clouds.

When all physical processes are acting simultaneously in the GCM, many feedback loops become active and the result of the evolving strongly depends on those interactions. An example of feedback is the classic case of temperature-snow albedo feedback. As the temperature warms, snow melts and the surface albedo is reduced, resulting in more absorption of solar radiation and a greater warming. Another important case is the soil moisture-temperature feedback: warming of the surface dries the ground and reduces evaporation and cloud formation, but increases solar heating and surface warming. The number of possible feedbacks is large and an essential part of physical-climatology is to evaluate and quantify their strength.

Types of Models Used in Kuwait Oil Fires

In the context of the Kuwait oil fires, two broad applications of models are forecasting and scientific analysis for assessment of smoke effects. Forecasting served in daily operation and evaluation of health hazard conditions for the population, workers and transportation. The second category of application is dedicated to the evaluation of smoke, and its transformation products on the surrounding ecosystem, on health and on climate.

Models are further divided in term of their spatial range: near-field, medium (hundreds of kilometres) to long-range (thousand of kilometres) and global (GCMs) scales. In each of those, several research groups around the world have done experimental simulations. Some of them have been presented at the "WMO Meeting of Experts on the Atmospheric Part of the Joint U.N. Response to the Kuwait Oilfield Fires" (Geneva, 27-30 April 1991). The following is a summary of their application.

Near-field Models were used to forecast actual exposures and their probability of occurrence by predicting the downwind concentration of smoke materials. Those models strongly rely on the conditions of the emitting sources and meteorology for their input data. The main inputs are: emission rate for individual wells and locations, heat release and combustion efficiency, chemical composition of gases and aerosols, oil-water mixing ratio, exit velocity and temperature, effective diameter of the ruptured pipes, effective plume rise, variation of the transport layer depth with time, wind field (three-dimensional; 3-D) data, and atmospheric temperature (3-D) data.

Medium and Long Range Models are based on Eulerian grid points or Lagrangian (trajectories) methods. They are used to simulate transport, dispersion and deposition of pollutants (acidic rain). Some of those models, often used for urban and regional air quality prediction, include chemistry and wet and dry deposition of aerosol. The drawback is the need for input meteorological conditions and pollution concentration observation as initial fields. This information is often difficult to obtain during crisis times.

Global Models (GCMs) are mostly dedicated to regional (> 1,000 km) and global impacts of pollution on climate parameters like temperature, precipitation, and winds, or events like the Indian monsoon. They require much less initial information than other types when run in climate modes. The main data required is the emission rate of the source and the composition of the smoke cloud. When run in a predictive mode (forecast) they require global data initialisation that are not so sensitive to eventual missing data near the source. Due to their resolution and global coverage, GCM simulations are costly, computerwise. In the next section we illustrate the results obtained from the CCC/GCM, version 2 model.

At the moment, there is not a single model that handles all the possible scales and products. Furthermore, the use of several models is valuable during the evaluation process due to the limited accuracy and complementarity of individual models.

Application of a Climate Model to Kuwait's Smoke from Oil Fires

The effects of smoke on the regional short-term climate variation have been investigated with the CCC/GCM2 (McFarlane et al., 1992; and Blanchet et al.). In this study, the concentration of soot in the smoke cloud is evaluated assuming a steady state between a constant injection rate and a prescribed removal rate. An "e-folding time" of 5 to 10 days is assumed to account grossly for removal processes by dry and wet deposition and horizontal advection. Here, soot concentration depends only on the volume of atmosphere being filled. This approach is a gross simplification of the actual situation. The concentration of soot ranges from 5 to 10 times the actual concentration and the shape of the cloud is maintained constant over the region (Fig. 1), with the highest concentration near the source and decreasing eastward with distance as the atmospheric volume increases. The main reason for these assumptions is to obtain a statistically significant signal and to reduce variability of the external forcing term. The objective is not to provide a forecast but to investigate how the atmosphere and the climate responds to this type of event. This experiment provides a scale permitting estimation of the consequences of the Kuwait oil fires on climate.

Two seven-month simulations (January to July) have been made, with a spatial resolution of 32 wavenumbers. The particular focus is on the links between smoke concentration, radiation and heat budget, surface and air temperature, snow melt, winds and monsoon activity. Smoke has been confined to the 700 to 900 millibar (mb) layers of the GCM, forcing the smoke to contour high terrain and mountains. The mean smoke optical depth was about 2 over Kuwait and decreasing with volume extending eastward from the source. Figure 1 shows the top of the atmosphere radiation balance watts per square meter (W/m^2), showing the heating due to soot in the lower atmosphere for the period of May-June-July of the model simulation. It is also a good indicator of the relative smoke distribution in this model experiment. The shaded area indicates the regions where the anomaly is significant at the 95% confidence level. Figure 2 shows the corresponding change of ground temperature for July. In the Kuwait area, the model indicates cooling of the order of 2 to 6°C. Downwind from the source, warming of about 2°C is found. Beyond about 1,000 km downwind from Kuwait, natural variability dominates and nothing can be inferred from this short simulation. It is important to note that these temperature changes are larger than actually expected due to the assumed large optical depths. This study is not a forecast of the actual situation but a means to investigate the relationships between smoke and meteorological parameters. It also indicates a trend and provides a scale for assessment purpose. Figure 3 shows a modelled change of surface pressure of 2 to 4 mb, downwind from Kuwait. The reduction of pressure over land generally enhances the monsoon activity and increases the probability of a tropical storm drifting inland as was the case in the Bay of Bengal at the beginning of the 1991 monsoon season. Figure 4 illustrates the change of wind speed (m/sec at the 850 mb level); we see a strengthening of the Shamal wind and south-westerlies over India. Finally, Figure 5 shows the change in precipitation, particularly in the Bay of Bengal; but, although substantial, the increase of precipitation does not exceed the natural variability and is not statistically significant.

Conclusion

Modelling is a valid scientific tool for investigating and evaluating the effects of atmospheric pollution. Many models are currently available for prediction of dispersion, transformation and impact of pollutants in the atmosphere. Generally, models are specialized for specific spatial and temporal scales. Each model has particular requirements for input data and initial condition for calculations. Some newer models, like the new Regional Climate Model (RCM) in development at the Université du Québec à Montréal, have nesting capabilities and provide a consistent, integrated and broader picture. It is generally advantageous to use several models to objectively assess a situation.

References

Blanchet, J.-P., R.K.R. Vupputuri, and H. Barker: Assessment of the short terms climatic effects of Kuwait oil fire smoke using numerical models. (In preparation).

McFarlane, N.A., G.J. Boer, J.-P. Blanchet, and M. Lazare, 1992: The Canadian Climate Centre Second Generation General Circulation Model and its Equilibrium Climate. (Accepted for publication in J. Climate).

WMO Meeting of Experts on the Atmospheric Part of the Joint U.N. Response to the Kuwait Oilfield Fires". Geneva, 27-30 April 1991. RDP 654.

Figure 1: Difference of the net radiation balance, in W/m^2, in upper left corner of map, between places with and without smoke. The hatched area indicates locations where changes are statistically significant. The isopleths of warming are indicative of the location and concentration of the smoke used in this simulation. The figure represents a mean value for June-July-August of a two year simulation.

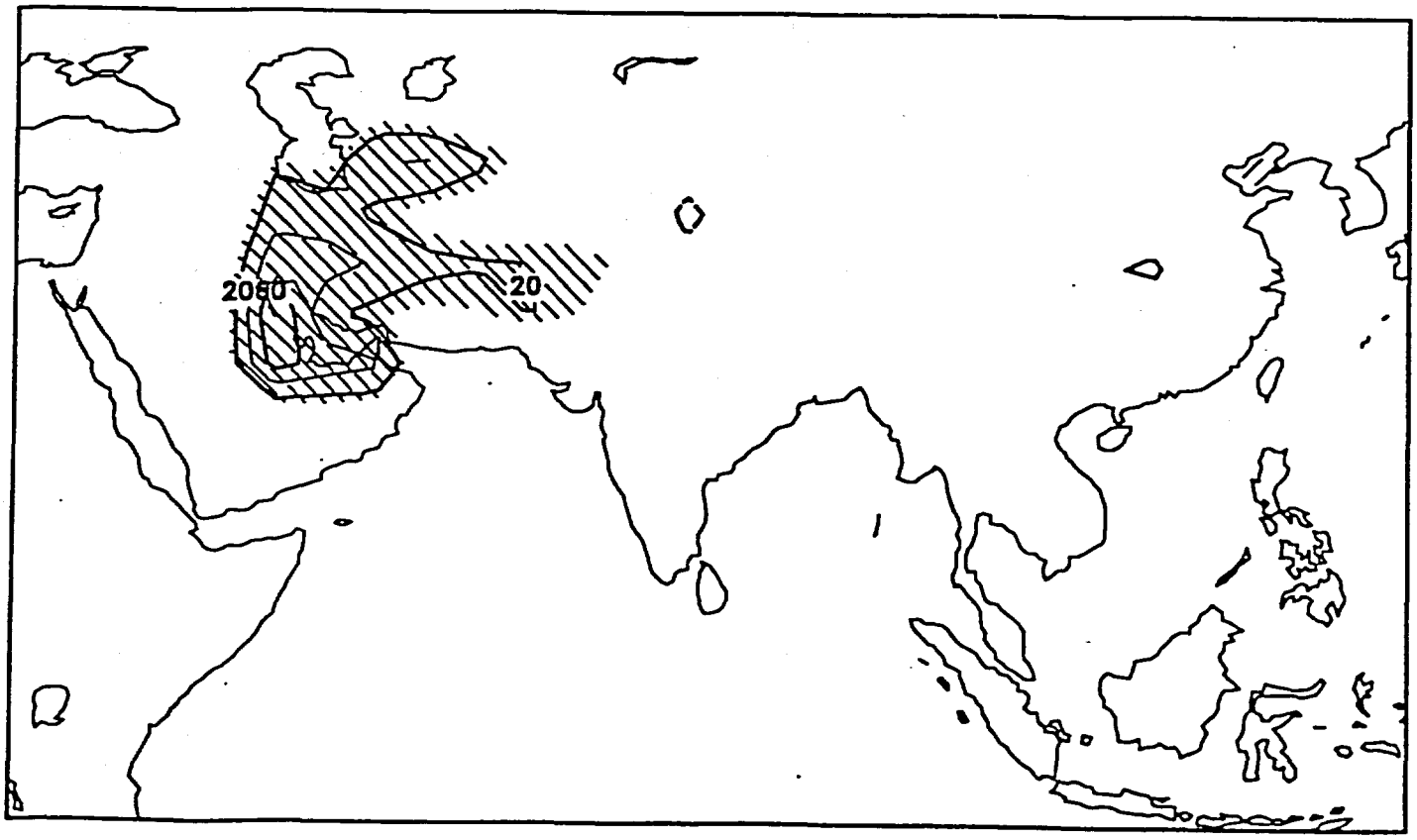


Figure 2: Difference of model ground temperature, in degree Celsius, between locations with and without smoke. A statistically significant cooling trend is observed near Kuwait, but warming dominates elsewhere. The time period is the mean of June-July-August for a two year simulation.

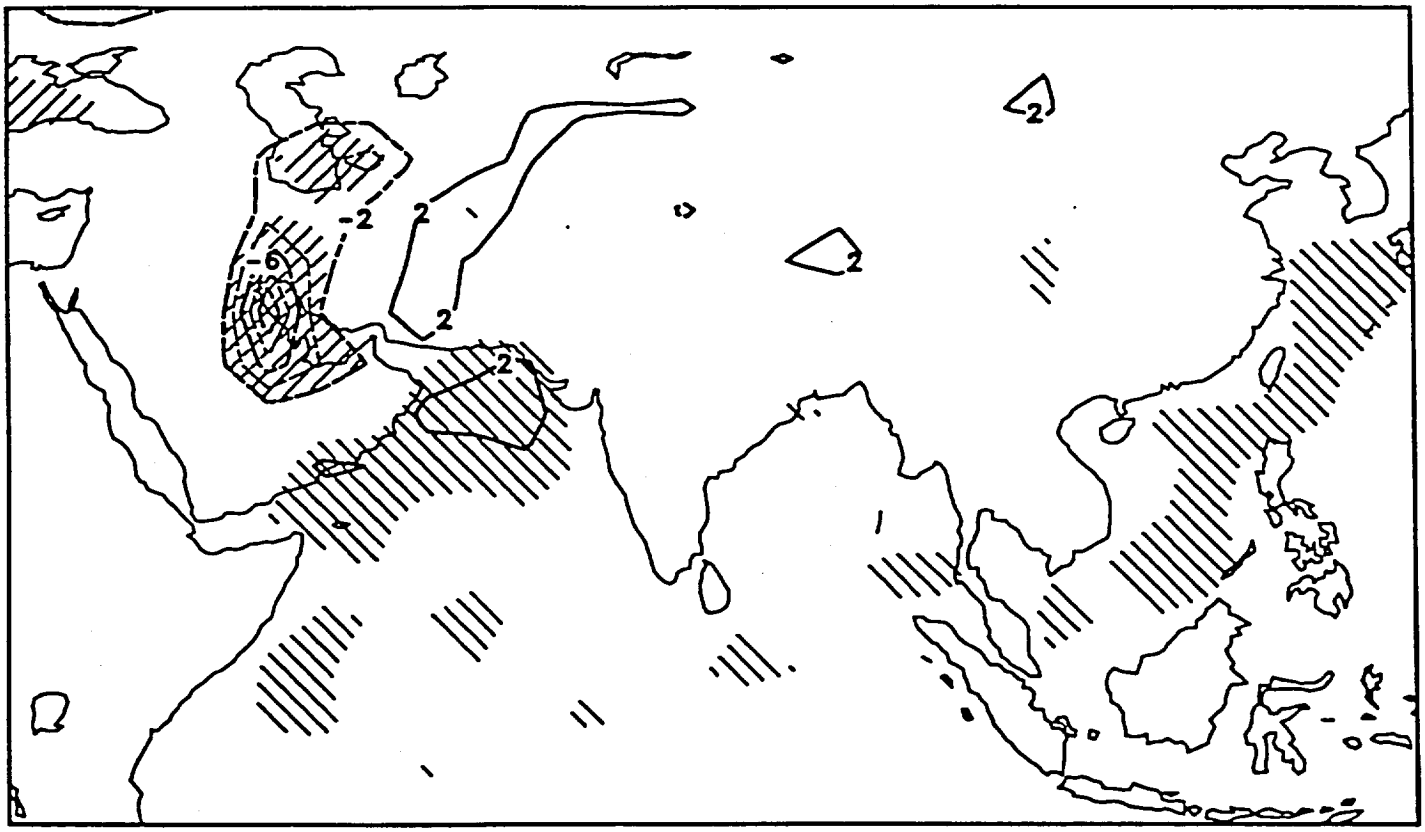


Figure 3: Differences of model surface pressure, in mb, between locations with and without smoke. A significant decrease in surface pressure is illustrated due to warming from smoke, downstream of Kuwait.

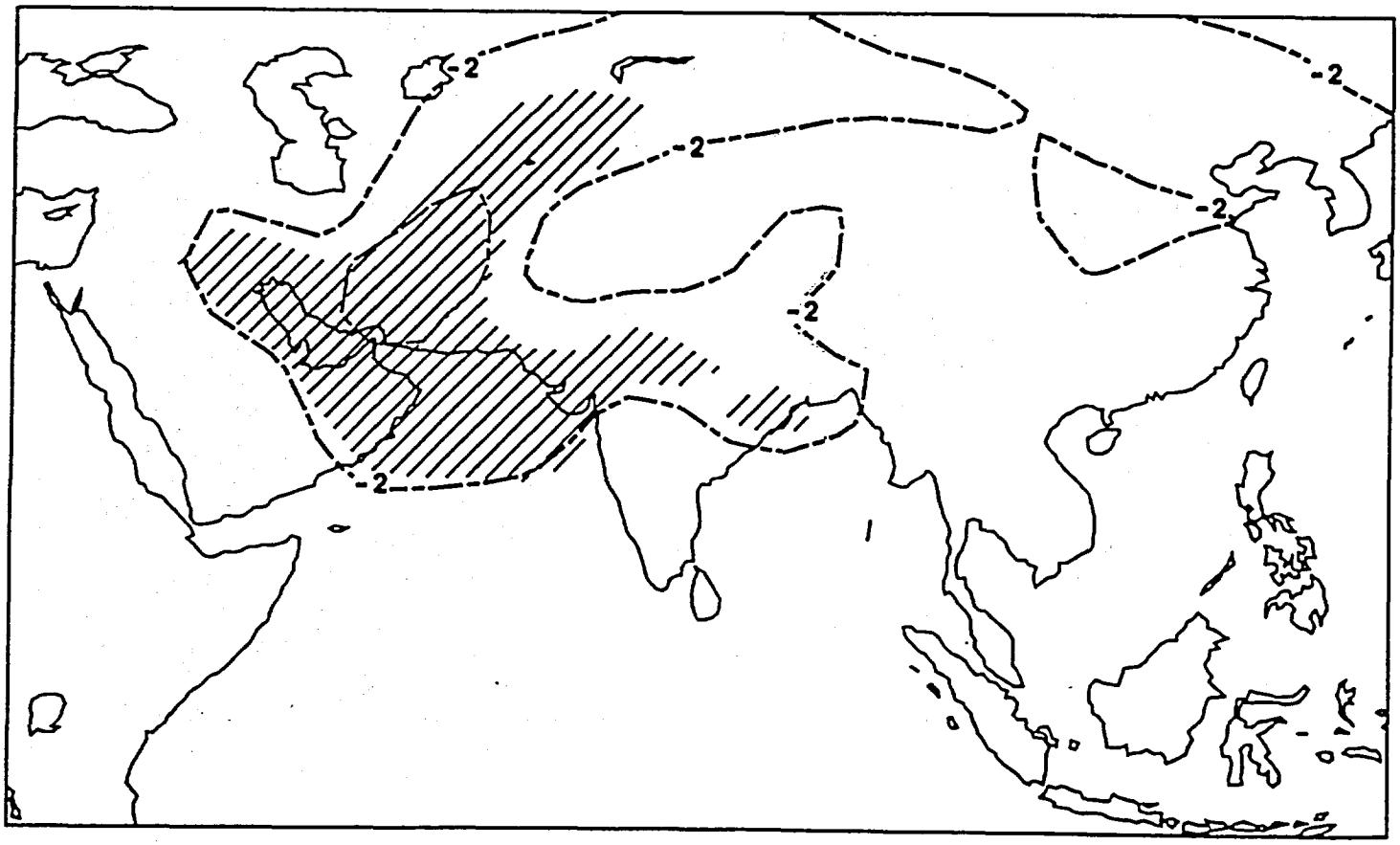


Figure 4: Change of mean wind speed at an altitude of 850 mg (1.5 km) associated with temperature changes shown in Fig. 2. Units are m/sec and the arrows indicate the direction of the change.

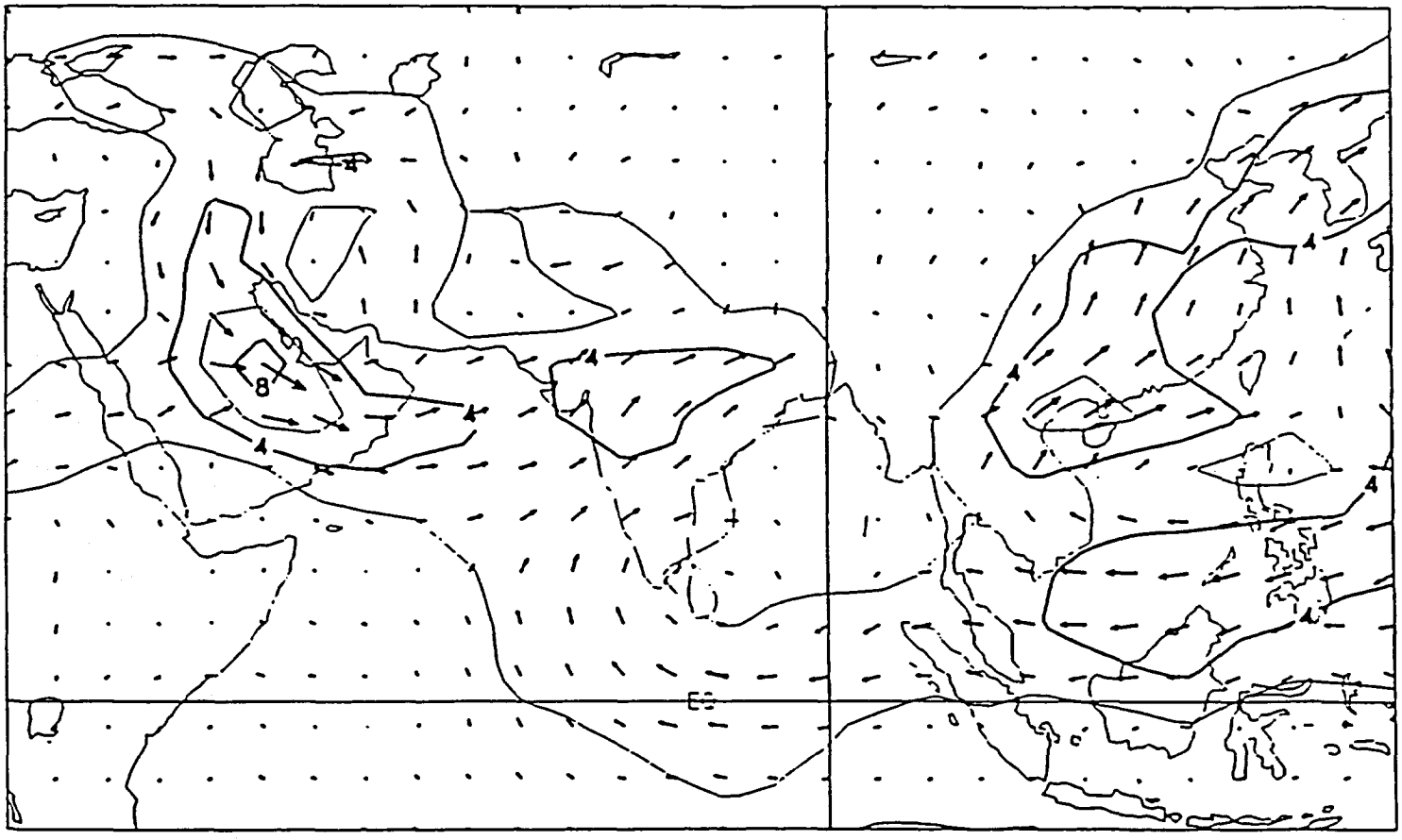
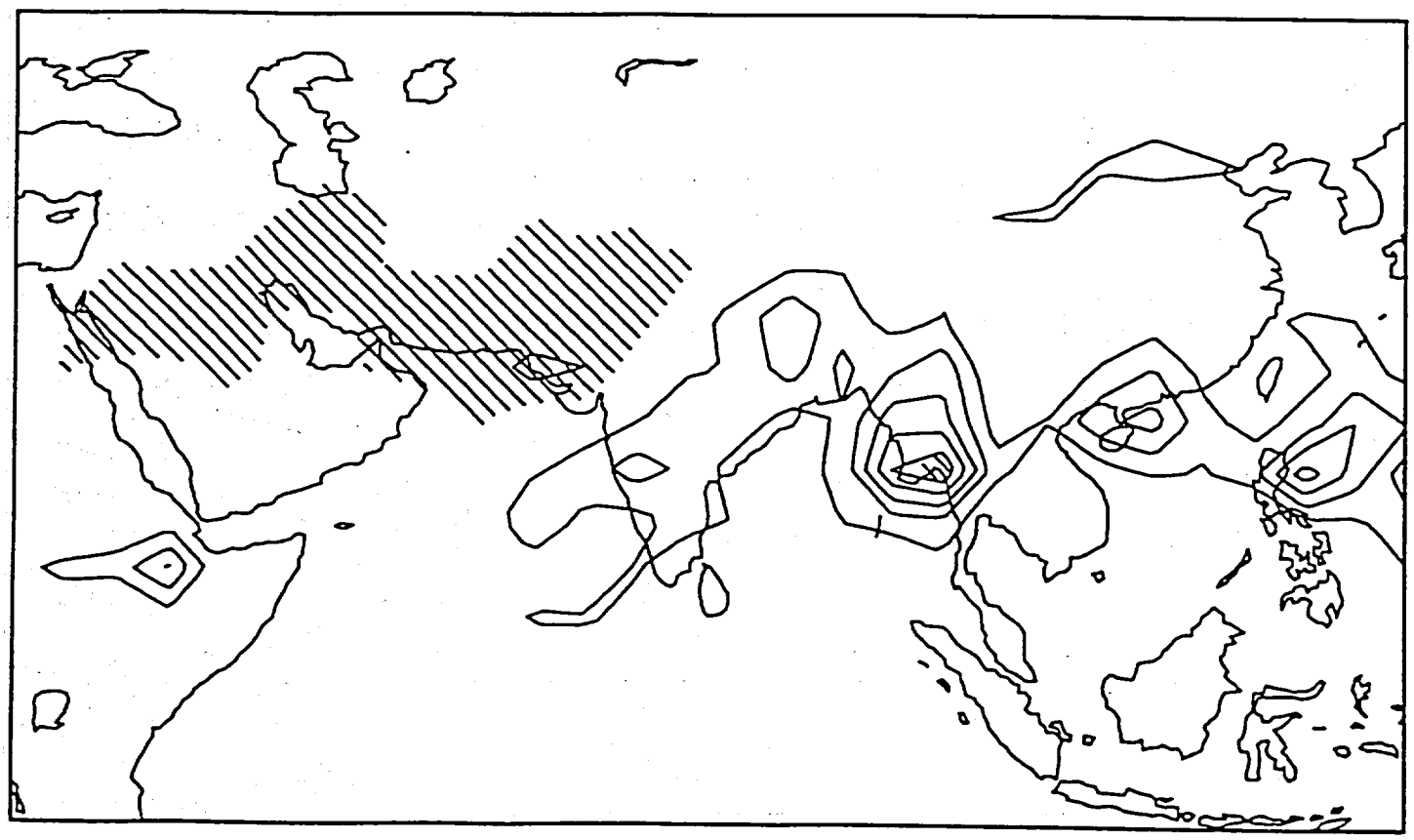


Figure 5: Differences of model precipitation rate, between locations with and without smoke, in units of 0.01 g/m^2/sec.



THE OIL-SPILL IN THE GULF AND ITS IMPACT ON THE MARINE ENVIRONMENT

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for the Arab States, ROSTAS

Abstract

The Gulf is located in a region that produces about one-third of the total oil production in the world and exports most of its oil to various destinations world-wide. The Gulf is always subject to oil pollution resulting from the exploration, production, loading and transportation of oil. Under normal conditions, the Gulf receives an estimated amount of more than one million barrels of oil per year (144,000 tonnes). Additional amounts of oil are released into the Gulf when accidents occur associated with tankers or oil wells. During the Iraq-Iran War, the release from oil wells resulted in the discharge of 1.5 million barrels of oil between 1983 and 1985. In the Gulf War, a total of 6 to 8 million barrels were deliberately released into the Gulf in a period of a few days. Tentative assessments indicated that the marine environment sustained potentially devastating damage, particularly along the Saudi coast and, to a lesser extent, along the coasts of Kuwait, Bahrain, Qatar and the United Arab Emirates. Regional and International efforts were made to control the pollution and the mitigation of its effects through the UN Interagency plan of action and the UNESCO/IOC Integrated Project Plan. The first phase of this plan is currently being implemented through a 100-day cruise by the USA R/V Mount Mitchel. Other phases, relevant to rehabilitation programs, will follow, provided that funds become available.

Introduction

During the 1991 Gulf War, the region was subjected to an unprecedented environmental catastrophe in which substantial amounts of crude oil were deliberately released into the sea and over 600 oil wells in Kuwait were deliberately set on fire. The Gulf, a semi-closed sea of limited area (240,000 km^2), received, in a very short period (8 days), the largest amount of oil (6-8 million barrels) ever reported in a single oil spill world-wide. This makes the Gulf pollution the worst in history. It may also be the first time that a war was waged against the environment, which resulted in devastating destruction in land, sea and air. In the pre-1991 war period, the Gulf used to receive, as pollutants, an average of 1 million barrels of oil per year. During 1991, the amount of oil dumped into the Gulf in a matter of days was equivalent to the amount that used to be discharged into the Gulf in 6 to 8 years, under normal conditions. The continuation of hostilities delayed efforts to stop the oil leakage, control the oil-spill and to start clean-up processes. Programs for the recovery of the affected habitats were also delayed because of the presence of a large number of unexploded mines planted along the coastal area which hindered access to polluted sites. During the crisis, it was extremely difficult to estimate the quantity of the oil released, identify its source, or monitor the path of the oil slick in the Gulf. Also, the lack of information on the dynamics of the water in the Gulf, local residual currents and the dominant water circulation made it difficult to develop reliable models for the prediction of the behaviour of the oil slick in the Gulf. In the early days of the oil crisis, the quantity of the oil released was overestimated as 11,000 barrels. This stimulated commercial firms all

over the world to flood the Gulf countries with offers in anticipation of contracting regarding pollution control and clean-up.

After the war was over, teams from national institutions and regional/international organizations/ agencies undertook a preliminary assessment of the damage sustained by the marine environment. Their tentative assessments show that the impact was severe in some of the coastal areas (especially along the Saudi coast), but mild in others. No apparent pollution was observed in the open sea. Intensive quantitative investigation is urgently required in order to properly assess the state of the marine environment. Short- and long-term programs were proposed within the framework of the UN Interagency plan of action for the rehabilitation of the Gulf environment.

The Basic Environmental Conditions of the Gulf

The Gulf (Fig. 1) is a shallow basin, rarely deeper than 100 m and its mean depth is 36 m. It extends 990 km along the NW-SE direction, with an area of 239,000 km and a volume of 8630 km^3 (Emery, 1956). The Gulf lies in an arid region where intensive evaporation exceeds scarce precipitation and river discharge. This enhances water exchange through the strait of Hormuz.

The Gulf is dominated by north-western wind all year, but south-eastern wind is occasionally observed in autumn and winter. Our knowledge of the water circulation is incomplete due to the lack or absence of data. Several authors (e.g., Schott, 1918; Koske, 1972; Brewer et al., 1978; and Hunter, 1985) have suggested the existence of a counter-clockwise circulation (Fig. 2) with an outflow of dense high-salinity water along the bottom of the Hormuz Strait. The outflow is balanced by surface influx of lower salinity water from the Indian Ocean through the Gulf of Oman. The surface inflow proceeds towards NW along the Iranian Coast.

The turn-over time (defined as the time required for all the water in the basin to come within the influence of the open boundary) was estimated by Hunter (1985) as 2.4 years and 230 days in the presence and absence of vertical mixing, respectively. The flushing time (defined as the time required to replace all the water in the basin by water from the open sea) was estimated as 3 years by Koske (1972) and 5.5 years by Hughes and Hunter (1979).

The tides in the Gulf are complex, with an average tidal range of one meter everywhere except at Shatt Al Arab in the north western end where it exceeds 3 m (Lehr, 1985). These large ranges cause strong currents which flow westward and northwestward during flood and in the opposite directions during ebb.

The environmental condition in the Gulf is harsh with a salinity variation from 37 parts per thousand at Hormuz to about 41 parts per thousand in the south-western and southern areas, and may reach more than 70 parts per thousand in some lagoons and embayments. The water temperature varies from 16°C in winter to more than 33°C in summer. The temperature range may even be greater in shallow lagoons. It was thought that these extreme and unfavourable conditions contribute to the fragility of the ecosystems of the Gulf and to the limitation of the diversity of its marine life. However, this is not true and the marine biota of the Gulf proved to be very rich (Nelson-Smith, 1984). The inhabitants of such environment have to adapt themselves in order to survive. As an example, coral-building reefs flourish at

optimal conditions of 25-29°C and 34-36 parts per thousand. These conditions are not fulfilled in the Gulf, but the coral reefs survive. This stimulated Kinsman (1964) to revise the old records on the tolerance by corals of extremes beyond the recognized ones.

Extensive mats of blue-green algae, sea-grass beds and patches of mangroves occur in the intertidal flats and in the shallow water of the Gulf. The Gulf is the habitat of a variety of endangered animals such as green turtles and dugongs. A wide variety of migrating birds use the offshore islands as breeding grounds.

The State of the Gulf Environment Before the 1991 Gulf War Oil Spill

The Gulf countries produced, in 1979-80, an average of 21 million barrels of oil per day (Table 1) which represents more than one-third of the global oil production, but consumed only 2.4% of the total oil consumption world-wide (British Petroleum Co., 1980). Accordingly, the bulk of the Gulf oil is exported to various destinations and this constitutes about 60% of the total amount of oil transported by ships around the world. Many oil-loading terminals are located offshore. In addition, most of the existing and planned oil-related industries are located in the coastal zone. All these activities, from the exploratory drilling stage to production, loading and transportation of oil, are chronic sources of pollution in the Gulf. There is no reliable information on oil spills from the above mentioned sources. An estimate only can be given from the statistics reported by Golob and Brus (1984). These authors indicated that, on average, a total annual spillage of 1.05 million barrels (144,000 metric tonnes) of oil were released into the Gulf during 1979 from different sources shown in Table 2. This represents 3.1% of the total oil pollution in the world.

In Table 3, a brief account is given on previous oil spill incidents in the Gulf during the period 1966 to 1985, for the sake of comparison with the catastrophic oil spill of 1991. The most outstanding pre-1991 oil spill that seriously affected the Gulf was the Nowruz spill of 1983-1985. One well in the Nowruz oil field, northwest of Kharj Island, was severely damaged in January, 1983, during the military hostilities of the Iraq-Iran War. An estimated 2,500 barrels of oil per day were discharged into the Gulf, in addition to about 70,000 cubic feet of gas per day. In March, 1983, another three wells were hit and set on fire, releasing 6,000 barrels of oil per day. These four wells were capped after 8, 26, 32 and 13 months. The total amount of the spilled oil from Nowruz field was estimated to be 1.5 million barrels (205,000 tonnes) during the whole period.

Very few data are available on the level of petroleum hydrocarbons in the water, sediments and biota of the Gulf. El-Samra and El-Deeb (1988) indicated that the average concentration of the dissolved and dispersed oil hydrocarbons in the zone of the shipping route, 22 μg/l, was generally higher than that along the Arabian Coast. The following levels of petroleum hydrocarbons were observed in the coastal waters of the corresponding countries: Oman: 7 μg/l; United Arab Emirates: 17 μg/l; Qatar: 2.5-11 μg/l; Bahrain: 5.7 μg/l; Saudi Arabia: 4.3 μg/l; and Kuwait: 31 μg/l. In the zones of offshore oilfields which are considered as fixed sources of oil pollution, the concentration of oil in water was more than 60 μg/l (Figs. 3, 4 and 5).

The average range of hydrocarbon content in the sediments at the northern, central and southern parts of the western region were reported to be 0.6-310, 0.5-3950 and 0.1-119 μg/g dry weight, respectively (Zarab, 1985; Fowler, 1988; Burns et al., 1982). The lower and higher concentrations in the above range represent the base level and the concentrations in sediments directly affected by oil input. There was no correlation between the oil content in the sediments and their grain size or their organic contents.

The concentration of petroleum hydrocarbons in biological indicators, such as the bivalves in different areas of the Gulf during 1980, ranged between 0.0 and 683 μg/g dry weight. The lower value of this range represents the level of organisms living in areas not directly exposed to petroleum input, while the upper range is the concentration in animals living in highly polluted areas.

The Catastrophic Oil Spill of 1991

One of the unfortunate consequences of the 1991 Gulf War was the deliberate act of terrorism against the environment. In this catastrophic spill, a sizable quantity of oil was discharged into a very limited area of the semi-enclosed Gulf over a short period, counted in days, thus causing devastating damage to the marine environment.

According to the best available information, an estimated 6-8 million barrels of crude oil were deliberately released into the Gulf during the period from 19-28 January 1991 (the dates of discharging and stopping the oil spill). The sources of this oil were traced to the Kuwaiti Sea Island Terminal and 8 Iraqi tankers located in the battlefield in the northwestern part of the Gulf. Nearly half the spilled oil came from the tankers and the other half from land sources and from the Sea Island Terminal. Until late April, 1991, an additional 3,000 barrels of oil continued to be spilled daily from the damaged tankers and ruptured pipelines. It was difficult to estimate the exact quantity of oil released into the Gulf because some of the tankers and the loading terminals were on fire, with considerably reduced the amount of oil released into the Gulf.

An oil slick was formed from the leaked oil and began to drift. On February 4, the slick was about 100 km long and 30 km wide. The movement and the fate of the slick was continuously monitored by response teams in Saudi Arabia, Bahrain and Qatar, with support from other countries and organizations. Two computer models developed at King Fahd University of Petroleum and Minerals (KFUPM), Saudi Arabia, were used to carry out relative trajectory analysis for the determination of the path followed by the oil slick as well as its fate (KFUPM, 1991). The first model (GULF-SLIK II) was used for the prediction of the short-term trajectory, using seven-day wind forecasts. The predicted trajectory of the oil slick was simulated during the period from 19 January to 10 April 1991 (Fig. 6). The predicted trajectory showed that the oil slick near Al-Ahmadi moved in the southeast direction, nearly parallel to the Saudi Arabian coast, under the influence of the northwest winds. The predicted and actual results were very close, indicating the accuracy of the predicted values (Table 4).

A second computer model (OILPOL) was also used for the prediction of the transport, fate and distribution of the spilled oil at the surface and subsurface layers during the period of 80 days (from January 19 to April 28, 1991). Figures 7-10 illustrate the surface and subsurface path and distribution of the oil slick after

20, 40, 60 and 80 days, respectively. The actual path and distribution of the oil slick at the surface during the period from February 6 to April 6, 1991, are shown in Figures 11-14. The results indicate heavy impacts on the coasts extending from Al-Ahmadi in Kuwait (Lat. 28 45′ N) to Abu Ali Island in Saudi Arabia (Lat. 27 10 N), where the oil slick was trapped in Musallamiyeh Bay, thus delaying its movement southwards. The impact of the spill was very severe in the Bay and to the north of Abu Ali Island, but was much milder than expected at coasts to the south of the island. After 80 days, the results showed that, of the initial volume of the oil spill, 45% hit the coastal region between Al-Ahmadi (Kuwait) and Ras Abu Ali (Saudi Arabia), 32% evaporated, 15% was suspended in the water column or sank to the seabed, and 7% remained on the sea surface. A small fraction of the oil, about 1%, dissolved in the water and may have a significant effect on the environment.

Response centres, formed during the crisis, gave absolute priority to safeguarding the industrial strategic facilities in the region against threats posed by the oil pollution. Urgent measures were taken to protect the desalination plants and the petroleum related industrial complexes which are vital to the region.

After the war was over (28 February 1991), efforts were made on the national, regional and international levels to initiate field assessments of the oil-impacted areas. Technical help was rushed to the region from different countries such as the U.S.A., the European community, the United Kingdom, France, Germany, The Netherlands, Canada, Norway, Japan and Australia. The timely response of the regional and international organizations (e.g., ROPME, UNEP, UNESCO/IOC, IMO, IUCN & WWF) was through the provision of consultants, financial support and training of local personnel.

This was a clear manifestation of the solidarity of the international community in dealing with such an environmental crises.

Ecologists believe that the marine environment of the Gulf was severely impacted by the 1991 oil spill and that its rehabilitation may need decades. The northwestern and southern parts of the Gulf are rich in ecosystems and habitats such as salt marshes, mud flats, coral reefs, sea-grass beds, mangroves, sand beaches, rocky habitats and kelp beds that support and high diversity of marine life. There are also locations of primary importance to the marine food chain, especially for shrimp and fish spawning grounds (Fig. 15).

Some fifty experts from twelve agencies and twenty institutions from within and outside the region used information collected by field surveys and remote sensing for the preliminary assessment of the damage inflicted by the oil spill on the marine and coastal environments. Their work shows that some of the above mentioned ecosystems/habitats were deeply affected by the oil spill. However, the extent of the damage in the long-run is not yet known. It was found that the Saudi Coast was heavily impacted by the oil. The mangroves, mud flats and salt marshes were oiled. Sand and rocky beaches were covered with oil strips of 10 to 100 m wide. Tar balls were reported in many locations along the Saudi and Bahraini coastlines. Two million migrating birds of 52 species were at risk and the reported death toll was more than 20,000. On the other hand, there was no evidence of coral contamination (King-Volcy, 1991). It appears that the benthic, pelagic and planktonic communities were not significantly affected.

The alarming reports on the high mortality among seabirds, together with the lack of trained personnel in this domain in the Gulf countries, stimulated UNESCO/ROSTAS to organize a workshop on the rescue and rehabilitation of oil-affected birds. The workshop was held in Bahrain during May, 1991. Its intensive program included field training of the clean-up and the medical and rehabilitative care of the contaminated birds. Fifty technicians from the Gulf States were trained by a highly qualified team of professionals who worked under the umbrella of the Tri-State Bird Rescue and Research Inc., U.S.A. By the end of the workshop, the trainees acquired the necessary skills to provide the medical care and clean-up to the oil-affected birds.

Some field observations were made in August, 1991, at 35 sites on the Saudi Coast (Fig. 16) and the results were compared with data collected in 1968 at the same sites by IUCN/MEPA. Surprisingly, it was found that the abundances of algae, birds and fish were greater in 1991 than in 1986. This makes scientists conclude that the effect of the oil spill was largely limited to the littoral zone while the shallow neritic zone appeared to be relatively unimpacted by the oil. In the intertidal zone, oil stains and asphalt lumps were found. Many oil clots and oil patches were observed on the bottom of the shallow subtidal (neritic) zone. Oil was also seen attached to or covering sea weeds and sea grasses.

Mangrove trees on the outer margin of the forest were heavily affected by oil and the colour of some of them was changed to light brown. Trees in the middle of the forest seemed to be healthy. The impact of oil on the mangrove trees cannot be determined at this stage, but further investigations are needed. Mangroves are not suffocated by oil. They would die when low molecular toxic hydrocarbons damage their excretory organs which get rid of the accumulated sodium and chlorine in their saps. This shows that low and middle molecular hydrocarbon fractions of the spilled oil were decomposed, evaporated or lost during natural processes. Accordingly, the acute toxicity of the oil was removed, but chronic toxicity may be the main threat to the marine life.

In general, no apparent significant decline was observed in the abundance of the major fauna and flora groups (King-Volcy, 1991). Sea surface in most of the investigated areas in August, 1991, appeared to be relatively clean, without any iridescent oil film, compared to the conditions in March, 1991.

The above discussed contradictory reports on the impact of the 1991 oil spill on the marine environment indicate that preliminary assessments were too hastily done. They were mainly based on visual qualitative observations rather than on quantitative actual measurements. Moreover, the proper assessment of the impact of the oil on the marine ecosystems needs long-term/monitoring programs.

The results of these surveys were presented in a comprehensive UN report that constitutes the scientific basis for a rehabilitation and restoration program to be presented to funding agents and donor countries. As of August 1, 1991, a total of US$ 2.6 million were donated: by Norway, $1.1 million; Japan, $1 million, and The Netherlands, $0.5 million. Canada provided the services of an aircraft with remote sensing capabilities to collect high-resolution environmental information on the coasts of Kuwait, Saudi Arabia, Bahrain and Qatar. The over-flights succeeded in obtaining high quality data on the region.

Programs for the Oil Impact Assessment and the Rehabilitation of the Gulf

The pollution crisis in the Gulf attracted the attention of United Nations Agencies as well as environmental institutions world-wide. UNEP organized a consultation meeting (Geneva, 5-6 February 1991) for representatives of the UN Agencies in order to coordinate the work of these agencies and to direct their diverse capabilities towards the rapid and efficient response to combating pollution in the Gulf. A series of meetings of UN specialized agencies resulted in the development of what is called the UN Inter-Agency Plan of Action (UNIAPA) which was adopted by ROPME. The Plan consists of three phases: survey, assessment and the action plan design (Table 5). The plan covers four interlinked areas: coastal and marine environments, atmosphere, terrestrial, and hazardous waste (Fig. 17). IOC of UNESCO was responsible for the marine aspects of the plan of action that include assessment and monitoring of oil pollution and coastal marine ecology, oceanographic observation, air/sea interaction and data processing and storage.

In order to carry out its share of the UN Inter-Agency Plan of Action, IOC of UNESCO convened a series of meetings to coordinate the action of different international/regional agencies, institutions and individuals for the formulation and the implementation of an Integrated Project Plan (IPP) in the Gulf region. The IPP was the outcome of efforts made by the working group consisting of local experts from the Gulf countries, mainly Saudi Arabia, Kuwait and Qatar, and outside consultants who either were involved in combating oil pollution or offered their technical assistance for the same purpose. The working group includes also international organizations and agencies who are cooperating with IOC in the studies on the WET component of the UN Inter-Agency Plan of Action. The IPP incorporates elements of the national plans of the Gulf countries for combatting oil pollution within their territorial boundaries. These elements are integrated with those of IOC on the strategy of short-term and long-term plans relevant to the pollution problems in the region. It also takes into account the remarks and comments made by IUCN and IAEA in their work programs.

A steering committee was jointly set up by IOC and ROPME to be in charge of the project. It was conceived to execute the IPP in three phases: immediate, short-term and long-term. The immediate phase was supposed to be carried out in December, 1991, through a cruise on the Qatari R/V Mukhtabar Albihar to collect basic oceanographic information as well as some assessment of the state of the environment. Unfortunately, this phase was postponed because the ship was not ready. The short-term phase began in late February with a survey cruise on board the R/V Mount Mitchel of the U.S.A. National Oceanic and Atmospheric Administration (NOAA), with the support and cooperation of IOC and ROPME. The cruise is scheduled to take 100 days for investigating the impact of oil on the shoreline and the near-shore areas, especially along the Saudi coastline. The principal objective of the cruise is the collection of information on the pollution problem and its effects on matters of direct concern to the decision makers and the general public, such as the safety of sea food resources and desalinated water. Other objectives include studies that ensure combatting pollution, mitigating its effects and facilitating the rehabilitation efforts. Among these are:

- the regional circulation patterns, especially in the northwestern part and in the vicinity of the Strait of Hormuz, in order to determine the path and the dispersion of the pollutants;

- the quantitative determination of the extent of the oil spill and its effects on key biological habitats and ecosystems such as the intertidal and sub-tidal muddy sediments, sea-grass beds, coral reefs, salt marshes, mangroves and migratory birds;

- the evaluation of the level of petroleum hydrocarbons and trace metals in the water column, sediments and biota;

- the study of water stratification patterns, in order to determine mixing processes.

The long-term study was planned in order to fully assess the extent of the damage sustained by the environment and to evaluate the natural recovery processes. It also should serve as a scientific basis for the development of computer models to predict the behaviour and fate of pollutants in the Gulf to improve future oil spill responses. The long-term program should be based on the results of the short-term studies, particularly in defining the sites that need extensive work. The visualized core elements of such a program are:

- study of the circulation pattern for the whole of the Gulf to be used for tracing the track taken by pollutants;

- evaluation/estimation of the residence time of build-up of pollutants in the water column and bottom sediments in the Gulf;

- determination of the flushing time of the Gulf in order to estimate the rate by which the Gulf gets rid of its pollutants;

- development of accurate models for water circulation and improved existing oil spill trajectory models for application in future spills;

- determination of the critical damage indices such as: disappearance of sensitive species, injury marks on corals, and sublethal stress indicators in bivalves. Also, the valuation of their recovery rates.

The short-term plan should be implemented over a period of at least 12 months. Some elements of the plan may be completed in a shorter time, but the 12-month period is necessary for the environmental measurements that should be made in the four seasons of the year.

The long-term plan could, in principle, last for as many years as possible, but for our purpose, a five-year period would be adequate.

The costs of the execution of the short- and long-term programs were not estimated as these depend on the exact duration of each plan along with the number of parameters to be measured.

Conclusion

The Gulf receives, under normal conditions, an estimated average of 144,000 tonnes per year of oil which is about 47 times the average amount received by a similar area of oceans of the world. Additional amounts are dumped in the Gulf when accidents occur. In spite of the release of these substantial amounts of oil into the Gulf, the average level of petroleum hydrocarbons in the water, biota and sediment is within normal levels and the sea surface water remains clean and free of any iridescent oil film. This may be attributed to the physical processes and the natural characteristics of the Gulf that tends to renew its water and get rid of its pollutants. The relatively short flushing time of the Gulf (about 4.5 years)

enhances the rapid replacement of its polluted water with cleaner water from the Indian Ocean. In addition, the pollutants are not given sufficient time to accumulate in the water column or in the sediments. These natural characteristics contribute to keeping the Gulf cleaner than expected. Even during the last oil spill crisis of 1991, with its massive oil spill (about 1 million tonnes) discharged in a matter of days, the water and sediments of the Gulf appeared less contaminated than was anticipated. The natural recovery of the Gulf environment may, hence, be probable. The rehabilitation programs should take this probability into consideration during the clean-up and restoration activities.

The Gulf area is one of the most rapidly developing regions in the world. The average investment per each kilometre of the coastline ranges between $20 and $40 million (Neuman, 1979). This means that the total investment in this region, which has a coastline of at least 2,000 kilometres, is between $40 and $80 billion U.S. dollars. If only 0.1% of this investment is directed to the environment, an amount of $40 to $80 million would be available for environmental research and restoration programs.

Research studies, as well as programs for combating pollution should primarily be formulated and implemented by the countries of the region, with outside assistance only where and when required. Regional contributions should be the main source of the funds needed for the implementation of the research and rehabilitation programs in the Gulf. Outside support should be subsidiary to the regional resources. The eight Gulf countries (Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates), upon initiative from UNEP, established, in 1979, the Regional Organization for the Protection of the Marine Environment (ROPME), with its headquarters in Kuwait. Its main objective is the protection and preservation of the marine environment of the region through an action plan which they agreed upon. To do so, ROPME launched, in the early 1980s, a monitoring and research program on oil and non-oil pollution, in addition to baseline studies. The program continued for almost ten years, but its outcome was not encouraging. The collected data are inconsistent and incomplete and are not commensurate with the funds spent. Had this program been executed properly, data would have been available for use during the 1991 oil spill crisis and as reference to the pre-'91 war conditions in the Gulf.

References

1. BREWER, P.G., A.P. FLEER, S. KADAR, D.K. SHAFER, and C.L. SMITH, 1978: Report A, Chemical oceanographic data from the Persian Gulf and Gulf of Oman. Report WHOI-78-37, Woods Hale Oceanographic Institutions, Massachusetts, U.S.A.

2. BRITISH PETROLEUM CO., 1980: BP Statistical Review of the World Oil Industry 1979. London, British Petroleum Co.

3. BURNS, K.A., J.P. VILLENEUVE, V.C. ANDERLINI, and S.W. FOWLER, 1982: Survey of tar, hydrocarbon and metal pollution in the coastal water of Oman. Mar. Poll. Bull. (13)7, 210-247.

4. EL-SAMARA, M.I., and K.Z. EL-DEEB, 1988: Horizontal and vertical distribution of oil pollution in the Arabian Gulf and the Gulf of Oman. Mar. Poll. Bull. (19)1, 14-18.

5. EMERY, K.O., 1956: Sediments and water of the Persian Gulf. Amer. Assoc. of Petr. Geol. Bull. 40, 2354-2383.

6. FOWLER, S.W., 1985: Coastal baseline studies of pollutants in Bahrain, UAE, and Oman. Proceedings of ROPME Symposium on Regional Marine Pollution Monitoring and Research Programmes, UAE University, Al-Ain, 8-11 December 1985; 155-180.

7. GLOBE, R., and E. BRUS, 1984: Statistical analysis of oil pollution in the Kuwait Action Plan region and the implications of selected world-wide oil spills to the region. UNEP Regional Seas Report and Studies No. **44**, 7-34.

8. HUGHES, P., and J.P. HUNTER, 1979: Physical oceanography and numerical modelling of the Kuwait Action Plan region. UNESCO Division of Marine Sciences, Report MARINF/27.

9. HUNTER, J., 1985: A review of the residual circulation and mixing process in the KAP region, with reference to applicable modelling techniques. UNEP Regional Seas Reports and Studies No. **70**, 149-174. 1991: Report of King Fahd University of Petroleum and Minerals on environmental impact of oil spill; unpublished report, 40 pp.

10. KING-VOLEY, N., 1991: Lessons to be learned from the environmental consequences of the Arabian Gulf War. WWF Discussion Paper, 22 pp.

11. KINSMAN, J.J., 1964: Reef coral tolerance of high temperatures and salinities. Nature (Lond.) **202**, 1280-1282.

12. KOSKE, P., 1972: Hydrographische Verhaltnisse im Persischen Golf Grund Von Beobach tungen von F.S. "Meteor" in Fruhjahr 1965 "Meteor" Forschung Ergebnisse. Gebruder Borntraeger, Berlin, A: **11**, 58-73.

13. LEHR, W.J., and H.M. CEKIRGE, 1984: Oil slick movements in the KAP region. UNEP Regional Seas Reports and Studies, No. **44**, 147-153.

14. NELSON-SMITH, A., 1984: Effects of oil-industry related pollution marine resources of the Kuwait Action Plan Region. UNEP Regional Seas Reports and Studies No. **44**, 35-52.

15. NEUMAN, L.D., 1979: The protection and development of the marine environment and coastal areas of the Kuwait Conference Region: The program of the United Nations System. In Proceedings of 1979 Oil Spill Conference, Los Angeles, CA, 287-291. Washington, D.C. American Petroleum Institute.

16. SCHOTT, G., 1918: Ozeanographie und Klimatology des Persischen Golfes und des Golfes von Oman. Annalen der Hydrographie und Maritimen Meteorologie **46**, 1-46.

17. ZARBA, M.A., V.C. ANDERLINI, P. LITERATHY, and F. SHUNBO, 1982: Distribution of petroleum hydrocarbons in marine sediments of Kuwait. Annual Research Report of KISR, 140-152.

Table 1: Average Oil Production mn bbl/day and Year First Exported

	1950	1960	1970	1975	1979-1980
Inner Region					
Iraq (1927)*	0.1	0.9	1.5	2.2	3.5
Kuwait (1946)	0.4	1.7	2.9	2.2	2.5
Saudi Arabia	0.5	1.3	3.8	6.8	9.5
(1938)	.03				.05
Bahrain (1934)	0.7	.05	5.4	.06	3.1
Iran (1913)**		1.1		5.4	
Outer Region					
Qatar (1949)	.03	.17			.51
Abu Dhabi (1962)	0	0	.36	.44	1.5
Dubai (1969)	0	0	-	1.4	.35
			-		
				.25	
Gulf of Oman					
Sharjah (1974)	0	0	0		.12
Oman (1967)	0	0	-	.38	.29
				.34	

* Some by pipeline to Mediterranean ports.
** Recently some to Outer Region.

Table 2: Total Estimate of Oil Pollution in the Kuwait Action Plan Region During 1979

Source	Estimate in Tonnes	Percent of Total
Natural seeps	13,815	9.6
Offshore production	32,162	22.4
Tanker transport	82,032	57.1
Non-tanker accidents	1,717	1.2
Coastal refineries	1,347	0.9
Atmospheric fallout	396	0.3
Coastal municipal wastes and coastal non-refinery wastes	4,911	3.4
Urban run-off	2,456	1.7
River run-off	4,909	3.4
TOTAL	143,745	100.0

Table 3: Major Oil Spill Accidents in the Gulf in the Period Between 1966 and 1980

Year	Location	Tonnes spilled	Type of oil
1966	24 59'N, 51 37' E	13,000	Qatar Crude
1970	26 48'N, 49 54' E	14,000	Arabian Crude
1971	26 50'N, 53 20' E	14,000	Crude
1974	28 44'N, 48 28' E	5,000	Crude
1974	28 32'N, 48 59' E	1,000	Crude
1980	26 12'N, 50 38' E	1,000	Bunker oil
1980	26 06'N, 50 30' E	2,750	Undetermined
1980	27 50'N, 49 40' E	14,000	Crude
1983-1985	near Kharj Island	205,000	Crude

Table 4: Actual and Predicted Oil Movements in the Gulf Using GULFSLIK II

Date (1991)	Actual Movement		Predicted Movement	
	Latitude	Longitude	Latitude	Longitude
February 8	27° 31'	49° 00'	27° 38'	49° 28'
February 9	27° 29'	49° 18'	27° 36'	49° 31'
February 10	27° 19'	49° 19'	27° 31'	49°40'
February 11	27° 25'	49° 20'	27° 26'	49° 45'
February 12	27° 24'	49° 21'	27° 16'	49° 52'
February 13	27° 19'	49° 22'	27° 12'	49° 55'
February 15	27° 11'	49° 30'	27° 08'	49° 58'
February 16	27° 10'	49° 30'	27° 09'	49° 56'
February 18	27° 09'	49° 30'	27° 12'	49° 52'
February 19	27° 08'	49° 30'	27° 11'	49° 51'
March 9	27° 06'	50° 39'	27° 01'	49° 49'
March 10	26° 56'	50° 57'	27° 00'	49° 51'
March 13	26° 50'	50° 43'	26° 54	49° 58'

Table 5: Activities of the UN Interagency Plan of Action and the Responsible Organizations/ Agencies

Areas/Activities	Responsibility
a) Coastal and Marine Environments:	
- Oil pollution response and clean-up operations	IMO
- Oil pollution assessment and monitoring, water quality	IOC/IAEA
- Oceanographic observations and data support	ROPME/IOC
- Coastal/marine ecological assessment	IUCN/WWF/IOC
- Living marine resources	IUCN/FAO/IOC
- Coastal infrastructure	UNCHS (Habitat)
- Remote sensing/data-base support	ROPME/UNEP
b) Atmosphere:	
- Air quality/effects on human health	WMO/WHO/IAEA
- Air/sea exchange	IOC
- Meteorology and long range air pollution transport	WMO
c) Terrestrial:	
- Food, soil, agriculture	FAO/IOC
- Terrestrial ecosystem/desertification	UNEP (ROWA)
- Food safety, drinking water	WHO
- Shelter/welfare	UNCHS(Habitat)/WHO
d) Hazardous Waste Management:	
- Assessment of damage to industrial sector and risk of release of hazardous wastes	UNIDO/WHO/UNCHS
- Industrial safety	UNEP(IEO)/UNIDO

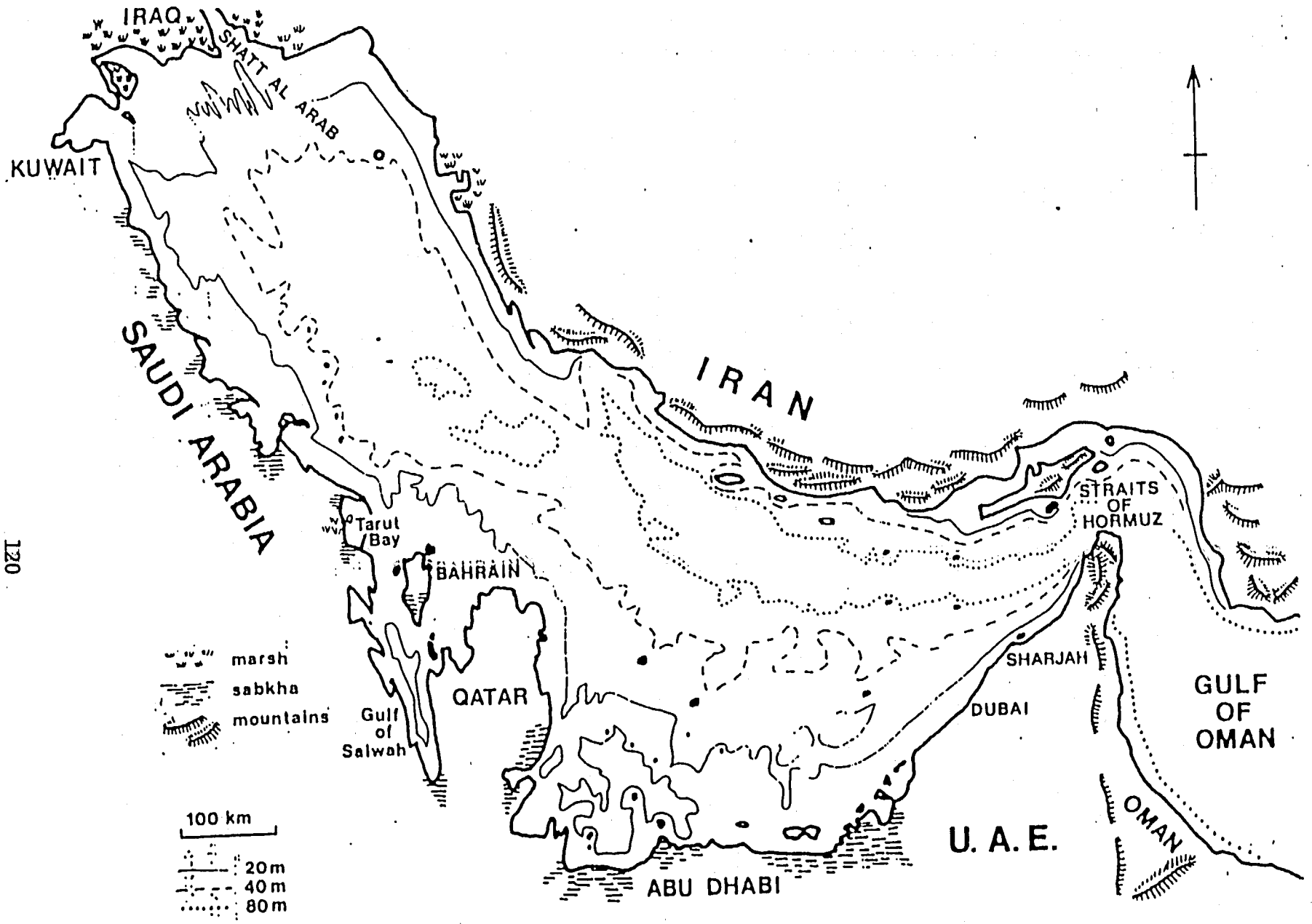
IRAQ
SHATT AL ARAB
KUWAIT
SAUDI ARABIA
IRAN
STRAITS OF HORMUZ
Tarut Bay
BAHRAIN
QATAR
Gulf of Salwah
SHARJAH
DUBAI
GULF OF OMAN
U. A. E.
OMAN
ABU DHABI
marsh
sabkha
mountains
100 km
20m
40m
80m

Figure 1

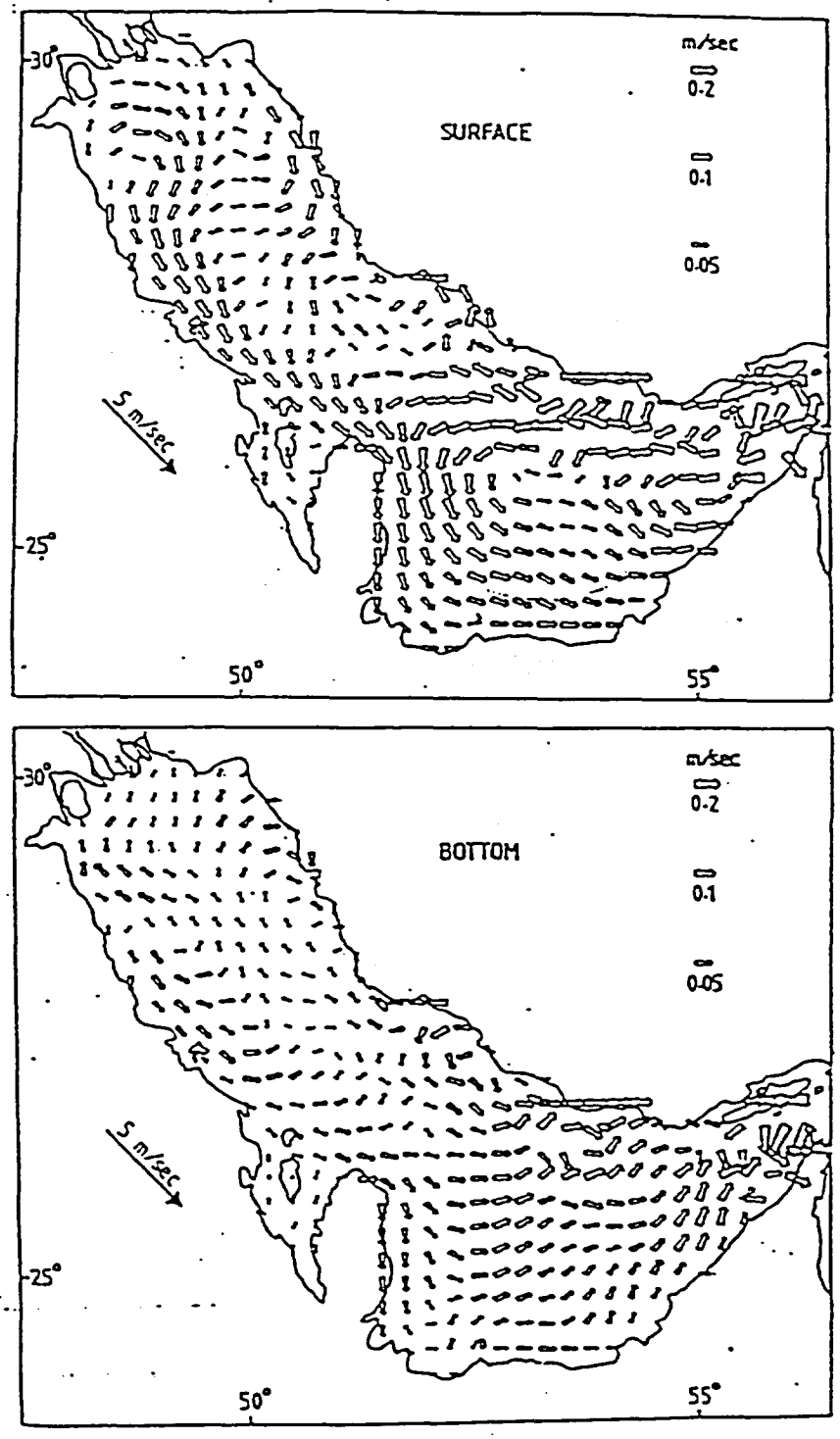

Figure 2: Predicted model velocities for surface and bottom cells with prescribed wind stress (vector lengths proportional to cube root of velocity) (after Hunter, 1982b)

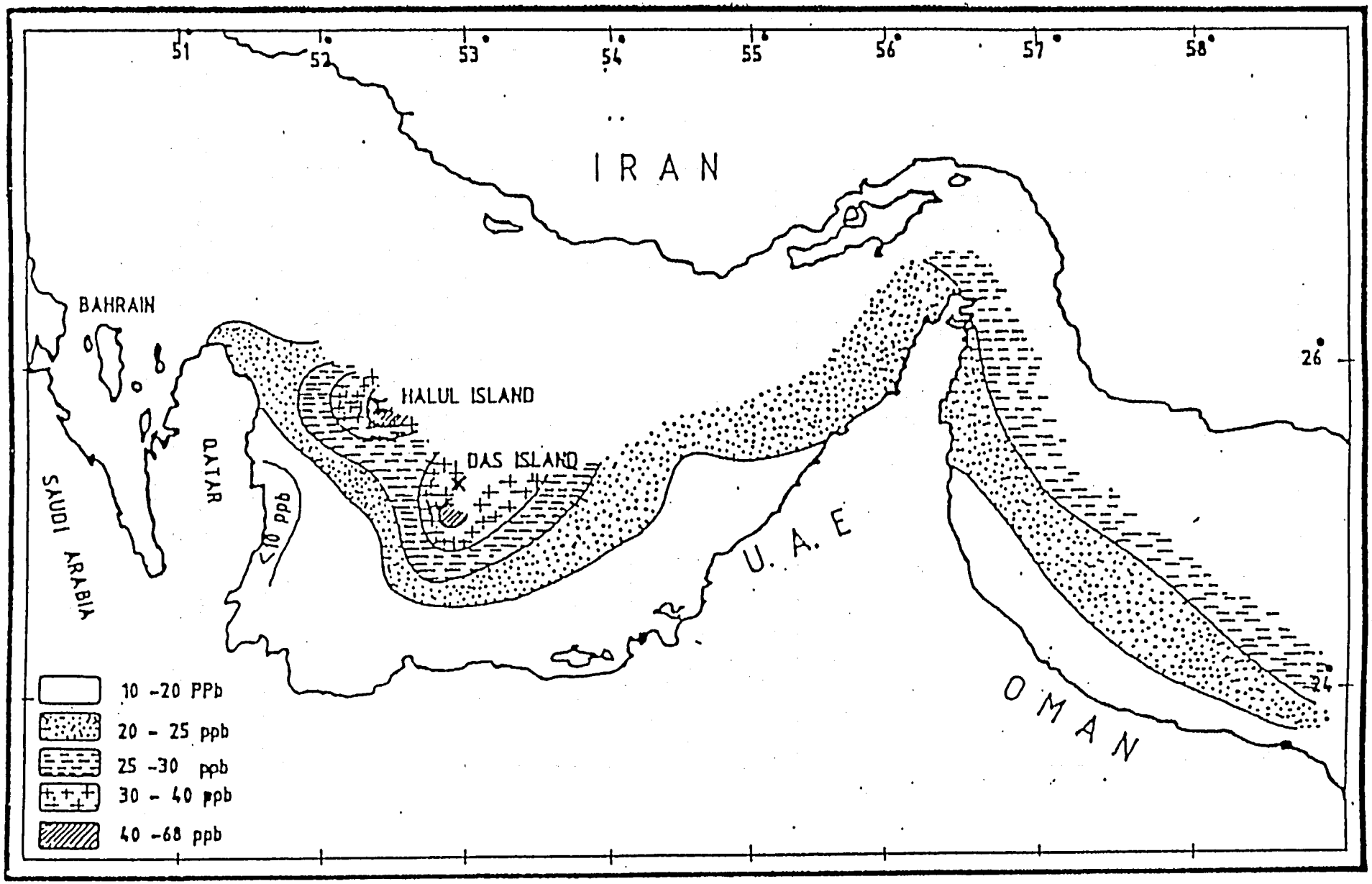

Fig. 3. : Hydrocarbon levels in the Arabian Gulf

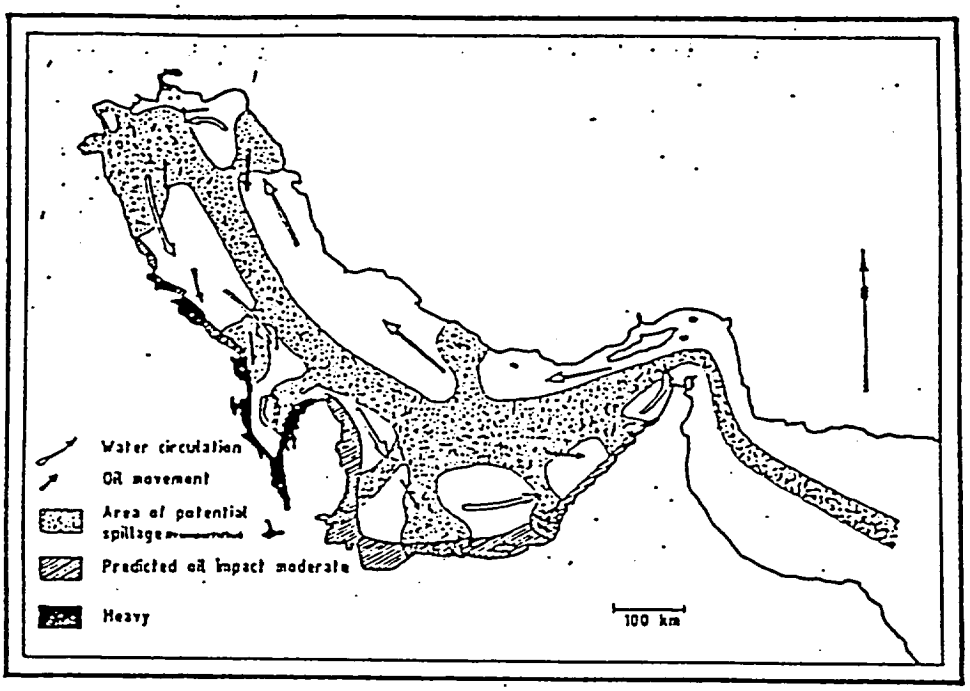

Fig. 4 : Oil movements in the Gulf (Neuman, 1979)

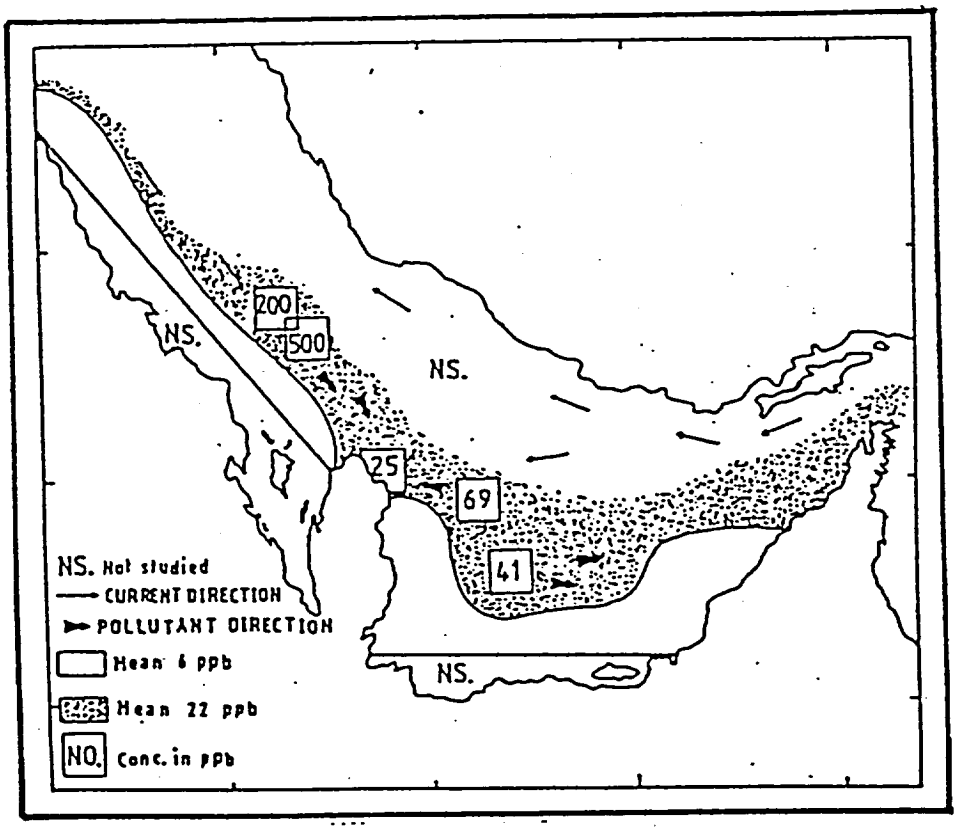

Fig. 5 : Circulation pattern and the potential risk of oil pollution

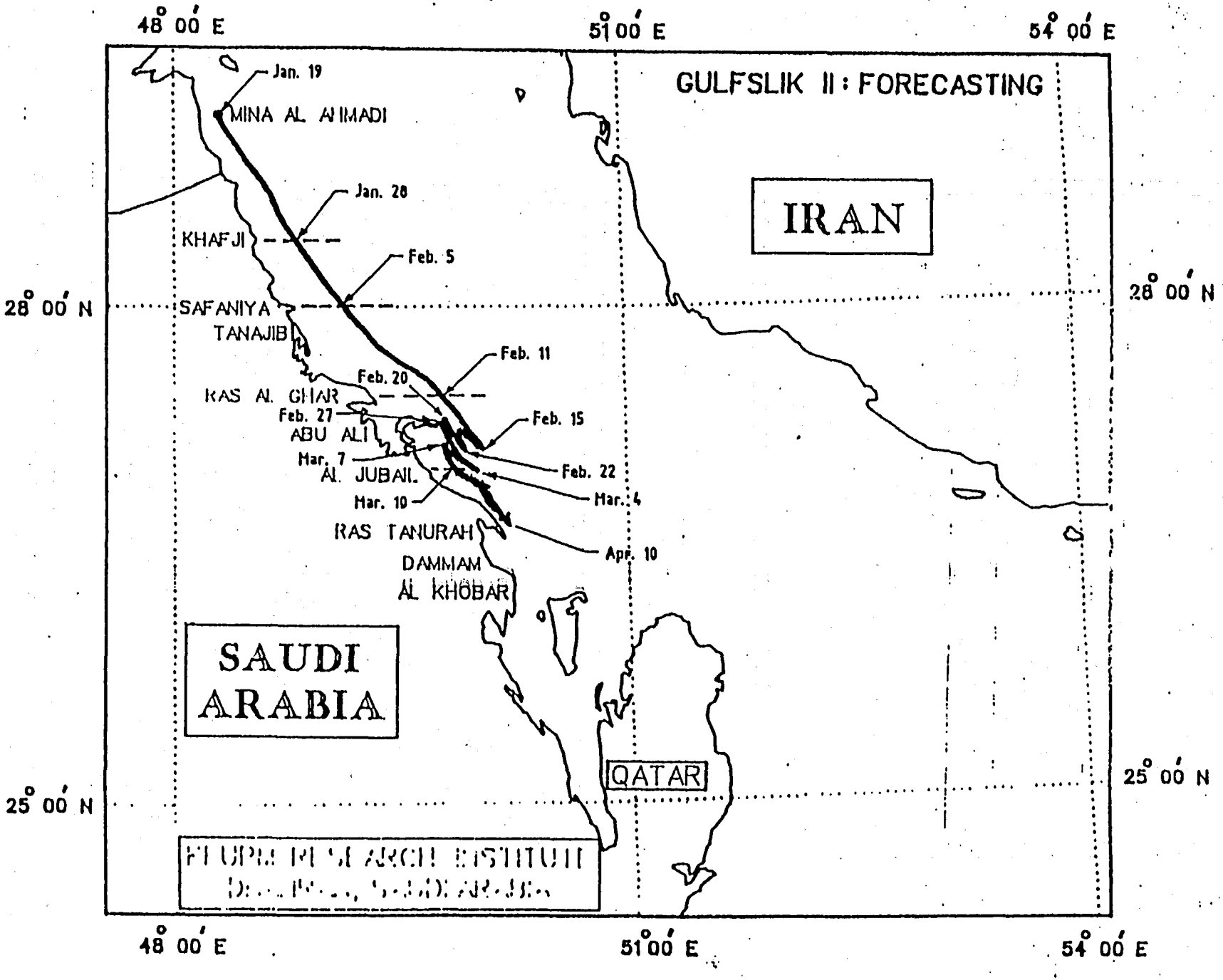

Figure 6. Predicted trajectory of the oil spill over 80 days using GULFSLIK II.

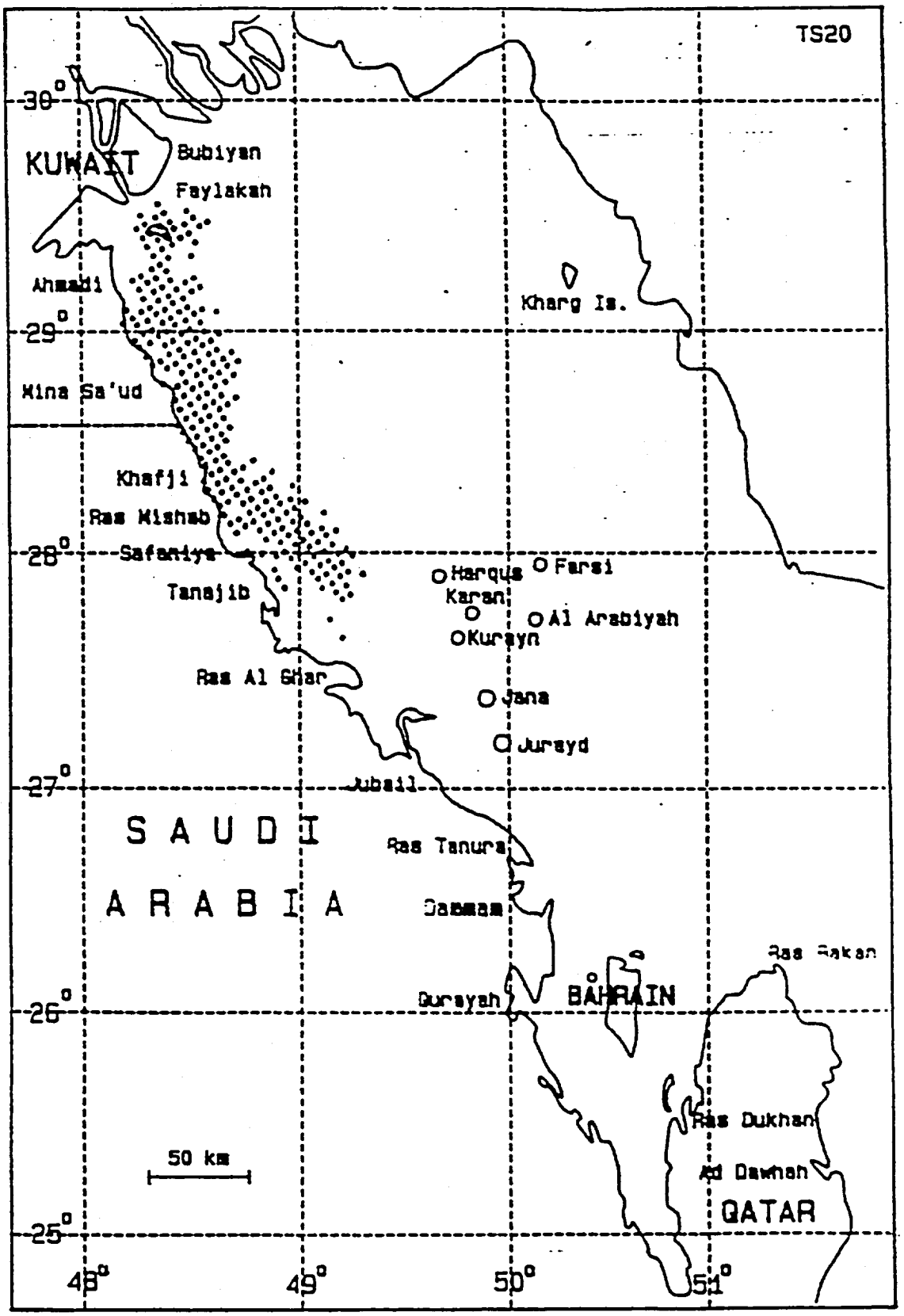

Figure 7. Surface distribution of oil after 20 days from the start of the spill.

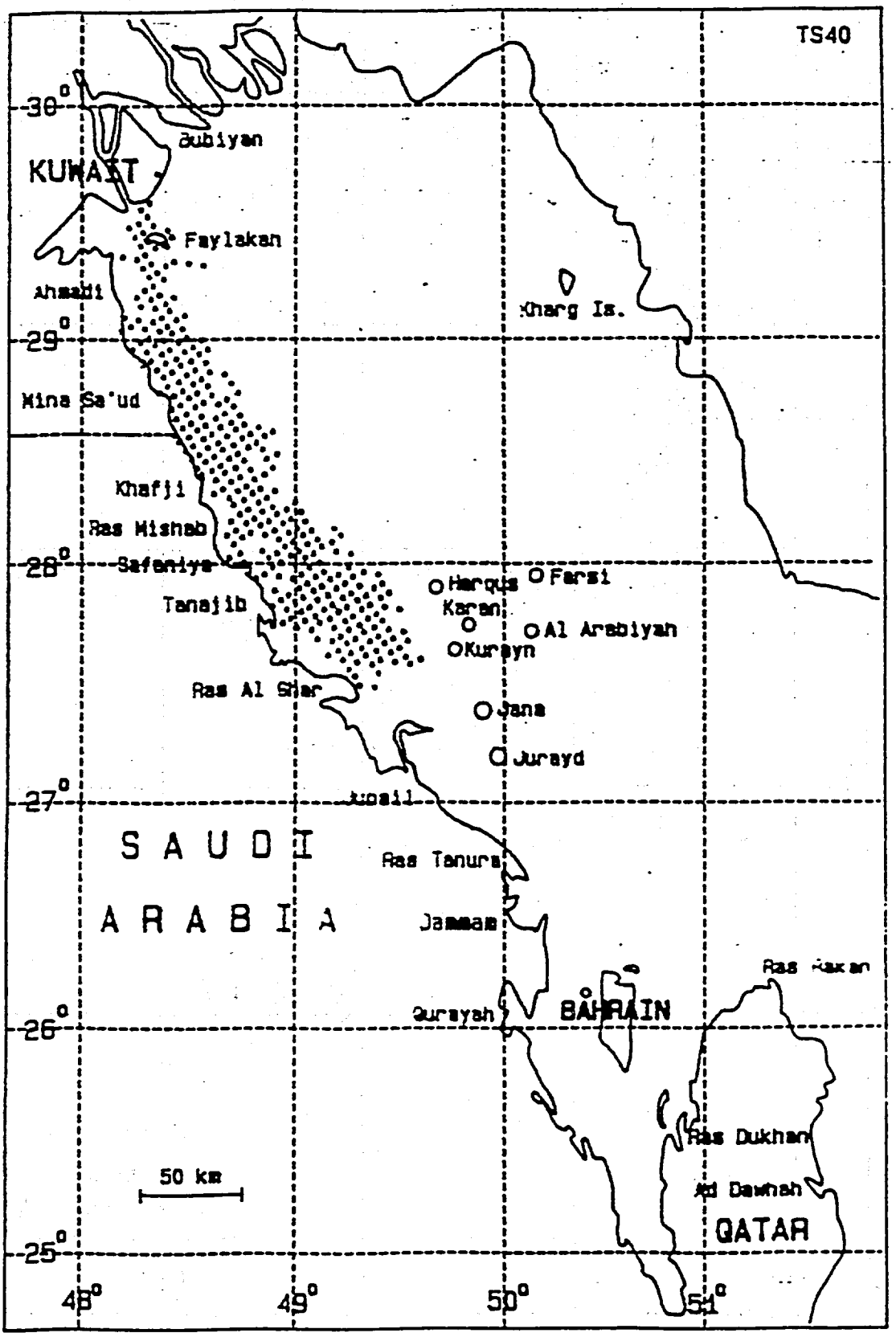

Figure 8. Surface distribution of oil after 40 days from the start of the spill.

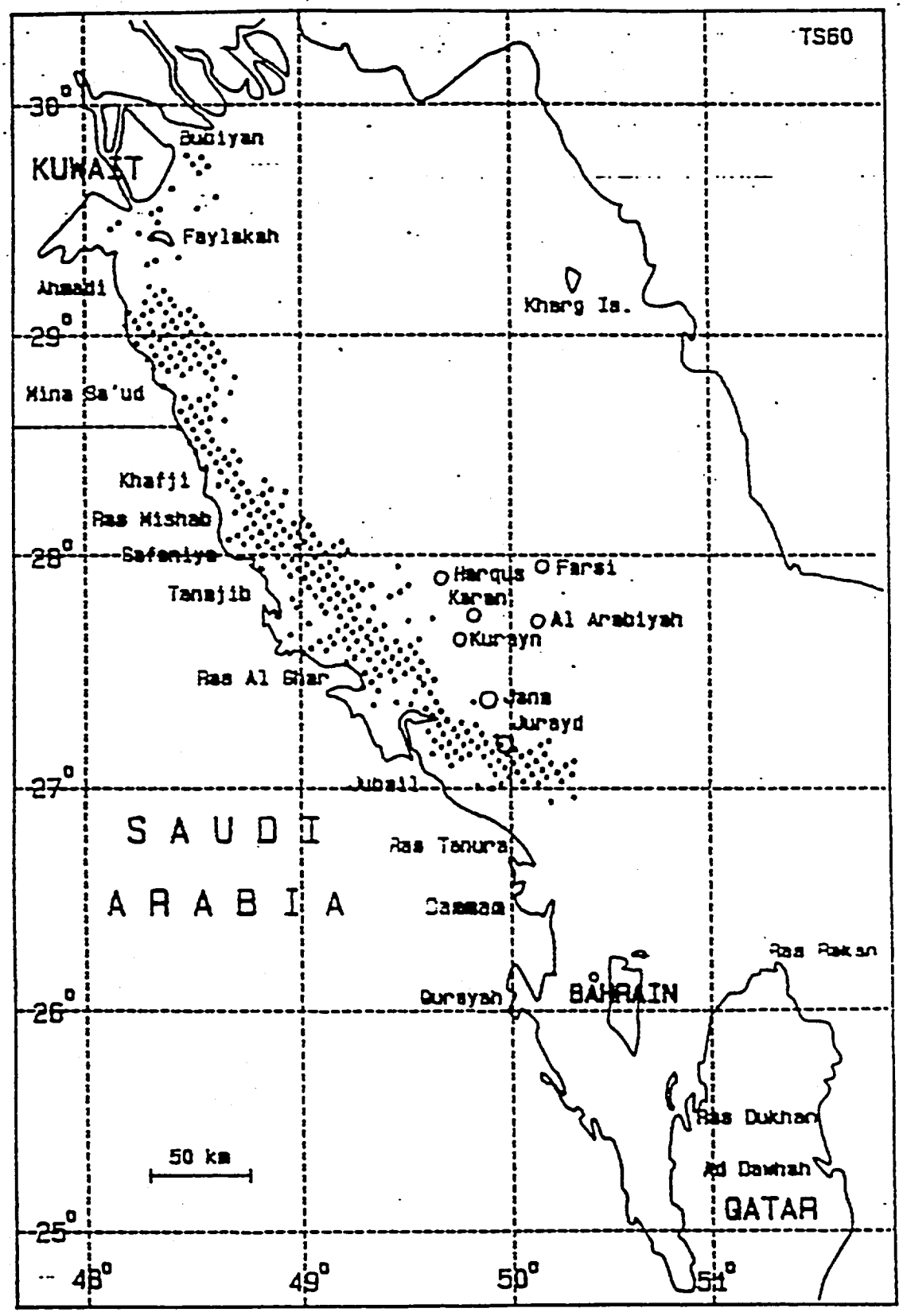

Figure 9. Surface distribution of oil after 60 days from the start of the spill.

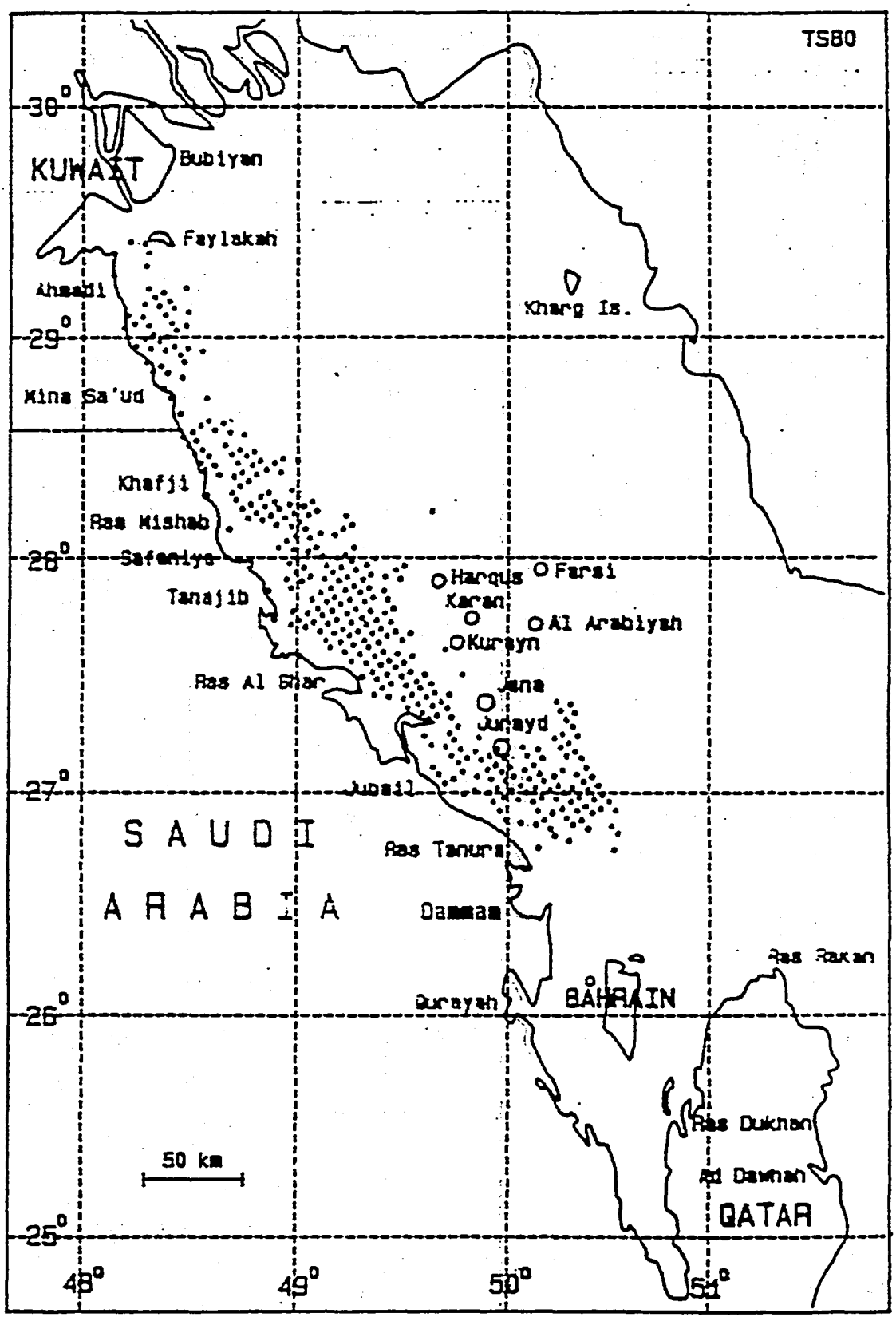

Figure 10. Surface distribution of oil after 80 days from the start of the spill.

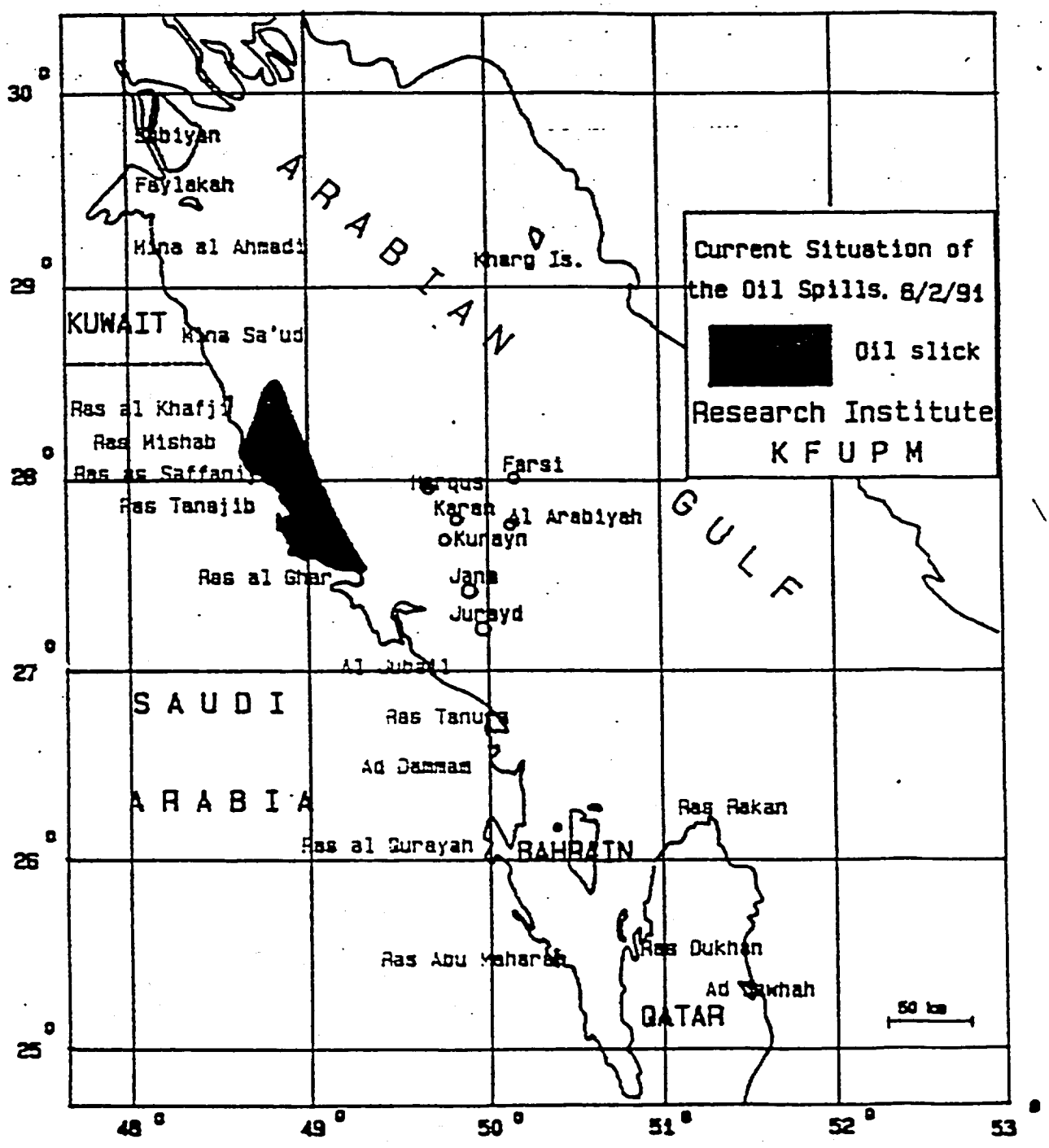

Figure 11 Actual oil spill distribution on Feb. 6, 1991.

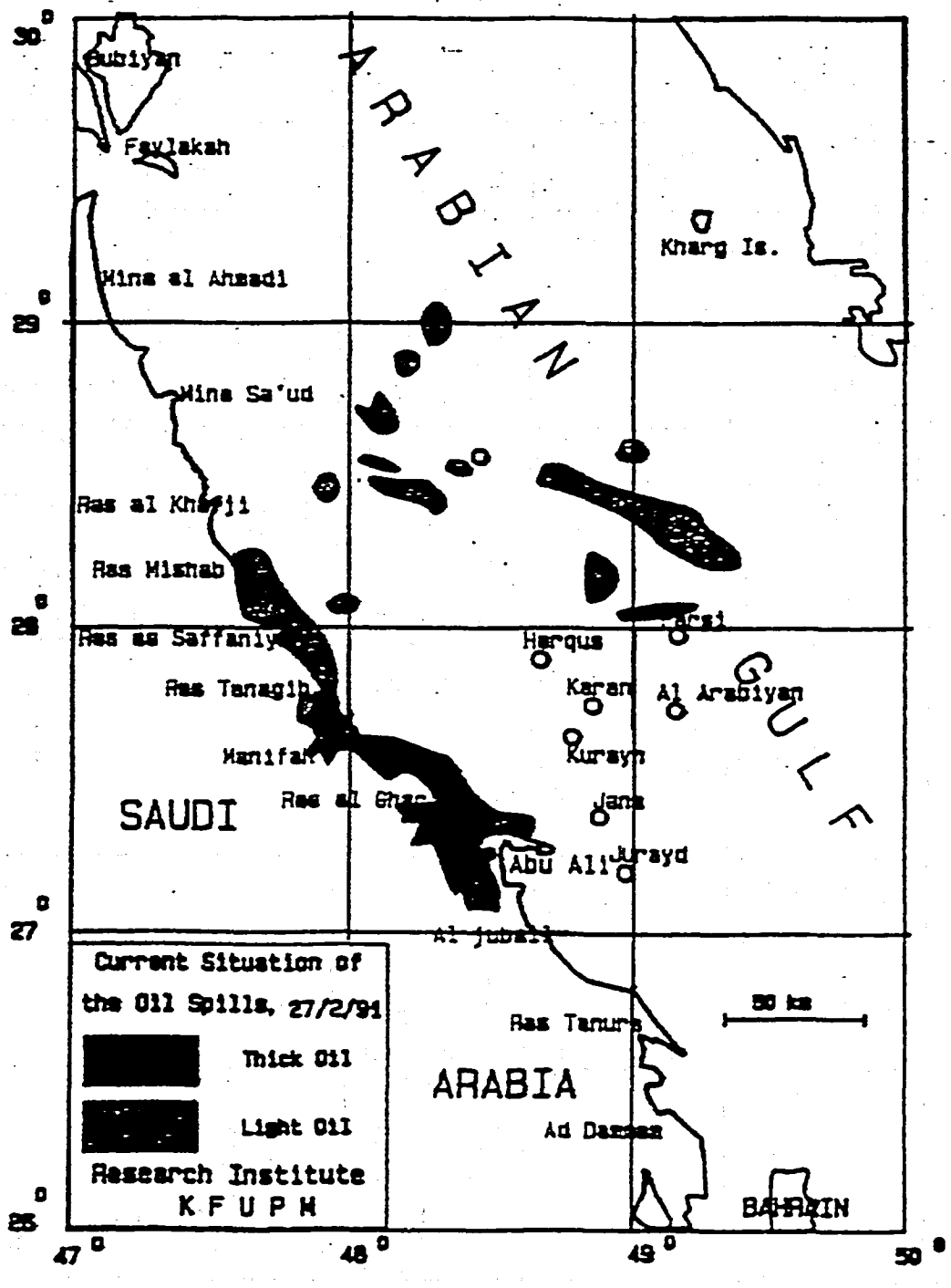

Figure 12. Actual oil spill distribution on Feb. 27, 1991.

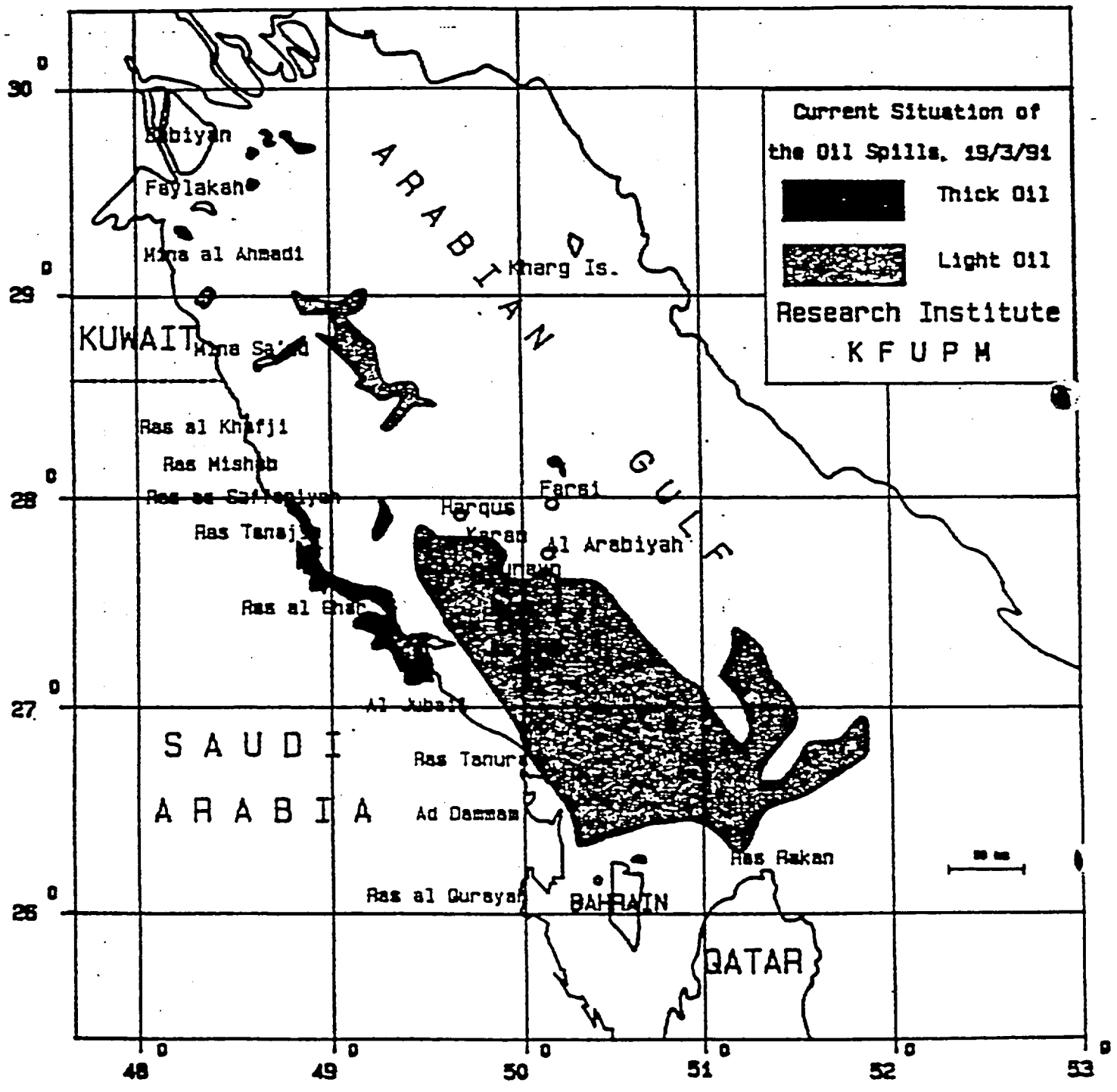

Figure 13. Actual oil spill distribution on Mar. 19, 1991.

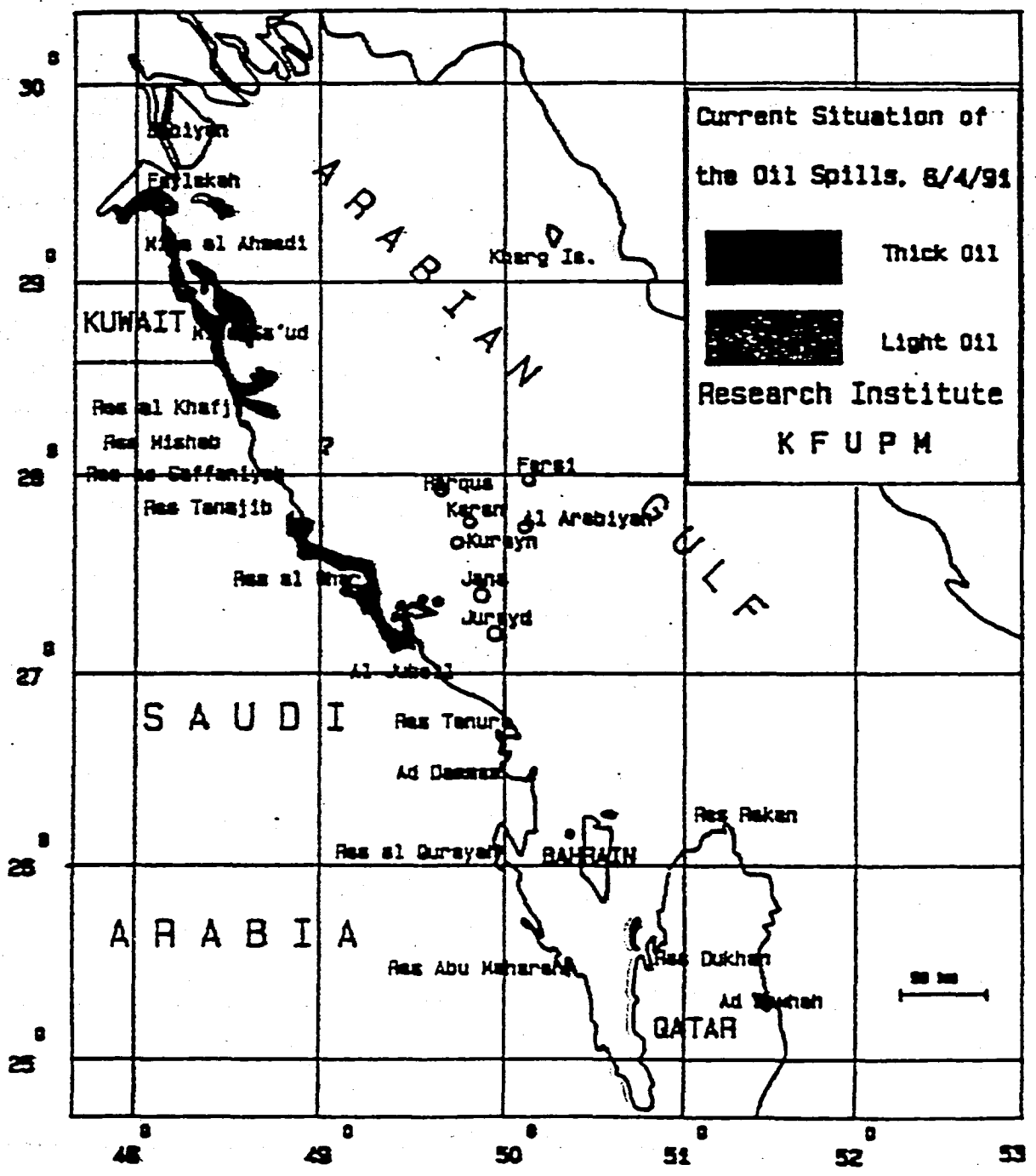

Figure 14. Actual oil spill distribution on Apr. 6, 1991.

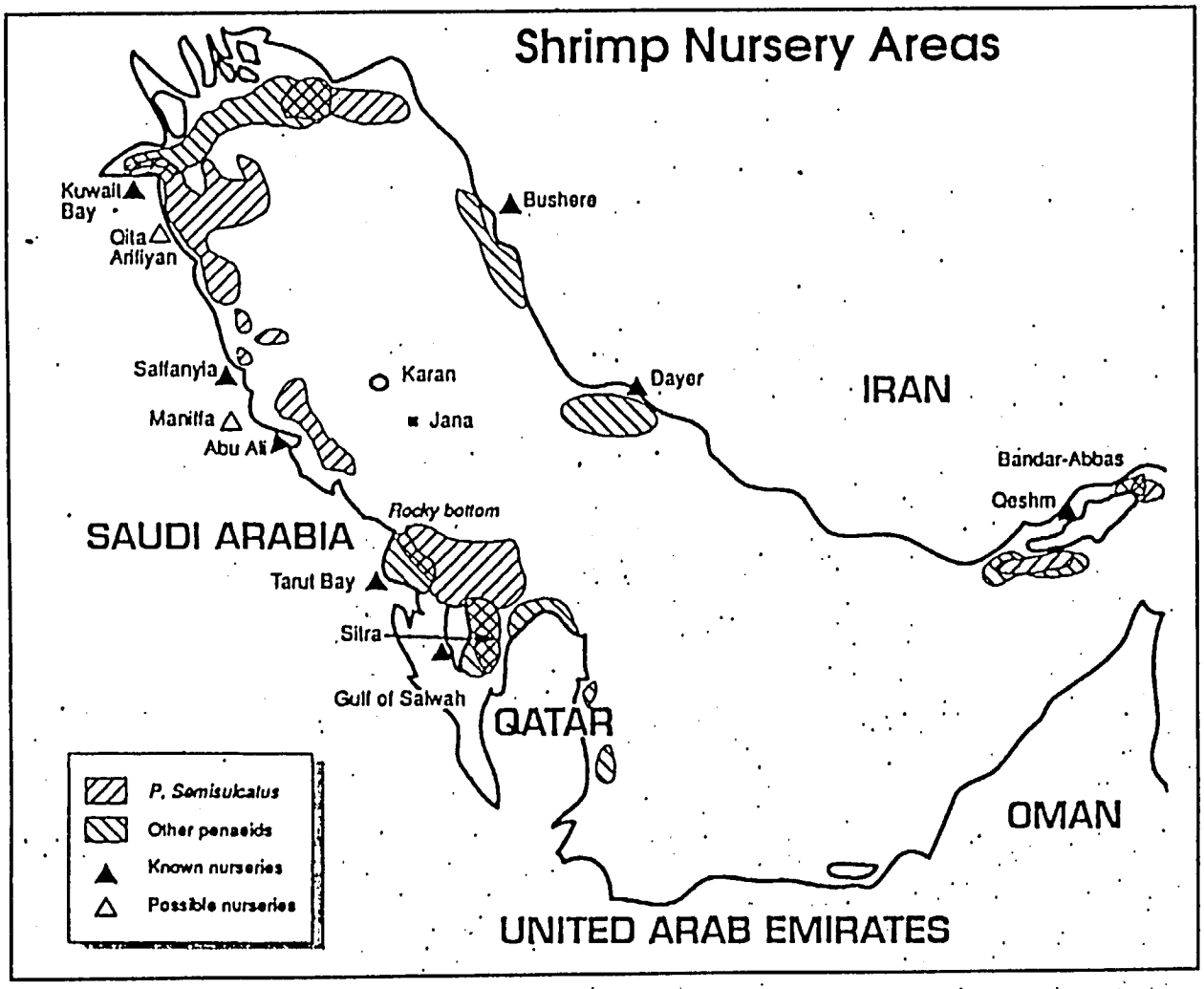

Figure 15. Location of principal nurseries..
Data obtained through interviews with boat captains.
Source: FAO (1982),"Assessment of the shrimp stocks of the west coast of the gulf between Iran and the Arabian Peninsula"

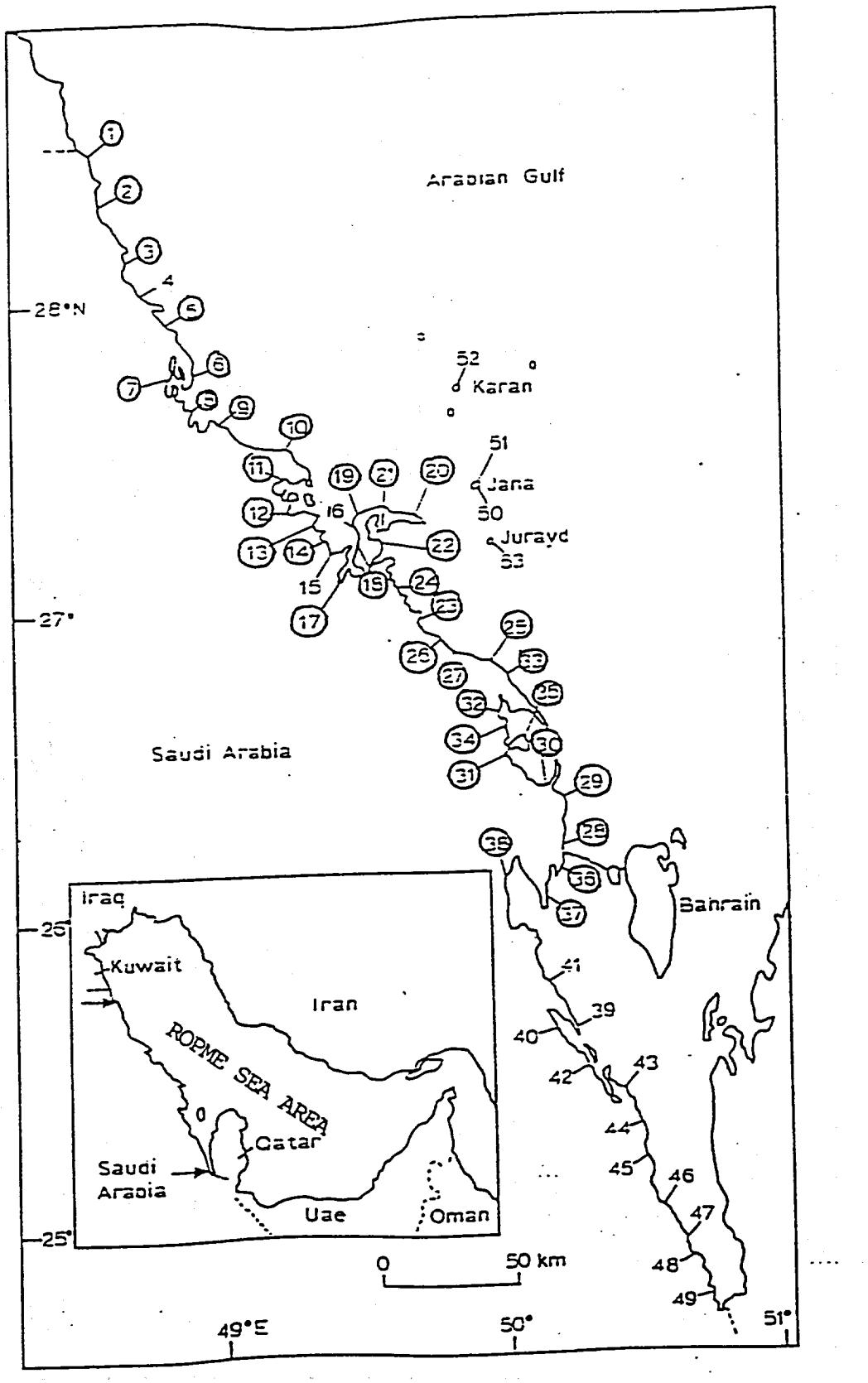

Figure 16. Map of Saudi Arabian RSA showing locations of coastal study sites. Sites 1-53 were examined during 1986, and encircled numbers denote sites resurveyed during 1991.

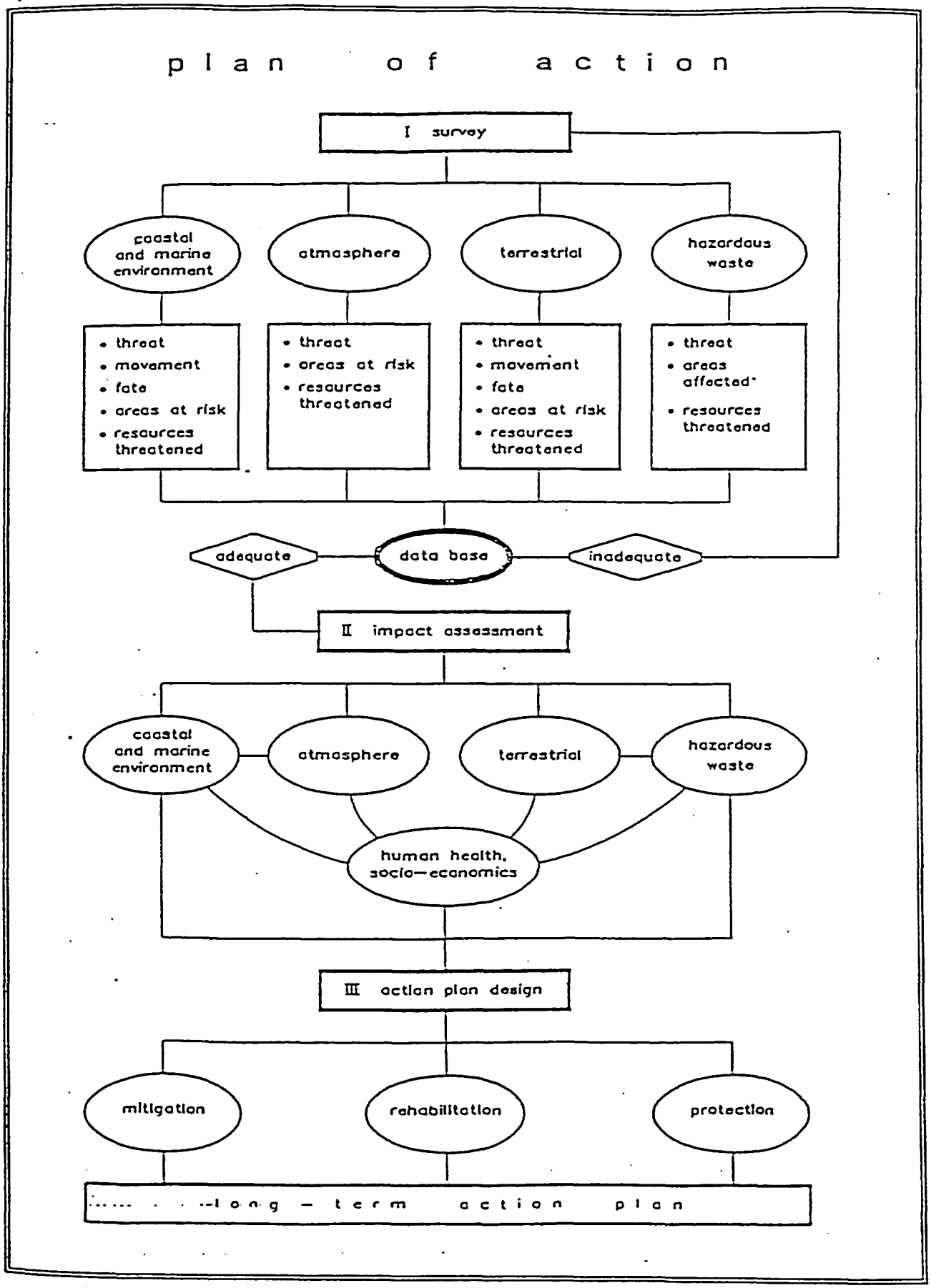

Figure 17. Schematic diagram of the UN Interagency Plan of Action for the ROPME Region

LONG-TERM ENVIRONMENTAL HEALTH EFFECTS: AN ASSESSMENT

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University of Saskatchewan

Introduction

The title suggests that I am going to talk about long-term environmental health effects. As it is, the words "environmental health" have become somewhat ambiguous. Those focusing solely on health of humans will understand this title to mean: effects on human health due to environmental conditions. Others expect that I am going to talk about the health of the environment in general, which includes humans, other mammals, and all other living things.

A thirty-minute time allotment is, clearly, not enough to cover the health effects on all aspects of the environment in general, therefore the emphasis will be on human (mammalian) health mainly, but not exclusively so. Before we enter into the discussion of the effects, I have to review, briefly, the chemical compounds that are to be considered. In particular, I have to explain: What is in crude oil? What is in the smoke of oil fires?

What is in Crude Oil?

Crude oil, or petroleum, or hydrocarbons, or petroleum hydrocarbons (all these designations are used) are very complex mixtures of aliphatic, olefinic, and aromatic carbons. In general, it can be said that the higher the viscosity (e.g., grease, heavy oil), the lower the toxicity or incidence of adverse health effects, with one exception: aspiration/inhalation of oil droplets will lead to lipid or oil pneumonia[1].

The best known toxic gas associated with oil exploration is hydrogen sulphide (H_2S), a gas that is heavier than air. In spite of the high sulphur content of Kuwaiti oil, little is known about H_2S emissions in that region. H_2S will burn at higher temperatures, and will break down into hydrogen and sulphur, which may then be reformed or incorporated into other molecules and compounds (see later).

Toxicological Considerations of Crude Oil

Petroleum or hydrocarbons can enter the body through the oral, cutaneous and inhalatory routes. The acute toxicity of crude oil is not in focus here, but a few examples have to be given[2]. The pattern described below emerged after the following studies: primary eye and dermal irritation tests in rabbits; dermal sensitization studies in guinea pigs; acute oral toxicity tests with rats; acute and sub-acute dermal toxicity tests in rabbits:

- Heavy fuel oils produced the most severe signs of eye irritation, but of short duration only.
- Middle distillates produced severe dermal irritation.
- All oils were, essentially, non-sensitizing.

- Heavy fuel oil was most toxic after oral application (LD_{50}: 4.7 g/kg. Note: 10 ml are considered as possibly lethal in man[1]).

- Hydrocarbons cause mucous membrane irritation, vomiting and CNS-depression[1].

- Inhalation of hydrocarbons causes cyanosis, tachycardia, tachypnea, hematuria, hepatic enzyme derangement, cardiac arrhythmia and renal tubular nephropathy, and may lead to renal tumours in rats[3].

- Damage of erythrocytes is most evident in avian species, but not so evident or important in mammalian species[4].

- Although H_2S is mentioned only occasionally, it appears quite believable that corneal opacity ("clouding of the eyes") occurs in some animal species after exposure to H_2S, making it difficult for these animals to find food, or to orient themselves[5].

- With respect to cancer-causing properties, there is unanimous agreement that the hydrocarbons are potent inducers of enzymes, which may pave the way for cancer. This starts already after dermal application, when percutaneous absorption occurs[6]. Mixed Function Oxidases (MFOs) were reported to be activated after application of Kuwait crude to the skin of rat[7], and application of such oil to the skin resulted in skin cancer, with Kuwaiti oil creating tumours more rapidly than other oils.

Chronic Toxicity of Crude Oil

Since we know that hydrocarbons are MFO inducers, can be mutagenic, and have a carcinogenic potential, increased numbers of cancerous lesions are likely to occur in the Gulf region. Other fractions, such as hexanes, have very specific chronic neurotoxic effects[1,8].

In summary of this point, one can say that there is, clearly, a probability of increased cancers, but probably no more than what can be expected from workers in the oil industry, or residents living close to sites with such industrial activity.

What is in the Smoke of Oil Fires?

The events during a fire of an oil well are much more complex than is portrayed in popular reporting. We know that oil (and whatever came out of the underground at the same time, at speeds of up to 800 miles per hour) will burn like a candle. That means: there will, probably, be complete combustion of all components at the tip of the flame, but the "belly" of the flame is made up from many layers (like an onion) of varying temperatures. Given the speed of ejection from the ground, and given "cooling" cross-winds, not everything will be combusted. In fact, due to the intense heat convection, many particles (and that may even include sand from the surroundings) and compounds will be simply projected into the air, not combusted at all, or incompletely combusted, or worse, new compounds may be formed. One major effect is that non-combusted oil particles will also be propelled into the air, and many such droplets will be in a size that is respirable.

Other components of complete or incomplete combustion are:

- Particles ("soot") which can be inhaled, and can carry other chemicals or toxicants, including the dreaded Poly-Aromatic Hydrocarbons (PAH's), many of which are carcinogenic.

- Sulphur dioxide (SO_2) and NO_x's, the more familiar combustion products (more about these compounds, later).

- Carbon disulphide (CS_2), a lesser known toxic compound as a result of incomplete combustion (see later).

- Finally, given all kinds of other potentially present chemicals, combustion—at various levels of temperature—can create numerous new compounds, about which we know little or nothing. No wonder that it has been suggested that the best way to prevent troubles from oil fires is to prevent the fire itself.

An air pollution score from Kuwait, 1991, is given in Table 1.

Toxicological Considerations of "Smoke from Oil Fires"

In theory, we should know much about the combustion products of petroleum, because we have been living with automotive exhaust and oil fires for many years. We are all familiar with lead emission problems, CO_2 and NO_x emissions, never mind carbon monoxide. But, other problems? The long-held view that automobile exhaust poses no real problem for humans, besides lead, has been shattered, since we know that at least diesel exhaust is probably carcinogenic[9,10].

Inhalation of oil particles, alone, will lead to what is known as lipid or oil pneumonia. This is a very serious process, that cannot be treated or slowed down; it will lead inevitably to chronic pulmonary fibrosis.

Other compounds of concern are:

- SO_2 and NO_x's are known, typically, as irritants of mucous membranes (particularly of the eyes and the respiratory tract[1,11]. Most people react with decreases in pulmonary function to concentrations of 5 ppm or higher, but asthmatic persons respond to levels of 0.25 to 0.5 ppm. However, it should be noted that National Geographic (v. 180, August 1991, pp. 2-35) reported that SO_2 levels in Kuwait were considered safe, judged from U.S. Standards.

- Carbon disulphide (CS_2) causes severe intoxication (damage of brain, eyes and ears; causes coronary heart disease; and endocrine and reproductive system damage) after prolonged exposure to vapour at concentrations as low as 30 ppm (note that the new TLV is 1 ppm).

- Occurrence of high levels of compounds such as cadmium, lead and other toxicants in the smoke have been mentioned (Scientific American, July, 1991)[1], but it is not quite clear what adverse health effects may result from these compounds, given the wide dispersion and, hence, low levels.

- With respect to "cancer-causing" chemicals, naphthalene has been mentioned, but any of the polyaromatic hydrocarbons might play a role here.

- High levels of particulates, particularly soot, on which cancer-causing compounds might be hitch-hiking, are always of concern.

According to TIME (March 18, 1991), the smoke caused gagging and choking, and there have been reports of respiratory problems from as far away as Bahrain. This is totally believable, but has to be considered as an acute effect only. The desire of Kuwait residents to stay indoors, under such conditions, is/was a very wise choice (various media reports), but TIME (May 17, 1991) has reported, indeed, numerous respiratory problems, such as bronchitis and asthmatic reactions in Kuwaitis. However, with all due respect to the suffering of the individuals involved, this cannot be considered as particularly serious. Any major fire, even forest fires in Canada, will produce similar effects.

Assessment of Environmental Health Impact

When we talk about environment, we mean air, water, and soil and, of course, all the creatures living in, or depending on, these environments.

Polluted air is probably the most commonly noted sign of environmental health problems. We all know how serious polluted air has to be taken[12]. Witness the London Fog in 1952, when coal fumes killed 4,000 people in eleven days. How much of the atmospheric/air pollution in the Gulf region may eventually enter the food chain has yet to be ascertained. It is certainly too early to say that "the whole region is in for a bath of carcinogenic, mutagenic and possibly teratogenic chemicals," as suggested in TIME, March 18, 1991.

With respect to water, we all have seen the photographs of cormorants, covered with oil, and we are well aware of the serious impacts of the oil on all kinds of other marine creatures, but we have data from other major oil spills in the past that indicate that oil spills are not as serious as they appear to be, first. The more recent oil spill, when the Exxon Valdez ran aground, is probably in everybody's memory, yet we do not know the final assessment of that particular event.

However, it is helpful to go back into history. Dr. Jacqueline Michel, Science Adviser to the National Oceanic and Atmospheric Administration (NOAA), reported[13] on the Exxon Valdez oil spill on March 24, 1989 (11 mill gal. of oil were spilled). Dr. Michel has researched the effects of oil spills for the National Science Foundation and NOAA since 1974, and participated in studies of the Amoco Cadiz disaster which dumped 68 million gallons of oil on the coast of France in 1978 (Note: 4-6 million barrels were estimated to have been released into the Gulf = 144 to 216 million gallons, assuming 1 barrel = 36 gal). Within three years, scientists found that most of the major impacts of the Amoco Cadiz event had disappeared. "The story is much the same in all crude-oil spills," Dr. Michel said. "On exposed rocky beaches with much wave action, little oil is left after a year. On quieter beaches, the oil persists from two to three years and is frequently mixed with sand and buried. Salt marshes suffer the most damage.... In general, fish and bird populations tend to be replaced. The possible long-term effects on the tidal and intertidal ecosystems will take years to learn."

From such events, one may construct the following "time table" of events after a spill (Table 2).

While each region has its own set of "activities," such as water temperature, sunlight hours, wind speed and wave action, etc., there is little reason to suspect that the Persian Gulf ecosystem will behave differently. As Dr. Meshal pointed out earlier, while the acute impact in the marine ecosystem has to be categorized as catastrophic, there is no reason to suspect that there will be long-lasting effects -- with one exception, that is not mentioned very often in publications. That exception is: we know very little about the bioaccumulation of hydrocarbons, particularly the polyaromatic hydrocarbons. Will they enter the food chain (via marine animals) and pose a threat as cancer-causing agents? Let's hope for the best, that microorganisms will be able to reduce such PAH's to basic components.

Soil (and Plants)

Numerous newspaper and magazine articles have referred to the potential damage to soil (and plants), mentioning "acid rain," coming from the considerable amount of SO_2 and other acid precipitation (NOx's). Unless one is concerned about long-range transport (which appears to be unlikely), one should remember that much of the area, where acidic precipitation may occur, is desert. Further, we know little about the soil conditions: what is the pH? Depending on the pH, acidic precipitation may be a bonus (like here in western Canada), but this issue has to be looked at more carefully by soil scientists. One might also get concerned about sulphur-loading of soils, in the long-term. But this may happen due to the oil-operations, anyway.

There have been reports of "oil rains" as far away as Qatar (TIME, May 27, 1991), 645 km to the south, and blackened snow has been seen as far away as Kashmir, 2,600 km to the east. Oil coats have been found on palm tree leaves, starving them from sunlight. Again, we really do not know what this will mean in the long-term. We should not underestimate Nature's ability to use bacteria, or other methods, to get rid of such contamination. Another question is the presence of "lakes of oil" (some of which are pumped out) in the desert. What is the impact? Probably very little; it may even do some good to the desert, as experiments with waste oil in Saskatchewan's grain growing areas have shown.

In summary of this very superficial assessment of the impact on the environment, in general, it is appropriate to refer those interested in details of the effects of environmental pollution, in general, to a book written by Bill Freedman from Dalhousie University[14]. You will find in this book valuable information, much of which is pertinent here.

Public Health Aspects

The Public Health Service (PHS) of the U.S. Department of Health and Human Services issued a Plan of Action for Protecting Public Health in May, 1991[15]. It identified six priority health issues related to the oil pools and oil well fires:

- acute or chronic hazards;
- exposure from the oil pools and oil well fires;
- nature and extent of exposure;

- public health infrastructure to be developed to identify and evaluate possible adverse public health effects;
- risk management and disease prevention policies for those exposed; and
- new knowledge about the possible adverse health effects associated with exposure.

It was also stated that hospital admissions could be another indicator of "how a population is dealing with a health threat," and that "long-term health effects were not readily predictable because little is known about the consequences of such intermittent kinds of exposures."

PHS issued also a health advisory (March 21, 1991[15]) recommending four precautions and five actions in light of the health threat posed by the fires. The four precautions were the following:

- use protective clothing and medical evaluations for personnel stationed or working near the oil fields;

- advise residents of methods to reduce exposure, and early warning signs and symptoms of exposure;

- advise medical personnel of potential health hazards; and

- evaluate the public health infrastructure.

Key actions recommended by the Public Health Service were:

- developing a preliminary assessment of the areas through site visits by experts;

- evaluating medical facilities for their diagnostic and treatment capabilities;

- monitoring of air in all residential areas of Kuwait and Saudi Arabia;

- exploring the feasibility of establishing a surveillance system for adverse health effects; and

- assessing resources and facilities to provide health alerts and information to local residents.

It remains to be seen what has been learned from these precautionary statements and action plans.

Verification Aspects

The main theme of this workshop is "Verifying Obligations Respecting Arms Control and the Environment." How does all of what I said connect with this theme? Admittedly, there are only a few connections. However, there are some parallels, such as:

- It would have been helpful if more use of existing data as baselines would have been made. For instance, the U.S. Congressional Hearings referred to particulates levels from the time before the Gulf War[15], and I am sure that there are other data on file about hydrocarbon concentrations, toxic gases, etc. Combined with data gathered during the oil well fires, this would allow for an evaluation. I hope such work is under-way.

- Somebody should write (or should have written) a comprehensive review of the potential toxicity and risks to health of oil fires. While the Kuwait oil fires were probably unique in their dimension, oil fires of storage facilities, etc., have occurred before. Maybe data from these events are buried in some industry or government files, and it might be useful if a national or international agency would evaluate such files.

- It may be advisable to organize an international conference of combustion experts (engineers, chemists, toxicologists, physicians, etc.), to discuss this topic, exchange data, and evaluate the potential long-term effects.

Summary and Conclusions

I sympathize with you if you have come to the conclusion that this excursion into the world of toxicology has not provided you with an answer to the problems at hand. I am not willing to apologize for that, because I don't have all the answers.

I think it is time, though, to relate the toxicological considerations to the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, opened for signature at Geneva on May 18, 1977, and entered into force on October 5, 1978.

Article I defines the term, "environmental modification techniques," as changes, by deliberate manipulation, of natural processes, such as "the dynamics, composition or structure of the earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space." This is modified, in Article III, by saying that the Convention shall not hinder the use of environmental modification techniques for peaceful purposes..." How do we differentiate?

During the drafting of the Convention, the following illustrative examples of "environmental modification techniques" were given: "earthquakes; tidal waves; an upset in the ecological balance of a region [we do this all the time in oil/gas exploration regions!]; changes in weather patterns, or ocean currents; changes in the state of the ozone layer [aren't we doing this, anyway?] and changes in the state of the ionosphere."

Since I am not trained in legal aspects, I can't help but notice the poor quality or lack of definition of the supposedly fundamental or underlying scientific criteria. Who defines what is a "widespread" effect (How widespread? From what viewpoint?), "long-lasting" effect (How long? Years? Decades?), or "severe" effect (How do we define "severe"?).

Seen from a very general viewpoint of effects of toxicants over a long period of time, I suggest that the effects of the Gulf War on the environment are just a "drop in a bucket." However, if we are talking about how to handle the real or perceived problems, associated with an environmental disaster like the Gulf War, we need more than just legal considerations and "band-aid" type public safety concerns. No war has ever succeeded in receiving a medal for "least environmentally disturbing

war," ever. Wars are messy, don't solve problems in the long-run, etc., yet they seem to be unavoidable. The environmental impact aspects are, in my view, minor, viewed from an "eternal" viewpoint. The acute, short-term impact on a number of individuals and their environment, however, are probably much more sinister than we can determine now.

All I can say, as a concluding remark, and the idea is taken -- more or less verbatim -- from Canada's GREEN PLAN which promises to take action to care of the Environment: We need better science; we need to ask scientists about their views of the risks of environmental modification, for peaceful purposes or not. As it is, there seems to be little, if any, money to fund such basic research. Thus, we will probably continue to sail through uncharted seas towards destinations unknown.

References

1. Amdur, M.O., J.D. Doull and C.D. Klaassen (eds.): Casarett and Doull's Toxicology. The Basic Science of Poisons, 4th ed. Pergamon Press, 1991, page 935.

2. Beck, L.S., D.I. Hepler and K.L. Hansen. Chapter 1: The acute toxicology of selected petroleum hydrocarbons; pp. 1-16, in: Applied Toxicology of Petroleum Hydrocarbons, Vol. VI, Advances in Modern Environmental Toxicology. Ed. by H.N. MacFarland, C.E. Holdsworth, J.A. MacGregor, R.W. Call and M.L. Lane. Princeton Sci. Publ., New Jersey, 1984.

3. Page 368 in ref. #1.

4. Leighton, F.A. The systemic toxicity of Prudhoe Bay Crude and other petroleum oils to CD-1 mice. Arch. Environ. Contam. Toxicol. 19, 257-262, 1990.

5. Beck, B. The effect of gas and oil well blowout emissions on livestock in Alberta; pp. 68-75, in: Highly Toxic Chemicals: Detection and Protection Methods. Proceedings of an International Symposium; ed. by H.B. Schiefer, Toxicology Research Centre, University of Saskatchewan, Saskatoon, Saskatchewan, 1985.

6. Franz, T.J. Chapter 5: Percutaneous absorption of benzene; pp. 61-70 in reference #2.

7. Rahimtula, A.D., P.J. O'Brien and J.F. Payne. Chapter 6: Induction of xenobiotic metabolism in rats on exposure to hydrocarbon-based oils; pp. 71-79, in: reference #2.

8. Spencer, P.S. Chapter 15: Experimental evaluation of selected petrochemicals for subchronic neurotoxic properties; pp. 199-214 in: reference #2.

9. Buzik, S.C. Toxicology of diesel exhaust. A Review. Toxicology Research Centre, University of Saskatchewan, Saskatoon, Saskatchewan, 13 pages, 1991.

10. Hobbs, C.H. and J.L. Mauderly. Risk assessment for diesel exhaust and ozone: The data from people and animals. Toxicol. 29, 375-384, 1991.

11. Koenig, J.Q. and W.E. Pierson. Air pollutants and the respiratory system: Toxicity and pharmacologic interventions. Clin. Toxicol. 29, 401-411, 1991.

12. Aldrich, F.D. Air pollution illnesses: Overview and challenge. Clin. Toxicol. 29, 307-313, 1991.

13. National Geographic 177 (No. 1), Jan. 1990, pp. 5-45.

14. Freedman, B. Environmental Ecology. The Impact of Pollution and Other Stresses on Ecosystem Structure and Function. Academic Press, 1989.

15. Report of the Senate Committee on Environment and Public Works. Gulf Pollution Task Force: The Environmental Aftermath of the Gulf War. Congressional Research Service, March 4, 1992.

Table 1: KUWAIT - Air Pollution Score (May 16 to June 12, 1991)

Particles (30 percent soot):
12,000 metric tons/day
(Equal to about 10% of the particles emitted daily from biomass burning worldwide)

Carbon dioxide (CO_2):
1.9 million metric tons/day
(Equal to about 2% of the daily worldwide emissions of CO_2 from fossil fuel and biomass burning)

Sulphur dioxide (SO_2):
20,000 metric tons/day
(Equal to about 57% of daily emissions from electric utilities throughout the U.S.)

Source: Peter Hobbs, University of Washington, in: National Geographic 181 (Feb.) 122-134, 1992.

Table 2: Time Table of Events After an Oil Spill

0-3 weeks:-
- microscopic oil droplets disperse into water.
- as much as 25% of that oil evaporates.
- lighter and intermediate components dissolve.
- solar radiation intensifies evaporation.

3 weeks to 18 months:
- photooxidation further breaks down oil.
- water combines with oil to form an emulsion called mousse.
- tar balls are formed (may wash ashore).
- microorganisms degrade oil biologically; stimulation of bacterial growth by nitrogen and phosphate may be beneficial (oleic acid, lauryl phosphate, and urea; not toxic to marine organisms).

Adapted from: National Geographic 177 (Jan.), 5-45, 1990.

SESSION 2: DISCUSSION

It was pointed out that a verification regime in the Gulf War intended to deter acts of environmental aggression, would not have prevented them from occurring. Sanctions are the only effective mechanism to counteract such events. Punishment is an important element of sanctions.

Another participant indicated that as a result of the Gulf War and the deliberate setting afire of the oil wells by Iraqi forces, there was a tremendous amount of soot produced. Soot is not a carcinogen itself, but it can carry carcinogenic compounds. The major problem of soot during the War was it's inhalation and deposition onto the skin. Would increased cancer rates constitute a long-lasting effect along the lines of the ENMOD Convention?

The question of the interpretation of the ENMOD Treaty with respect to what is long term, and what is tolerable as a deliberate environmental disaster was discussed. If the Treaty, as it is presently worded, cannot provide environmental protection simply because of interpretation problems, then what is its use? The original Understandings of Articles I, II, III, and IV were draft understandings suggested by the Conference of the Committee on Disarmament and were rejected by the General Assembly. Therefore, any Understandings of the ENMOD Convention are of little help in it's interpretation. The interpretation of the phrase "manipulation of natural processes" appears to be the one of the weakest parts of the Treaty, and the majority of participants at the Ottawa Conference shared the viewpoint that the oil well fires were not a manipulation of natural causes.

The protection of the environment in wartime today is more related to the 1977 Protocol I to the 1949 the Geneva Convention than to the ENMOD Convention. Protocol I offers a higher degree of protection for the environment than ENMOD and perhaps efforts should concentrate more on widening the broad participation of Protocol I than trying to turn the ENMOD Convention into a different instrument.

It was pointed out that the priority assigned by the Kuwaiti government to the environmental damage caused by the oil fires was not as high as might have been expected. It is difficult to view environmental problems as more important internationally than they are locally.

It was also suggested that the oil well fires deliberately set ablaze in Kuwait cannot be used as a test case for the ENMOD Convention because the Convention does not apply. Nevertheless, they can be used as a test case to think about what would be needed in a situation where the Convention was applicable and to demonstrate at the ENMOD Review Conference where there are weak points within the Convention that might be strengthened and, if need be, amended.

One of the larger problems with the ENMOD Convention is how to deal with non-state parties. The Chemical Weapons Convention is now attempting to address these problems, and lessons learned from the CWC in this respect should be considered. At the moment, ENMOD is limited in scope due to a limited number of state parties. Another important flaw of ENMOD is the lack of conditions and prohibitions on the development of environmental modification techniques.

Some discussion also focused on the purpose of the ENMOD Review Conference, which is to review the operation of the Treaty with a view to assessing a number of

issues. One will be whether or not the Convention has been complied with. Countries attending will be looking at recommending potential measures for strengthening the operation of the Treaty. The Treaty provides a mechanism for amendment. There would never be an amendment considered seriously unless it was very clear that there was support for it. The most likely process for implementing amendments is through the use of the establishment of a group of experts. The most important consideration in attempting to introduce amendments into an existing treaty is the risk of weakening the treaty through widespread disagreement among the parties.

Two important aspects of the ENMOD Treaty that have not been addressed, it was suggested, are: 1) the use of outer space as a source from which to change the environment, and, 2) the increasing importance of the United Nations Security Council in international security affairs. The ENMOD Convention should include outer space. Even though interpretation of the Convention can result in ambiguities, this should not limit the real purpose. Perhaps the Security Council would be the best source of a straightforward interpretation of the Convention, rather than relying on legalistic views from various conferences such as the Munich, London, and Ottawa Conferences.

SESSION 3

LONDON, OTTAWA AND MUNICH CONFERENCES

Chairperson: Ron Cleminson

THE LONDON CONFERENCE ON ENVIRONMENTAL PROTECTION AND THE LAW OF WAR

Ambassador Philippe Kirsch, Q.C.
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As other meetings that have been convened on Environmental Protection and the Law of Way in the past year, the London Conference which was held on June 3, 1991, was triggered by the impact of the Gulf War on the environment. The two major events were the pumping of crude oil by the Iraqis into the Gulf and two major slicks, and the setting of fire to many well-heads in occupied Kuwait, before and during the Coalition land offensive. But the Coalition bombing also resulted in damage to a number of facilities in Iraq, including nuclear and chemical installations and at least one installation claimed by the Coalition to be a biological production plant (and by Iraq to be a baby-food factory).

The London Conference had some special features to it. It was the first on the subject and as close to an expert conference as could be, comprising experts on the laws of war, environmental law and more general areas of international law. Indeed, none of the participants who belonged to governments responded to an invitation to say something on their behalf. Despite unmistakable signals that the politics of the issue were bound to play a major role, the discussion was probably less influenced by government positions than the conferences that followed. There was, however, an accidental absence of significant military representation from which the conference suffered.

The conference was assembled by three very different organizations: Greenpeace, the London School of Economics and the University of London's Centre for Defence Studies. Greenpeace's approach was very clear. As a campaign organization, it wanted to publicize the issues and to influence the decision-making process in certain directions. On the very day of the Conference, Greenpeace published an extensive case-study of the Gulf War, called "On Impact," which concludes that "unprecedented environmental ruin" took place. The London School of Economics, and in particular the Rapporteur of the Conference, Dr. Glen Plant, provided the intellectual direction to the conference, and later, published a book on it, with an appropriate green cover (Plant, 1992).

One of the elements that made the London Conference different was the tabling by its Rapporteur of an extensive working document which was supposed to serve as the basis for discussion. It did not quite work out that way, partly because, as a result of unpredictable circumstances, including a sudden illness of the Rapporteur, the document could not be made available to many participants until very late. This is unfortunate because its concise treatment of many issues of policy and law could have led to a highly focused discussion. In the event it was not possible for most participants to give it a considered reaction in the time available.

The document was entitled "Elements of a Fifth Geneva Convention on the Protection of the Environment in Time of Armed Conflict." The general premise of its author was that the deliberate, massive environmental damage in the recent Gulf conflict called for a distinct instrument on the laws of war and the environment. That instrument would restate and consolidate the relevant rules of customary law

concerning State responsibility and international criminal law. It would bring the laws of war up to date to reflect major developments in international environment law as it applies in time of peace. The instrument would also improve Geneva and Hague Law to afford greater protection to the environment, and establish a specific threshold of protection. It would also establish a rapid response body, called the "Green Cross," which would carry out in the environmental field functions similar to the Red Cross/Crescent in the humanitarian field, including acting as a Protecting Power for the Environment. What the Rapporteur did not attempt to do was to define "environment" or determine the degree of damage to the environment warranting regulation or prohibition. Nor did he attempt to regulate the first use of nuclear weapons and other weapons of mass destruction.

The document included five parts: Part 1, on "General Principles," defined the scope of application of the Convention (all situations of armed conflicts); restated general constraints on methods, means and objectives of warfare under customary law; and established general obligations regarding the protection of the environment, such as notification and consultation vis-à-vis neutral states and the "precautionary principle." The general principles also provided that the principles of State necessity and military necessity did not automatically prevail over the principle of environmental protection.

Part 2, entitled "Geneva Law" or "Targetry," announced an intention to establish the threshold at which methods and means of warfare were prohibited because of their intended impact upon the environment, but left that threshold entirely open, with four options ranging from a prohibition on <u>any</u> damage to the environment to a prohibition starting at a particular degree of damage, using variations on the criteria used in Geneva Protocol I [Article 35 (3)] and the ENMOD Convention (Article 1). Part 2 focused on the <u>effect</u> of military action on the environment. It largely borrowed and adapted various articles of Protocol I, and established certain obligations accordingly, for example prohibitions on reprisals, prohibitions on attacks upon works and installations containing dangerous forces and on attacks against zones under special protection, and precautionary measures.

Part 3, by contrast, focused on "Hague Law" or "Weaponry" and imposed prohibitions or restrictions on the use of some <u>weapons</u> which might be considered to be excessively injurious to the environment. That part included specific provision on defoliants, herbicides, <u>daisy cutter</u> bombs, massive conventional bombing or cratering and forest plows, as well as mines and booby traps, incendiary weapons and blast effect weapons. Those weapons were not all totally prohibited, but their use was much more severely circumscribed than in existing instruments. As I will not return to specific provisions of the Rapporteur's proposal, let me just comment here that the notion of having Geneva Law and Hague Law coexist in the same document raised a number of queries from participants.

Part 4 dealt in particular with repression of <u>breaches</u> of the Convention and characterized some of them as "grave breaches," for example methods and means of warfare exceeding the (as yet undefined) threshold of warfare I mentioned earlier and contraventions to provisions dealing with attacks on works and installations containing dangerous forces and attacks on localities and zones under special protection. In those cases, criminal prosecution of responsible individuals was justified, under a principle of universal jurisdiction. Some provisions of Protocol I (articles 86, 87, 89 and 90) were reproduced including the establishment of an

International Fact-Finding Commission. Specific criminal proceedings were left open, with a choice between the relevant provisions of Protocol I, providing for mutual assistance in criminal matters, including qualified cooperation in extraction, and more demanding provisions giving a choice between prosecution and extradition along the lines of multilateral conventions against various acts of international terrorism.

Part 5 required the Parties to the "Fifth Geneva Convention" to accept a new organization (Green Cross) for the purpose of applying the Convention and safeguarding the environment, with specific responsibilities for relief. The Parties would provide the new organization with the necessary facilities and could not regard actions that were impartial and remedial of environmental damage as interference in the conflict as unfriendly acts.

At this point, I will leave the structure of the Conference and deal with issues more generally. Indeed, there was little discussion in London of specific provisions of Geneva Law or Hague Law, of a threshold of protection or of non-discriminating weapons. The various segments of the discussion overlapped to a great extent, and tended to revolve around a few general themes:

- State of existing law,
- Methods of supplementing existing law,
- Responsibility and liability, and
- Institutions.

Existing Law

The introductory speech by Carlo Ripa di Meana, European Environment Commissioner, and the initial presentations by Jeremy Leggett of Greenpeace, Professor Richard Falk of Princeton University and Ambassador Helmut Turk of Austria, all pointed in the direction that existing law was inadequate. Professor Falk, in particular, considered existing law scattered, controversial, vague, uneven and of differing levels of authority. Among the points he made were the following.

Military necessity has been subjectively defined in wartime, and has prevailed over inconsistent customary international law with reference to the legal duty to take account of the distinction between military and non-military targets (Principle of Discrimination), to adopt military responses that are proportionate to the situation (Principle of Proportionality) and to avoid tactics that inflict superfluous and severe suffering (Principle of Humanity). Falk's basic premise: what dominant States found useful in war is unlikely to be prohibited and, if it is, the prohibition is unlikely to be respected in the next war. On the other hand, some of the practices of a defeated country are likely to be condemned and incorporated in the laws of way, by interpretation or law-making. Consequently, interpretation and implementation have been inconsistent and arbitrary. So has enforcement which, in addition, has been highly exceptional. However, the Gulf War has generated a legislative moment because the Iraqi practices causing environmental harm fell outside the general perception of military necessity and were performed by a belligerent politically opposed by most and badly beaten.

Falk's approach — that existing law was inadequate and that the Gulf War had created a legislative moment — was strongly supported by some but by no means

generally shared in the course of the discussion. The representative of the Red Cross, for example, was not convinced that there were enough innovative proposals to make, or that these could be accepted. The argument was also made that, because any proposals for new rules might be seen by the parties to the Gulf conflict as implying that their action in that context were illegal, the legislative moment proclaimed by Falk was not really there.

For the sake of simplicity, rather than describing specific positions, I will now give my own impression of the main trends at the Conference on the state of the law. As, understandably, no attempt was made to summarize or draw conclusions at the Conference, any general perception is of course subjective. You will find a more elaborate and slightly different description of those trends by the Rapporteur himself in the book he published at the London Conference and its aftermath. From that description, I will simply mention the common ground that the Rapporteur felt was shared by the various camps. Simply (and selectively) put:

- Deliberate and wanton destruction of the Environment in circumstances where no legitimate military objective is served is contrary to international law.

- The Environment is indirectly protected by certain rules such as the principle of proportionality (between means and methods and the objective), and the prohibition on attacks against non-legitimate military targets, and the prohibition on destruction of enemy property no imperatively demanded by the necessities of war.

- The general criteria of established custom, the principles of humanity and the dictates of public conscience (Martens clause, reflected in Article 1 (2) of Protocol I) now include a requirement to avoid unjustifiable damage to the Environment.

- Destruction by an Occupying Power of enemy property not required by military necessity, gives rise to civil liability. Wanton destruction is a grave breach and can lead to individual criminal responsibility.

- States should widely disseminate and effectively implement existing obligations.

- In addition, general principles applicable in peacetime apply during all armed conflict vis-à-vis neutral States, such as responsibility of States for damage to the environment and other States or of areas beyond national jurisdiction, and the principle of notification and consultation in case of transboundary risk.

Beyond agreement on these basic points, there were two opposite views in London on the state of existing law. The first view was, essentially, that the common ground is all that is needed. The existing customary principles of the law of war, such as the principles of proportionality, military necessity and avoidance of unnecessary suffering, together with the conventional law, which codifies or has come to represent customary law, are adequate to protect the Environment. A number of arguments, some rather disingenuous, were advanced in support of that position. The most serious was, of course, that efforts to limit environmental damage, particularly

collateral damage, to the extent set out in the draft Fifth Convention, made no military sense. Or, as put by a participant in London: "the logic of some of the statements made this morning would be that Kuwait should still be occupied by Iraq."

There were shades and variations, of course, as to what existing law exactly included, notably whether Geneva Protocol I was part of customary law or not. But the bottom line of that position generally was that no further development of the law was required, certainly not now. What was required was essentially better application of existing provisions. A variation was that, irrespective of the merits of supplementing existing law, it was not feasible for political reasons and, therefore, implementation should rather be the focus now.

The opposite position was that existing law was inadequate and had to be further developed, as well as better implemented. Leaving aside for the time being the question of how the law should be further developed, a few minimum improvements were later identified by the Rapporteur:

- Both deliberate and collateral damage must be regulated, with more attention being paid to collateral damage.

- A lower threshold of environmental harm than that in Protocol I is desirable (i.e., less than widespread, long-term and severe damage).

- The law should be adequate to protect the natural environment per se, as opposed to protecting it indirectly through property or human beings. At least, a precautionary approach to the impact of military activities upon ecosystems and the ecology in general should be taken.

- Developments in the international environmental law in peacetime should be reflected as fully as possible in the laws of war — but dealt with in the framework of the laws of war.

- Specific provisions should be further elaborated, e.g., those dealing with objects containing dangerous forces, environmentally harmful weapons, specific areas of land, international crimes or criminal-enforcement mechanisms, other procedures such as verification procedures and the establishment of a new organization.

A third group, which I will simply mention, argued that the distinction between wartime and peacetime in the context of acts of environmental destruction, was vague or even irrelevant. A number of expressions of support in principle for this position were made, but the form this approach might take, or any assessment of prospects for its implementation, was not articulated. Interestingly, this approach was advocated by, among others, the representative of the Red Cross. One of the arguments was that it was illogical to run the risk of setting higher standards, inadvertently, for wartime than for peacetime.

Methods of Supplementing Existing Law

Again, the first speakers in the debate fully supported the development of a Fifth Geneva Convention. The European Community Commissioner went so far as to "pledge that the European Community will do all in its power to ensure adoption of

a Fifth Geneva Convention." Additional protocols were not sufficient to solve the magnitude of the problem. Greenpeace, of course, also fully supported the idea of a Fifth Geneva Convention. It is interesting to note, however, that the Red Cross itself was opposed to it, on the grounds that its primary concern, the protection of the Environment, was rather different from humanitarian law. Some alternatives were suggested, including a third Protocol to the Geneva Convention, or a Convention unrelated to the Geneva process but to be seen as a law of war instrument. None of those proposals were extensively supported.

A very different approach, which received more support, was based on the assumption that the conclusion of a single document that would be substantively satisfactory and politically acceptable was impossible. It was suggested to use interpretative understandings and establish procedures under existing instruments, so as to accelerate the process, i.e., broaden the interpretation of the meaning of "natural environment" and of the level of environmental degradation under Protocol I; further agreements on installations containing dangerous forces; convening a consultative meeting of the Parties to ENMOD in order to modify the accepted understanding on the threshold of environmental degradation, and agreeing to new Protocols under the CUSHIE Weapons Convention. Plus, some measures falling short of new legal obligations (i.e., resolutions, Code of Conduct, etc.).

Responsibility and Liability

It was difficult to find a trend in the discussion of responsibility and liability, despite the many references to these issues. Various options were put forward by the Chairman of the relevant panel: strict liability, along the lines of the International Law Commission's draft articles on "Liability for Injurious Consequences Arising Out of Acts Not Prohibited by International Law"; responsibility for wrongfulness (the strength of which would be increased if some reservations were removed from existing instruments, i.e., if the number of acts considered wrongful were to expand); personal criminalization of offenders, to which the ILC again gave a beginning in its draft code of Offenses Against the Peace and Security of Mankind, and even criminal responsibility of States, a concept so far undeveloped.

Not much discussion took place on these topics. A number of speakers favoured dispute-settlement provisions as a matter of principle. Some advocated the establishment of an international tribunal, others made reference to the competence of the International Court of Justice, but the debate was altogether inconclusive. Individual criminal responsibility was argued for and against with equal vigour.

Institutions

As mentioned earlier, the Rapporteur advocated the establishment of a "Green Cross," with special responsibilities for relief. This followed proposals that had been made for other types of institutions in the previous couple of years: one was for the establishment of a United Nations "Council for Environmental Emergencies," the other was a proposal by the then Pentagonale, dealing with the prevention and settlements of conflicts in this area. Both were primarily designed to deal with peacetime situations, but could have some wartime implications. The involvement of the Security Council had also been advocated.

None of those proposals matched exactly the role assigned by the Rapporteur to a proposed Green Cross, but what was particularly interesting was his rationale for making his proposal, i.e.: (a) a system based on Protecting Powers is inadequate, because the Environment requires an impartial organization; (b) a UN body is unlikely to be considered by certain States as sufficiently impartial to play a role equivalent to the Red Cross in the environmental field; (c) the International Union for the Conservation of Nature and Natural Resources, foremost among non-governmental possibilities, has some government components and might, therefore, also be unacceptable to some States.

With the exception of the same participants who supported the Fifth Geneva Convention in principle, there was very little support for the establishment of a Green Cross. The assumptions of the Rapporteur on the relative neutrality of various bodies because of their composition were questioned and the point was made that neutrality was not the key issue in any event. On institutions, there was a virtual consensus at the end that we should build on the structures of existing institutions, and that the United Nations was a primary candidate as a framework for any new arrangement or arrangements.

Overview

The concluding statement of the London Conference was made by Professor Adam Roberts of Oxford. His perspective was clearly that the legislative moment was not really there, and that application of the law as it exists should primarily be looked at. There was a danger, he said, in rushing into legislation on the basis of one recent episode.

For him, the real issue was that international law/obligations had not been absorbed internally by all (e.g., Iraq). The problem was not the series of flaws set out by Falk but a lack of serious/consistent attention to environmental damage, and that included the Security Council.

Turning to the future, Roberts did not endorse the proposals made by the organizers of the Conference. A basic point he made was that there should be parallel development of the law of war and peace. There was an overlapping area of crimes against the basic principals of both types of law that was not discussed enough.

More broadly, any approach, he said, must stick to two principles:

1) simplicity, given the unpredictability of new situations: one cannot expect legislators to legislate in advance for every eventuality;

2) deal more with principles rather than detail: only then can one allow for changes in technology and tactics.

To concentrate too much on a new Convention entailed the risk of leaving some governments off the hook, by imposing standards so high that they would be impossible to comply with. In any event, in the short term, priority should be given to better implementation of existing law, more ratification of existing Conventions and better dissemination of information within military establishments.

Conclusion

The London Conference was a first attempt to deal with the complex issue of environment and war and we will hear more in the next couple of days about subsequent events. It also did not lend itself to a very structured discussion. What the Conference showed, however, was that the subject matter was probably much too complex to be dealt with in the form proposed by the drafters of a "Fifth Convention." The constant mixture of humanitarian law, weapons law and environmental law made experts uneasy. It was impossible on the basis of the Conference to determine whether new instruments were necessary or what form any additions to the law might take. There was simply too much disagreement on the basic approach proposed at the Conference and too much uncertainty on alternative approaches. But the complexity and sensitivity of the subject matter was there for all to see. It created in the minds of some, myself included, a healthy dose of circumspection for the future, and I will leave it at that.

References

1. Plant, G. Environmental Protection and the Law of War: A Fifth Geneva Convention on the Protection of the Environment in Times of Armed Conflict. Behaven Press, London and New York, 1992.

THE OTTAWA CONFERENCE OF EXPERTS ON THE USE OF THE ENVIRONMENT AS A TOOL OF CONVENTIONAL WARFARE: A SYNOPSIS

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The July 1992 Conference of Experts on the Use of the Environment as a Tool of Conventional Warfare highlighted three main issues, on which I would like to elaborate today.

The first was the basis of the meeting: were there serious gaps in the International Law of Armed Conflict that allowed Iraq to carry out its acts of environmental depredation during the Gulf War? The experts concluded that important provisions of customary and conventional law had, in fact, been seriously violated, and cited UN Security Council Resolution 687, adopted on April 3, 1991, which reaffirmed that Iraq was liable under International Law to compensate for any environmental damage and the depletion of natural resources.

Some officials were under the false impression that there must have been lacunae in the applicable International Law, or else the release of the oil in the Gulf or the destruction of the oil wells would not have taken place. Such views are far from the reality of International Law, where major violations of international instruments occur commonly and the pressing need is not to add to the body of contravened agreements but to implement effectively those that exist.

In fact, the Gulf incident may be considered to be one of the better examples of international efforts to apply International Law. Especially the destruction of the oil wells at the conclusion of the war was a clear violation of the rule against the destruction of enemy property not imperatively demanded by the necessities of war and likely constituted a war crime (Article 23 [G] of 1907 Hague Regulations and Article 147 of the 4th 1949 Geneva Convention), the Rule on Proportionality (Article 22 of 1907 Hague Regulations) and the Prohibitions on Military Operations Not Directed Against Legitimate Military Targets (Article 53 of the 4th 1949 Geneva Convention). These violations are to result in the payment of reparations by Iraq out of oil revenues, according to Security Council Resolution 687, which cited the breaches and provided for settlement. This is the way International Law is theoretically supposed to operate, a far cry from many other serious violations where States do not even raise the matter on the international stage. Recall, for a moment, Iraq's wanton disregard for the 1925 Gas Protocol when it used chemical weapons against its Kurdish population and the heavy silence internationally that greeted the act.

A second important theme to emerge from the Ottawa Session was the evolution of the customary law of armed conflict to reflect the growing body of law on environmental protection. The "Martens Clause" from the Preamble of the 1899 and 1907 Hague Conventions on Land Warfare was cited as the basis for the development of the law. The clause states:

> "Until a more complete code of the laws of war has been issued, the high contracting parties deem it expedient to declare that, in cases not included

in the regulations adopted by them, the inhabitants and the belligerents remain under the protection and the rule of the Principles of the Law of Nations, as they result from the usages established among civilized peoples, from the laws of humanity, and the dictates of the public conscience."

Principle 21 of the 1972 Stockholm Declaration, provisions of the 1982 Law of the Sea Convention and other customary rules based on international cases such as the Trail Smelter Case were raised to reflect the heightened concern of the international community about environmental degradation. The subsidiary issue of how much of the peacetime law on environmental protection applied during wartime consequently became a spirited subject of debate but remained unresolved. Ultimately, the organizers were pleased that there was sufficient consensus to include in the Chairman's conclusions of the Conference the statement that, "The customary laws of war, in reflecting the dictates of public conscience, now include a requirement to avoid unnecessary damage to the environment."

A third issue of particular interest to our workshop was the general view about the application of the ENMOD Convention to the Iraqi actions in the Gulf War. Most experts agreed that the convention did not apply, not only because Iraq was not a party (it had signed but not ratified) but because for ENMOD to apply, it required a State to engage in a technique for changing the environment "through the deliberate manipulation of natural processes" (ENMOD Article II). Releasing oil into the Gulf and the burning of oil wells were generally not considered to fall within the definition. However, one speaker raised the interesting point that the deliberate destruction of the wells involved a serious reduction of the pressure contained in them and that such pressure is a natural process, thus bringing into play the Convention. This exchange highlighted the importance of having a mechanism for third party review. In fact, ENMOD does provide for the convening of a consultative committee of experts (Article V.2) to provide expert views on particular incidents. It is a reflection of the caution of the international community that no State Party to ENMOD requested a meeting of the Consultative Committee to address the Convention's possible application to Iraqi actions in the Gulf War.

In many of our international conventions and institutions, there exist elaborate mechanisms to deal with alleged violations of International Law. It has proven much easier to elaborate these provisions than to rely on them consistently to deal with difficult incidents. Verification of a violation is, of course, a key element in implementing our international rules, but it is important to appreciate that verification is but one element of a complete mechanism of enforcement. The mechanism starts with talking about the alleged breach bilaterally and internationally, and concludes with the assignment of responsibility and the making of restitution. Unfortunately, in many incidents of fault, we do not take even the first step.

THE MUNICH CONSULTATION

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The London and Ottawa Conferences we have just heard about were preceded by a discussion of the legal aspects of environmental protection in time of arm conflict at the Governing Council of the United Nations Environment Programme (UNEP)[2] and followed by a similar examination in the Sixth Committee of the United Nations General Assembly (UNGA).[3] After this second intergovernmental debate, the issue was once again taken up by experts speaking in their personal capacity. A group of fifteen legal experts met in Munich from 13 to 15 december 1991, at the invitation of the International Council for Environmental Law in collaboration with the Commission on Environmental Law of the International Union for the Conservation of Nature.

The London and Ottawa Conferences produced documents issued under the sole responsibility of their authors, respectively Rapporteur and Chairman. The UNEP and UNGA debates ended up in the first case with an invitation to give the matter further thought and in the second with a purely procedural decision. Contrary to these rather limited results, the Munich Consultation on the Law Concerning the Protection of the Environment in Times of Armed Conflict adopted by consensus a set of detailed recommendations, divided into two parts.[4]

This division reflects the participants' awareness of the fact that intergovernmental debates in this area run the risk of weakening the legal value of existing provisions. Any attempt to strengthen the law through the promulgation of apparently new rules could cast doubt on the binding character of earlier ones, particularly for States which would not bound by the new rules.[5] The same problem would arise in case of failure of such an attempt, particularly if in the process certain States explicitly refused to recognize that binding character. This risk explains why the observer of the International Committee of the Red Cross in the Sixth Committee stated that "in spite of certain lacunea and imperfections [the principal provisions of law applicable today] constitute a solid basis for the protection of the environment in time of armed conflict".[6] It is also what caused participants in the Munich Consultation to clearly identify in their recommendations those oriented towards increasing the effectiveness of existing law as opposed to further development of the law.

In the first part of its recommendations the experts group recalled in particular that Protocol I prohibits attacks on the environment per se, as well as making use of the environment as an instrument of warfare. It observed that the fact that the environment itself is an object of legal protection in time of armed conflict implies that traditional perceptions of proportionality and military necessity have become obsolete. It highlighted the importance of customary international law, which prohibits inter alia devastation not justified by military necessity.

The group also urged States to accept the competence of the International Fact-Finding Commission provided for in Article 90 of Protocol I, whose task it is to enquire into alleged violations of the 1949 Geneva Conventions or the 1977 Geneva

Protocols.[7] Finally it drew attention to the fact that the rules of international environmental law continue to apply between parties to an armed conflict and third parties and recommended clarification of the extent to which these rules continue to apply between parties to the conflict.

The second part of the Munich recommendations, relating to further development of the law, deals with the following subjects: duty to protect the environment per se; emergency preparedness; information necessary for environmental protection; prevention; duties of neutral or non-belligerent States concerning the environment; impact of scientific progress; dangerous forces, ultra-hazardous activities and potentially dangerous sites; threats to the peace; responsibility/liability; dispute settlement; and fora for the further development of international law.

Time constraints do not allow us to analyze here in detail the contents of the recommendations agreed to by the group under the preceding headings. Two issues, vigorously debated but finally reflected in a rather diluted form, nevertheless seem worthy of mention. Concerning the duties of neutrals or non-belligerents, the initially proposed text spoke of a right of intervention of these States on the territory of a State that could not or would not take the necessary measures to prevent damage to the environment. This proposal was inspired by the "right of intervention", humanitarian or otherwise, currently championed by some.[8] All that remains of it is a footnote referring to the "protecting power" concept under the Geneva Conventions.[9]

In the paragraph relating to threats to the peace, certain experts wanted to refer explicitly to Chapter VII of the UN Charter and state that the Security Council should consider hostile action causing or likely to cause significant damage to the environment as a threat to international peace and security and that it should exercise the powers it has in such circumstances. This question is part of a larger debate on an eventual extension of the Council's competence to non-traditional threats to international peace and security (terrorism, drug trafficking, weapons proliferation, human rights violations, etc.).[10]

References

1. The author was in charge of environmental law from 1983 to 1985 and Head of the UN, Human Rights, Peace and Security Section in 1987 and 1988 in the Legal Operations Division of the Department of External Affairs. The opinions expressed here are however his own and do not necessarily reflect those of the Government of Canada.

2. The UNEP discussion resulted in the adoption of Governing Council resolution 16/11 of 31 May 1991, section B, para. 2.

3. The UNGA examination resulted in the adoption of General Assembly decision A/46/417 of 9 December 1991.

4. These recommendations were reproduced in 27 Environmental Policy and Law (1992) 63-64.

5. This type of problem is neither insoluble nor unprecedented in international law. It occurred for instance in 1984 in the context of the incorporation of the prohibition on the use of force against civil aircraft in the Convention on International Civil Aviation, done at Chicago on 7 December 1944, in force on 4 April 1947, Canada Treaty Series 1944/36. Following the destruction by the Soviet Union of a Korean Airlines plane which had overflown its territory without authorization, care was taken to formulate this prohibition without casting doubt on the illegality of the Soviet action. This was done in paragraph a) of new article 3 bis of the Convention, according to which the contracting States "recognize" that "every State" (not only contracting States) "must" refrain from resorting to the use of weapons against civil aircraft in flight, a formulation which is clearly declaratory of existing law. See on this point Fauteux, La pratique du droit relatif au maintien de la paix et de la sécurité internationales, 47 Revue du Barreau du Québec (1987) 625-665, at p. 635-637.

6. Doc. A/C.6/46/SR.18 of 25 November 1991, para. 48.

7. As of 4 December 1991, 24 States, including Canada, had made declarations accepting the competence of this Commission.

8. See in particular in this connection Bettati, Un droit d'ingérence, 95 Revue générale de droit international public (1991) 640-670.

9. This concept appears in common article 8 of the four Geneva Conventions and in article 5 of Protocol I.

10. Concerning these threats see the Declaration of the President of the Security Council of 31 January 1992, doc. S/23500.

SESSION 3: DISCUSSION

In the discussion of three previous environmental conferences (the London Conference, the Ottawa Conference and the Munich Conference), it was first pointed out, in answer to a question, that the Secretary General of the United Nations has the distinction of being the depositary of the ENMOD Convention. A depository, however, has to be very careful because one of the issues is who is in authority and who is not. The Secretary General is trying to settle that before the Review Conference. Beyond the question of depository, under the UN Charter, the Secretary General has certain powers for fact-finding and making recommendations.

Another participant suggested that the negotiation of international agreements is a very lengthy and costly procedure. There is a risk that existing norms might be weakened by attempting to improve them through negotiation as opposed to establishing new stronger norms outside negotiations first. For example, after the shooting down of Korean Air Flight 007 in 1983, there was no treaty specifically designed for this instance. Therefore, customary international law had to be used to take action against the Soviet Union. But this was not sufficient until Western States were able to put the rule of customary law into treaty form through a general consensus by all States recognizing that it is prohibited to shoot down civil aircraft.

Another question raised in the discussion was whether the ENMOD Convention permitted differentiation among different countries. In some treaties there is preferential treatment for developing countries, such as the Montreal Protocol protection the ozone layer. Some treaties exist where there is differential treatment on the basis of development. This is not the case for the ENMOD Convention.

It was pointed out that a variety of organizations have proven to be helpful at conferences on the environment in establishing viewpoints and criteria related to environmental concerns. The Ottawa meeting was hosted by governments in conjunction with the United Nations. UNEP met very shortly after the Gulf War. A resolution was adopted inviting states to study ways and means of renouncing methods of warfare that may have severe effects on the environment and to consider elaboration of provisions. The Munich meeting was convened by the International Council of Law and the International Union of the Conservation of Nature. Some of these meetings have not been very successful in promoting change.

Discussions turned to the question of criminal responsibility. One important reason that Saddam Hussein was not tried for War Crimes was the inherent fear of arousing the Arab world against the West. The issue of responsibility and liability was a key one. It was suggested that the Coalition members wanted to maintain a degree of stability in the region. Another participant pointed out that Hussein was not tried as an environmental terrorist because of the lack of law on environmental terrorism. International law must be codified before Hussein could be tried for international crimes of environmental negligence and degradation.

The discussion again focused on the need for the development of an effective mechanism whereby new ideas could be introduced into an existing agreement without diluting the original intent and purpose of the agreement.

It was pointed out that one of the considerations at the ENMOD Review Conference will be to prevent any further loss to the credibility of international treaties. Iraqi behaviour with respect to the Nuclear Non-Proliferation Treaty had been seen to be in contravention of that agreement, even if the Treaty was not technically violated. Similarly, to the public, there seem to be a gross violations in Kuwait of all expectations regarding protecting the environment. The loss of public credibility in international instruments as a result of difficulties respecting the technicalities in the wording of the ENMOD Convention must be avoided.

SESSION 4

VERIFYING OBLIGATIONS RESPECTING ARMS CONTROL AND THE ENVIRONMENT: AVAILABLE TOOLS

Chairperson: A.D. Bryce

THE ENVIRONMENTAL MODIFICATION (ENMOD) CONVENTION: UPGRADING VERIFICATION THROUGH EXPERIENCE

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Introduction

The year 1992 seems likely to provide a significantly new perspective in terms of verification operations. Multilateralism, in particular, will likely become more important in this context. As the authors of the study entitled Verification to the Year 2000 concluded, in the next decade "multilateral agreements will become more complex and more significant than bilateral treaties".[1]

There are those who would say that with the change from confrontation to cooperation between East and West, the need for verification has vanished. Short-sightedness indeed. So long as there is distrust between nations -- and that has hardly diminished internationally -- verification will be essential. Perhaps the admonition "trust but verify" has a greater relevance today than in the timeframe within which President Reagan formulated it, nearly a decade ago.

The rapid evolution of events, particularly as they continue to unfold in Europe, has created a new climate within which the future of multilateral cooperation on security-related matters will be fashioned. The cumulative effect of these events is likely to be seen as the hallmark of the last years of the 1980s and the early part of the 1990s. It could determine the global security agenda well into the next century. The arms control and disarmament process, and its verification subset, cannot help but be affected by these dramatic events. It seems prudent, therefore, that the minimalist approach of verification which typifies the ENMOD (and other agreements created during the same time period) should be reviewed in terms of experience gained in the early 1990s.

New global verification considerations, which provide sharpened focus on the multilateral perspective, could become part of the verification provisions of a number of multilateral treaties completed in the 1970s that should be revisited. As with the BTWC, whose Review Conference called for such a revisit, the 1992 ENMOD Review Conference should consider the verification provisions in terms of their effectiveness for an agreement, which is in itself unique and one with significant implications for future global security.

Canada's Approach

Since the end of the Second World War, Canada has been a prominent participant in most of the multilateral arms control discussions of this period. Indeed, apart from the major powers, few countries can claim as long or as important an involvement in this process, as can Canada. This almost unrivalled background has provided Canada with a unique opportunity to contribute to the

multilateral arms control process and has permitted Canada to acquire considerable experience in, and understanding of, this process.

Experience from a number of initiatives and activities that are akin to arms control could have application to ENMOD verification. The Open Skies agreement just concluded is one current example. A second is the United Nations Special Commission (UNSCOM) and its operational mandate under Security Council Resolution 687 to verify Iraqi compliance. In Open Skies, as well as in future United Nations operations, experience suggests that resources available in the private sector have potential, perhaps from an unconventional perspective, to help in improving operational cost-effectiveness.

Open Skies

The "Open Skies" concept, initially proposed by President Eisenhower in 1955, revisited by President Bush in 1989, and under negotiation in Ottawa, Budapest and Vienna between 1990 and 1992, was signed in treaty format at the CSCE Follow-Up Meeting in Helsinki on 24 March 1992.

The Bush proposal expanded upon Eisenhower's earlier suggestion in terms of concept, geographic area and membership; throwing open for virtually unrestricted aerial surveillance all of the territories of North America, Europe and the Soviet Union. The significance of the proposal, which is not tied to any particular disarmament treaty scenario, lies more in its potential to build confidence than in the capabilities of the verification systems expected to be employed. The theme of this initiative is "openness" and "transparency" rather than "inspection" per se. Thus, the regime's major benefit derives more from the confidence-building dimension than from any treaty-related verification benefits which might be forthcoming.

For more than 30 years relatively little attention was focused on the use of aircraft in a strategic sense as a method for overhead reconnaissance for arms control purposes. In September 1986, this general pattern began to change with the signing of the Stockholm Declaration on Confidence- and Security-Building Measures in Europe. Termed the "Stockholm Document", the agreement provided for a system of monitoring and observation of military activities in Europe using a combination of aerial and ground inspection measures. Although not seen initially as a breakthrough in terms of airborne surveillance for disarmament verification purposes, the agreement by the 35 participants of the Stockholm negotiations to four paragraphs (numbers 89-92) of the Stockholm Document in retrospect proved to be a significant turning point.

Now that a successful Open Skies agreement has been achieved and given the explicit commitment to Aerial Inspections in Article XIV of the CFE Treaty, harmonization of these two concepts and capabilities, at least in terms of the Atlantic-to-the-Urals zone of application of the CFE Treaty, is essential. It seems likely, therefore, that technical meetings after Helsinki 1992 focusing on concept harmonization and practical application will be essential. The possible application of these technologies, as a supporting concept for the ENMOD Treaty, deserves to be explored.

UNSCOM Operations

The UN Special Commission (UNSCOM), established to verify Iraq's compliance with the provisions of Security Council Resolution 687, is not arms control in the traditional sense. Nevertheless, in terms of process, operational procedures are similar. Through an intensive set of first-phase inspections, UNSCOM has established a methodology for compiling sufficient baseline information to verify Iraq's capabilities and facilities in the nuclear, chemical, biological and missile fields. The significance of this experience is that it provides an opportunity, on a realtime basis, to understand and quantify results from an operational perspective.

The UNSCOM experience in fulfilling its initial mandate has been successful. Although the proverbial "smoking gun" related to a nuclear weapons production program remains elusive, the evidential "power burns" are clear enough to cause serious concern. Indeed, the International Atomic Energy Agency (IAEA) has, for the first time in its history, condemned a member state -- Iraq -- for violation of its safeguards agreement. It expressed its grave concern about Iraq's "deception and obstruction" of IAEA inspectors. Physical obstructionist tactics displayed by the Iraqis, and a general practice of misinformation/disinformation in other areas, continue to be worrisome indicators as the Special Commission turns its attention to the issue of longer-term compliance. Much of this experience could be relevant to a study designed to revamp the verification provisions of the ENMOD Treaty.

Commercial Space-based Imagery

Added to the application of experience gained from the Open Skies and UNSCOM concept of verification, is the possible use of overhead imagery as a means of improving on-site inspections. The use of commercially available imagery by Coalition forces during the Gulf War illustrates the potential and practical usefulness of commercial imagery in activities akin to verification and peacekeeping. Experience extrapolated from UNSCOM operations suggested a closer correlating between verification and peacekeeping in the future. As a result, it seems reasonable to suggest that commercial satellite imagery could be particularly well suited for preparation and planning for verification purposes for treaties such as ENMOD as well as for other activities such as peacekeeping operations. Even given its limitations, commercial satellite imagery could greatly improve the quality of information available for planning during the initial preparatory phase. Planning for operations must be done with little or no on-site access. Maps may well be out-of-date or have unsuitable scales.

Commercial satellite imagery is useful to detect new areas of development and to provide documentary evidence of widespread pollution. Developments located at the periphery of a city (Baghdad for example) are easier to recognize than those in areas that are already identified on the map as being developed. Areas of development within a city may be detectable if there is a clear change in land use that can be interpreted from the imagery. Such imagery can also provide basic information on military facilities that are not shown on maps, or for which very little information is shown. In some cases, when maps may be inadequate because of scale or quality, commercial satellite imagery might be the only reliable source of information. This type of support could significantly increase the effectiveness of on-site inspections.

The advanced notice that would be required to order the imagery would not necessarily be a serious problem for such an application. Much of the information derived from the satellite imagery could still be useful after one year or more.

Although commercial satellite systems are now well suited for direct monitoring of military capabilities, airborne systems such as those associated with Open Skies could provide more timely information with finer spatial resolution.

Conclusions

The conclusions to be reached in terms of the use of space-based imagery, of the application of the Open Skies concept and of on-site inspection, as verification mechanisms for purposes related to ENMOD, are both positive and promising in terms of the future. The Open Skies concept has been transformed from its Cold War origins, into a mechanism for coping with the multi-facetted arms limitation and disarmament problems of modern Europe. While it will serve significantly as a confidence-building measure in terms of pan-European security, it will also help strengthen the purposes of the CFE Treaty and could serve as a useful option in terms of reducing regional tension. From the standpoint of the Euro-Atlantic community, for example, it is the only measure encompassing the territory from "Vancouver to Vilnius to Vladivostok". From the global perspective, it could serve as a model which might, perhaps, be adapted in time to meet concerns in other regions.

The conclusions derived from the UNSCOM operations and their application to a possible modification of ENMOD verification principles are less certain. It is possible, however, that verification activities in the context of ENMOD could involve a similar lack of cooperation, even hostility, on the part of the country being investigated, as has been true in the case of Iraq, making the UNSCOM experience very relevant. As UNSCOM and the IAEA confront the difficult issues likely to arise in connection with the destruction, removal or rendering harmless of Iraq's weapons of mass destruction and the facilities for their production, and as the plans for ongoing monitoring and verification are put into effect, continued strong support of the Security Council, the Secretary General, the Secretariat and Member States of the United Nations is seen as essential.

Although commercially available remote sensing systems are similar in some respects to military reconnaissance systems, the context in which they are most likely to be used is quite different. Commercially available systems could be adapted appropriately for verification purposes in support of ENMOD compliance. Such technology used for verification-related monitoring can be made available to all participants in the treaty regime to prevent any perception that some are at a disadvantage.

References

1. Sidney Graybeal, et al., Verification to the Year 2000, Arms Control Verification Study No. 4, (Ottawa: External Affairs and International Trade Canada, February 1991), p. 50.

AFTER THE SHOOTING STOPPED: USING REMOTE SENSING TO FIGHT THE KUWAIT FIRES

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Coalition forces advancing through Kuwait encountered the most literal scorched earth retreat the world has ever known. Saddam Hussein's forces carried out their orders to set ablaze every oil well, gathering station, and pipeline facility throughout Kuwait. Virtually no well head escaped the destruction, and most of the gushing streams of oil were successfully ignited. The pall of smoke covering the Al Magwa and Al Burgan oil fields may have been the most optically dense cloud in history. It would be only a small exaggeration to suggest that no ray of visible light from the sun could penetrate the cloud to the ground and then survive reflection and retransit of the cloud. The ground beneath the smoke was wholly invisible from above, at least in that wavelength region to which human eyes are sensitive.

From the ground the scene was apparently one of darkness, illuminated only weakly by the "torch light" provided by more than 300 fires in the fields nearest to Kuwait City, and shrouded in a mist of unburned hydrocarbons and soot. At least as many more fires were burning elsewhere in the country causing local disruptions. Visibility was restricted to short distances in many cases. Indeed, travel in the Magwa and Burgan fields was made particularly hazardous not by the fires, but by the oil flowing from the few wells which did not burn. These wells produced mammoth oil lakes stretching several kilometres and often more than a kilometre wide.

The lakes were the hazard, for the oil in Kuwait is under enormous pressure from natural gas which becomes dissolved in the petroleum. The gas was trapped in the oil lakes by a thin skin which formed on the surface as the lighter fractions cooked off in the heat. The skin, of course, was fragile, and the lakes difficult to see from a car or jeep. At least once a vehicle cracked the skin, permitting natural gas to escape; the gas contacted the hot exhaust system of the car where it ignited, incinerating the automobile.[2]

Since a ground-based survey was not feasible, air- or space-based reconnaissance was the only remaining choice. Two tasks were identified by the firefighting team of Kuwait Petroleum Corporation: determine which wells were burning, and chart the boundaries of the oil lakes to facilitate ground operations.

Conventional aerial photography was useless because of the opacity of the smoke (in the visible region it is impossible to see the fires through the smoke, and in the near infrared waveband only a few fires near the periphery of the conflagration are bright enough to be detected); there are few airborne thermal infrared cameras; and the turbulence from the flames made it difficult for an aircraft to fly a straight course over the major oil fields.

In April of 1991 Henry W. Kendall of MIT asked me if I thought that the Landsat thermal infrared sensor was sensitive enough to detect the fires and if it had high enough resolution to distinguish between fires in adjacent wells. I said that I was certain that the sensor would be able to detect thermal differences at the top of the

clouds caused by heating beneath, and that the 120 meter IFOV of the thermal sensor was adequately smaller than the 1 kilometre (average) well-to-well spacing, but that I was not sure if the heat transport mechanism was primarily radiative or convective. Radiative transport would mean that one would see the fires directly; convective transport would smear the heating out over a much broader area, possibly permitting adjacent fires to merge into a larger blob. I said that I was willing to try the experiment if Kendall and the Union of Concerned Scientists could fund the purchase of a 15 kilometre square Landsat floppy disk set. In a matter of days UCS made the funds available and, acting with uncharacteristic speed, EOSAT prepared a data set covering the western part of the Burgan field and extending out into areas of the desert which were not shrouded in smoke so that some landmarks could be found.

Within minutes of bringing up the Landsat band 6 (10.5μ - 12.5μ) thermal image on my image processing system it was obvious that the fires could (a) be detected and (b) be distinguished, despite the "blooming" of the saturated thermal detector, which was designed to be sensitive to radiation from objects at temperatures between -70 C and +70C. Unattenuated radiation from a fire would have driven the thermal detectors into saturation except for the fact that the instantaneous field of view of the band 6 instrument is 120 m; hence, the reported temperature was an average of the temperature of the smoke at the top of the plume and the radiation from the fire, a relatively small source.

The heat transport mechanism appeared to be dominated by radiation with an admixture of convection. That was confirmed as the shorter wavelength infrared bands (7, 5 and 4) were examined: most of the fires were visible at 2.08 - 2.35 μ (band 7) and appeared as small bright spots, usually one pixel in extent, sometimes dimmer but covering four pixels. At successively shorter wavelengths fewer and fewer well fires could be distinguished. For this test image it was clear that only thermal infrared radiation in the wavelength region 10.5μ - 12.5μ was able to penetrate the thickest part of the plume.

Within the next several days photographs were taken of the image processor screen and forwarded to Mr. Ralph Brown of Kuwait Petroleum, Inc. in London, head of the firefighting task force. He concurred that the remotely sensed data had accurately located the burning wells, and equally importantly, seemed to have identified those wells which were not burning by the absence of a signal. The image with the greatest apparent value was density sliced into a very few discrete levels so that any band 6 signal above a reasonable threshold was displayed at very nearly the full (red) brightness of which the system was capable, mid-range temperatures were shown at a middle red, and temperatures at the level of the average smoke plume were represented with a very low data number. Because the individual fires were relatively small in spatial extent, they occupied only a small part of the 120 meter square (1.44 hectare) pixel; in consequence, the average temperature within a pixel which included a fire was not often high enough to saturate the detector.

Band 7 was displayed in green and band 5 in blue. Thus, the most intense fires appeared as red circles with blue-white centres, less-intense conflagrations were represented as red circles with yellow centres, and the least intense signals simply as red circles. This technique made it possible to identify small discrete fires within a region of extended combustion. I counted 169 fires within the 15km square image used for the test. The oil lakes from damaged but not burning wells were not visible.

The success of the test led to an agreement to survey all of the oil fields known or thought to have been burned during the war. Initial calculations indicated that four complete Landsat scenes would be necessary in order to carry out the survey (Path/Row combinations 166/39, 166/40, 165/39 and 165/40), and these images were ordered from EOSAT. Images from Path 166 were acquired on May 5 by Landsat 4; those from Path 165 on April 28 by the same satellite.

Work began at the Centre for Remote Sensing of Imperial College, London, on 17 June 1991 in collaboration with Dr. Michael Barnett, director of the Centre, and Mr. Vipin Gupta, a Marshall Scholar from the United States who was a graduate student at the Blackett Laboratory. The oil fields of interest were designated for the research group by a representative of Kuwait Petroleum, and image processing commenced that afternoon.

The weather on the acquisition dates was slightly more favourable to the analysis than it had been when the first test image was obtained. That is, the wind velocity was higher reducing the opacity of the smoke plumes. As a result it was possible to "see" the heat sources in band 7, thus providing significantly better spatial resolution (i.e., 30 meters rather than 120 meters) than was available with the band 6 sensor.

Imagery was displayed as bands 6,5,1 (Red, Green, Blue) or 7,5,1 (RGB). The visible blue band was used consistently in order to make clear which wells were emitting "white" smoke, indicating a higher water content in the fuel, and hence the likelihood of greater brine intrusion into the wells. Except for a small triangle intruding into the Burgan field from the east, the entire field appeared to be alight, with only scattered gaps in the regular grid of burning wells. The intrusion was later found to be in the area where the first fire fighting teams had already extinguished a large number of blazes.

The Wafra field near the southern border of Kuwait proved to be a surprise. It was expected that no fires would be burning there because the low pressure of the wells required pumping to lift oil to the surface. Instead, four burning wells were found together with a destroyed gathering station. Because Wafra had been the site of a farming village we used the normal techniques of remote sensing to determine the health (or lack of it) of the fields. All were found to be dead or dormant, but a strong algae bloom was found on a water lagoon at the gathering station.[3]

One field, known to be under high pressure, was burning both intensely and relatively cleanly. We attributed the relative lack of smoke plumes to the presence of a high content of natural gas which burned without forming soot. Within this same field Iraqi fire trenches, earth works, strong points, and military roads could be clearly identified, even at the relatively poor resolution of the Landsat instrument. This identification gave additional credence to the supposition that my inability to find such visible military features in the August and September, 1991 Soviet imagery indicated that those features were, in fact, not present at the time.[4]

Oil lakes were identified on the afternoon of 20 June in the Magwa and Burgan fields. Their detection was owed solely to the properties of the Landsat instrument, and could not have been accomplished without the use of both bands 5 and 7. It was recognized that the lakes could not be detected in reflected sunlight, even infrared insolation, because very little radiation reached the ground through the plume, and

because the sun's radiation is not terribly rich in mid-wavelength infrared (presumably if it were, our eyes would have evolved to see in that wave band). However, the ground is richly illuminated in the mid-IR range because of the light from the oil fires themselves.

It did not prove possible to measure the temperatures of the fires directly using satellite imagery.[5] Indirect evidence of the temperature of the fires comes from the fact that metal structures (presumably steel) were softened but did not liquefy. A reasonable guess is that the temperature at the surface of the flames was between 1500 K and 2000 K, placing the peak intensity of the illumination between 1.45μ and 1.93μ. TM bands 5 and 7 correspond to wavelengths of 1.55-1.75μ and 2.08-2.35μ, respectively, so both bands should be strongly illuminated by firelight. This is, of course, confirmed by our ability to see fires in both bands when the smoke was not too dense.

By performing a non-linear transformation of the data numbers from bands 5 and 7 it was possible to emphasize regions which were just barely brighter than the average as seen through the plume. By further exploiting the fact that oil appears to reflect more strongly in band 5 than in band 7, we found it possible to develop a signature which almost unambiguously selected out pools of oil on the ground. Pooled oil could, therefore, be identified along the northern edges and into the central regions of both the Magwa and Burgan fields using this technique. Naturally, this technique failed in the regions where the smoke plumes were opaque enough to obscure even the fires in band 5.

As of the date of the satellite survey my colleagues and I counted a total of 529 oil fires burning in liberated Kuwait. By far the majority of these were in the Magwa and Burgan fields south of Kuwait City. Luckily for the inhabitants of the city, the winds blew predominantly from the northwest, taking the worst of the pollution away from the center of population.

When the number of fires obtained by direct observation as of the dates of the survey was combined with the number known to have been extinguished by that date, a revised estimate of the number of burning wells was made. Taking into account some uncertainties in the identification of well fires, as opposed to fires at gathering stations, it appeared that the Iraqis had set alight between 640 and 650 wells[6], as compared to the original estimate of only 611.[7]

Copies of the images processed at Imperial College were rushed from London where they were prepared to the field. The satellite survey of Kuwait made a significant contribution to the planning and execution of the fire fighting effort. Although plans were made for a second survey using imagery acquired in August, 1991, the survey was not carried out because of the rapid progress made by the firefighting teams. The last well fire was snuffed out on 6 November 1991, more than a year ahead of the most optimistic of the estimates made in the first days after the war.

* * * *

I thank my colleagues at Imperial College, London, Dr. Michael Barnett, Mr. Vipin Gupta, and Mr. Miroslav Honzak, for their efforts in the analysis of the Kuwait survey images and for making available the resources of the Centre for Remote Sensing. I am especially grateful to Prof. Henry Kendall of MIT for suggesting that

Landsat imagery could be useful in fighting the fires and that I had a contribution to make.

References

1. Copyright 1992 by Peter D. Zimmerman; all rights reserved.

2. Discussions with Ralph Brown, head of the firefighting task force of Kuwait Petroleum.

3. Ralph Brown, Kuwait Petroleum. Private communication, 17 July 1991.

4. See Jean Heller's article in the January 6, 1991, St. Petersburg (Florida) Times, p. 1, for a discussion of the results of a study of occupied Kuwait using Soviet images from the KFA-1000 camera. No military activity in Kuwait was detected in this set of pictures, although Coalition forces and aircraft were clearly evident in a picture of Dharan airport taken by the same satellite on the same roll of film. The KFA-1000 images exhibited resolution between 5 and 7 meters.

5. Anthony R. de Souza, ed., Environmental Consequences of the Persian Gulf War, 1990-1991; remote sensing datasets of Kuwait and environs, National Geographic Society Committee for Research and Exploration (Washington: 1991), p. 18 and references cited therein.

6. Ralph Brown, private communication, 18 July 1991.

7. John H. Cushman, Jr., "Environmental toll mounting in Kuwait as oil fires burn on", The New York Times, p. C4, 25 June 1991 (quoted in A.R. de Souza, op. cit.).

AIRBORNE SENSING FOR THE VERIFICATION OF NON-COMPLIANCE OF THE ENMOD CONVENTION: APPLICATIONS AND LEGAL IMPLICATIONS

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Abstract

The use of airborne remote sensing techniques as applied to environmental monitoring are investigated. The legal implications on the use of remotely sensed imagery in courts of law are addressed through specific case studies where overhead imagery has been admissible as legal evidence. Some examples of existing remote sensors and their present day applications related to mapping environmental disasters are summarized. Suggestions for the use of airborne monitoring techniques for verification of non-compliance of the ENMOD Convention are presented.

Introduction

Airborne remote sensing techniques have been used for large-scale environmental mapping purposes for decades. Remotely-sensed images are used routinely for the mapping of environmentally affected disaster areas over land, sea and air. Some of the applications include: the monitoring of oil spills, real-time mapping of forest fires, forest damage assessment as a result of defoliation, and flood mapping. Airborne sensors are also flown to collect information on a regular basis for meteorological studies, including data collection for the assessment of air pollution and as a tool to promote the production of rainfall through the process of cloud seeding techniques. The sensors and sophisticated electronic equipment employed for these applications range from simple aerial cameras, to more exotic sensors such as imaging synthetic aperture radars and laser fluorosensors. First, some of the legal implications on the use of these overhead sensing techniques will be addressed.

Legal Implications on the Use of Overhead Sensors

Overhead remote sensing and detection techniques are only <u>one</u> tool that should be considered when used for the collection of evidence for environmental monitoring. The admissibility of remote sensing data and maps prepared from them in a particular litigation context will depend on adherence to the applicable rules governing scientific evidence (Jaynes, 1983). Each jurisdiction will have its own rules of admissible evidence and judge-made requirements related to the reliability of evidence from scientific procedures. When used as a forensic tool, remote sensing has been utilized in legal enforcement; remote sensing has been utilized in legal proceedings by the United States Environmental Protection Agency (EPA) and the United States Justice Department (Foresman and Williams, 1990). Courts have allowed the use of remote sensing imagery and maps based on the theory that their use represents an image based method of communication by a witness, similar to any other method of giving testimony (McDermott, 1986). <u>The Evidence Handbook</u> addresses the applications and acceptability of the use of graphics and photographs in a court of law, although the use of remote sensing imagery is not specified specifically (Donigan and Fisher, 1975).

The science of "policing from the air," because it involves relatively unknown and sophisticated technologies, is inherently full of areas which present immediate problems when used as legal evidence (O'Donovan, 1989). If remote sensing imagery is presented in a courtroom, the presentation format of the data is very important. The data must be presented in such a way that all parties have an equal view of the images, whether it is through the use of video monitors or by the use of "hard copy" images. In order for remote sensing imagery to be seriously considered as admissible evidence in a court of law, everyone must be educated on the basic operation of the equipment being utilized, its capabilities and limitations, and some understanding of interpretation and analysis of the data being presented. Trust in the data being used must be built through a complete understanding of the information, from its acquisition to its utilization. Remote sensing expert witnesses should be fluent in the technology which is being presented and be capable of providing concise and clear explanations of both data and methods (Jaynes, 1983). Most importantly, all overhead data presented must have complete ancillary information accompanying it, such as date and time of acquisition, positional information such as latitude and longitude and aircraft information such as flight height, direction and speed.

It could be argued that the collection of remote sensing data infringes upon a person's right to privacy. However, it does not appear that the acquisition of overhead data from an aircraft interferes with anyone's reasonable expectation of privacy (Tuerkheimer, 1972). Remote sensing data records information that is exposed in the open that could be observed from any passing aircraft and privacy is not jeopardized as a result.

Existing Agreements and Case Studies

While it is recognized that there are numerous types of agreements related to environmental protection, only a few are listed below. Also included are some selected examples of case studies where remote sensing has proven useful in a court of law. This by no means represents an exhaustive list of agreements or case studies, but does provide directly related examples with respect to law and the use of overhead imaging.

There are several international agreements now in effect which protect the environment, many of these related to pollution from ships. Some of these include: the International Convention for the Prevention of Pollution from Ships (MARPOL, 1973), the Bonn Agreement, the London and Paris Convention, the International Maritime Ships Traffic Separation Scheme Regulation, and the Fishing Protection Agreements. Of these agreements, the MARPOL Convention is the only one that utilizes internationally accepted standards for the assessment of the quantity of any visible oil spill. Experiences with remote sensing equipment in the Netherlands for oil spill monitoring, combined with the use of the MARPOL criteria as a standard, have been successful in establishing parameters for the establishment of evidence.

The utility of overhead remote sensing data as an investigational tool for the monitoring of flood studies has been demonstrated in Australia (Whitehouse et al., 1987). Remote sensing imagery in the form of aerial photography combined with Landsat satellite images has been used as hard evidence of flood behaviour, and when properly interpreted could not be challenged in the Australian courts.

The use of Landsat satellite imagery and aerial photography has been used in Florida in a case demonstrating surface drainage modifications and overall extent of vegetative damage due to flooding caused by site development (Foresman and Williams, 1990). All imagery and related maps made from the data were admissible in court.

Historical aerial photography ranging from 1971 to 1980 of illegally buried liquid industrial wastes in Michigan indicated suspected on-going burial activity. Photointerpretive information combined with affidavits by former employees were used to obtain evidence to direct more detailed on-site investigations, resulting in a conviction (Foresman and Williams, 1990).

Sensors and Airborne Monitoring Techniques

Airborne monitoring using sensors can be categorized into three areas of applications: land, sea or air. There are several different sensors that are capable of functioning optimally for various applications. Each of the commonly used remote sensor types and some of their proven environmental applications are listed below. This list does not include all remote sensing systems or applications available today, but does represent those systems commercially available "off the shelf" with proven environmental applications.

Aerial Cameras and Electro-optical Devices

The simplest and least expensive of effective sensors is the aerial camera. Aerial photography can provide very high spatial resolution imagery without the need for a highly sophisticated aircraft platform or complex data processing and interpretation equipment. The resolution and swath width of aerial photography are directly related to aircraft flying height. The higher the aircraft, the lower the resolution and the wider the area covered by the camera. Aerial photography has the flexibility of various lens and film combinations to optimize the scale and spectral ranges of the imagery.

The most recent advance in optical aerial camera systems is known as charged coupled devices (CCDs). These camera systems use digital technology with imaging detectors rather than film. The advantage of these systems over conventional aerial photography is their ability to operate in low-light conditions and produce high spatial resolution imagery. These systems and their associated digital data processing systems are very expensive, however. Both aerial cameras and CCD systems are restricted to daytime data acquisition and must operate below any cloud layers.

Multi-spectral Systems

Multi-spectral sensor systems are very similar to CCD systems. They use a series of detector arrays to acquire digital data of the scene below. Unlike the CCD systems, however, multi-spectral sensors, as the name suggests, are capable of acquiring several "bands" of spectral specific information simultaneously. Typically, multi-spectral systems collect information looking vertically from the aircraft, ranging from the ultra-violet part of the electromagnetic spectrum, through the visible part, into the infrared and thermal infrared portion of the spectrum. Combinations of these bands can be later digitally processed to optimize specific spectral characteristics of the area of interest.

Multi-spectral systems are currently used for various remote sensing applications, including oil spill and pollution monitoring, forest damage assessment, and forest fire mapping. One such sensor, developed and operated in Canada, is the Multidetector Electro-optical Imaging Scanner (MEIS) (McColl et al., 1984). The MEIS is a high spatial resolution pushbroom scanner capable of recording information from eleven specific parts of the visible spectrum simultaneously. The MEIS has very accurate programmable spectral sensitivity and high spatial resolution capability. A similar sensor, the Compact Airborne Spectrographic Imager (CASI) is a Canadian-designed and built imaging sensor utilized where multispectral applications are required. Ancillary information such as position, date and time provided by the aircraft navigational systems typically are married and cross-referenced to the image data from these systems. Multi-spectral systems are very expensive, however, and are restricted to daytime (except for the thermal infrared bands) and fair weather use only. Data processing of this data can be quite cumbersome and requires sophisticated digital processing equipment and considerable expertise in image processing.

The ultraviolet and thermal infrared bands of multi-spectral sensors are very effective for detecting and mapping large oil spills. The ultraviolet band is best suited for the detection of thinner layers of oil, and the thermal infrared is optimal for mapping the thicker layers. Most recently, the Canadian developed MEIS was employed in the Arabian Gulf for the purpose of oil spill mapping following the Gulf War. This same sensor was utilized effectively as a tool to help in the clean-up operations of the Exxon Valdez oil spill disaster in Alaska.

Multi-spectral sensors are often used to acquire imagery of damaged forest areas due to defoliation. The photographic infrared bands of these systems readily detect the differences in infrared reflectance between healthy and stressed or damaged vegetation.

Thermal Infrared Sensors

There is a distinction that must be made between specific areas within the infrared portion of the electromagnetic spectrum. The infrared part of the spectrum can be divided into two areas, the photographic part which can be detected by infrared sensitive film and certain bands of multi-spectral sensors, and the thermal infrared portion, which is sensitive to differences in heat. It is this latter part which is typically recorded by thermal infrared linescanners.

All objects emit thermal infrared radiation. The amount of infrared radiation emitted by an object is directly related to the temperature of that object. The cooler the object, the brighter it appears on thermal infrared imagery. Conversely, the warmer the area, the darker it appears on infrared imagery. Thermal infrared linescanners collect information of the scene directly below the aircraft. As the name suggests, data is collected line by line by a rotating mirror as the aircraft moves forward. Thermal linescanners are passive sensors in that they record infrared radiation emitted by objects. Quantitative thermal measurements with accuracies of 0.2 degrees Celsius are obtainable with thermal infrared systems, making it an ideal tool for precise remote temperature monitoring.

Thermal infrared linescanning is used regularly for the mapping of active forest fires (Tracey and Lawrence, 1986). Often, smoke obscuration is so severe that

visible observation of the active fire front is impossible. Forest fire management personnel use thermal infrared imagery for the detection and location of the most active part of large fires and thus obtain information where to intensify their efforts. Thermal infrared imagery is routinely used to map some of the larger forest fires in Canada and has been used as a useful tool in the management of the well publicized Yellowstone Park fire in the USA.

Thermal effluent discharged into rivers or oceans can be readily mapped using thermal infrared techniques (Tracey and Kleinhenz, 1985). Minute thermal variations between effluent and discharge sites and the "normal" ambient water temperatures can be distinguished and quantitatively mapped. Similar applications have been developed for the mapping of water current patterns in large water bodies.

Synthetic Aperture Radar

Common misconceptions persist that synthetic aperture radar (SAR) technology is complicated and difficult to understand, but this should not be the case (Raney, 1991). Synthetic aperture radar sensors are imaging systems capable of acquiring images day or night, in almost any weather condition. SAR systems are "active" sensors which emit a series of carefully timed microwave pulses from an antenna located beneath the aircraft. This antenna records the reflectance pattern of the transmitted microwave pulses reflected from the scene below. The resulting image is therefore based on the surface roughness characteristics of individual areas of the terrain. Smooth surfaces such as water and paved surfaces appear dark on SAR imagery and rough areas such as trees and cars will appear bright. Synthetic aperture radars typically look-sideways to the left or right of the aircraft as it progresses forward. Huge amounts of data can be acquired in one remote sensing mission. Approximately 60,000 square kilometres of geometrically correct SAR imagery can be collected in one flight, making this sensor ideal when broad area coverage is required of a particular area.

SAR data are typically collected over large land or water masses for large area mapping purposes. For example, SAR is effective in the mapping of oil spills on the ocean surface. The effect of the heavier oil surface reducing the small capillary wave action on the ocean surface results in a contrast between the microwave backscattering of the areas with oil, and those areas without oil (Hawkins et al., 1979).

Synthetic aperture radars have demonstrated their effectiveness for flood mapping purposes. Water reflects virtually no microwave radiation back to the SAR antenna, and because of its characteristic radar signature, appears black on radar data. The high contrast between the surrounding land and the water provides a distinct land/water interface. The all weather operational capability, combined with the broad area coverage of SAR systems makes this a useful sensor for emergency flood mapping. The geometric fidelity of SAR data also facilitates accurate area measurements and delineation of flood effected areas.

Laser Fluorosensors

In the late 1960s there was mounting concern over the deliberate dumping of oil into the marine and water environment. The detection of these oils was not deemed adequate by the utilization of existing remote sensors at the time and a new sensor

was developed in 1973, the laser fluorosensor. Canada is considered a world leader in laser fluorosensing technology.

The laser fluorosensor is an active sensor and uses an airborne mounted laser to excite or fluoresce a "footprint" on an oil spill. Fluorosensors employ the property that some compounds in the oil absorb light in the ultraviolet region and re-emit part of this energy in the visible region of the electromagnetic spectrum. This re-emission of light, or fluorescence, can be measured discretely from an aircraft. The most important aspect of the use of laser fluorosensors is the fact that different types of oil yield slightly different fluorescent patterns. It is therefore possible to differentiate specific types of oil using this sensor (Fingas, 1990).

Fluorosensors employ a laser which operates in the ultraviolet region of the spectrum. Rather than producing an image similar to other remote sensors, fluorosensors produce a graphic output detailing the part of the spectrum where fluorescence is at its maximum, with each oil type having its own specific fluorescence signature or spectra. Not only can these sensors identify the exact type of oil in question, but research is now under-way on their application to measure precise thickness of the oil spill. Operationally, they are flown directly above an oil spill at a relatively low flying height, approximately 150 metres above the ground. The data are recorded and printed in real-time on board the aircraft.

Atmospheric Sensors

There are a variety of airborne mounted atmospheric sensors that can be utilized for in situ measurements of the atmosphere. Most recently, the United States National Center for Atmospheric Research flew a suite of airborne sensors during a campaign in Kuwait to monitor the pollution levels as a result of the oil wells set ablaze during the Iraqi war. On-board the aircraft were several types of sensors, including instrumentation to measure aerosol concentrations within the clouds. Three different ozone measuring sensors were also utilized, as well as instruments to measure vertical profiles of temperature, humidity, pressure, and wind direction and speed. Some of the instruments included Counterflow Virtual Impactors, Aethelometers, Nephelometers, Aerosol Asymmetry Analyzers, Lidars and Radiometers.

Remote Sensing and the ENMOD Convention

Article II of the ENMOD Convention states that the term "environmental modification techniques" refers to those methods of changing the environment "through the deliberate manipulation of natural processes -- the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space." Although the ENMOD Convention provides an illustrative list of phenomena that could be representative of environmental modification techniques, it is not an exhaustive list, and does represent several unlikely examples that human activity is not capable of controlling, i.e., earthquakes or tsunamis. Some more likely examples of environmental modification techniques include deliberate setting of forest fires, intentional large-scale oil spills, large-scale burning, and flooding. These methods can all be interpreted as affecting the natural processes of the Earth's environment.

There are several types of airborne monitoring techniques that have proven applications in monitoring and mapping these calamities. Remote sensing imagery has been deemed as acceptable and admissible evidence in the courts. There appears to be no obvious reason not to utilize airborne remote sensing as a tool for the monitoring and verification of non-compliance related to the ENMOD Convention.

Airborne imagery can provide a legal mechanism with which to acquire direct evidence in the form of specialized images. These images can form the basis for detailed mapping with respect to time and location of the affected area by any deliberate and intentional hostile use of the environment. Some airborne monitoring methods can provide non-rebutable evidence through the determination of exact measurements.

Summary

The science of airborne remote sensing has progressed to a level high enough to be trusted as a reliable and accurate means of data collection that it has been used as admissible evidence in courts of law. The data that are produced from remote sensor systems, when presented by expert witnesses knowledgeable about data acquisition, data processing and interpretation and analysis techniques, have been considered like any other form of evidence. These techniques could play a valuable role in the verification of non-compliance with respect to the ENMOD Convention.

There are several types of remote sensing imagery that are available for the mapping of specific environmental disasters. All of these sensors are currently being utilized for legitimate environmental mapping applications. The more common aerial photographs, with which everyone is familiar, have paved the way for other more sophisticated sensors to be considered as tools to aid in the collection of evidence for legal proceedings. Multi-spectral imagery can collect spectrally specific data of areas which would not be readily visible on normal aerial photography. Thermal infrared sensors can map invisible emitted thermal radiation to produce accurate maps showing very subtle temperature fluctuations. Synthetic aperture radars are capable of producing geometrically accurate maps of very large areas in any weather condition, day or night. Laser fluorosensors can definitively identify specific types of oil on water surfaces from the air in real-time. A variety of atmospheric sensors, mounted in an aircraft platform, can acquire a voluminous amount of information on the existing state of the atmosphere.

References

1. DONIGAN, R.N., and E.C. FISHER, 1975: The Evidence Handbook, 3rd ed. The Traffic Institute, Northwestern University, Evanston, IL.

2. FINGAS, M., 1990: Remote Sensing of Oil Spills. Proceedings of the 13th Arctic and Marine Oil Spill Program, June.

3. FORESMAN, T.W., and D.R. WILLIAMS, 1990: Remote Sensing: An Environmental Enforcement Tool. Proceedings of earth observation systems workshop: Legal considerations for the 90's, New Orleans, LA and Colorado Springs, CO, March/April.

4. HAWKINS, R.F., A.L. GRAY, V. THOMPSON, and R. NEVILLE, 1979: Observation of Two Test Spills with a Radar Scatterometer and a Synthetic Aperture Radar (SAR). Proceedings of workshop of the NATO-CMMS pilot study on the use of remote sensing for the control of marine pollution, Washington, DC.

5. JAYNES, R.A., 1983: Effective Use of Remote Sensing Products in Litigation. Proceedings of the American Society of Photogrammetry, Salt Lake City, UT, September.

6. McCOLL, W.D., R.A. NEVILLE, and S.M. TILL, 1984: Multi-Detector Electro-optical Imaging Scanner MEIS-II. Proceedings of the 8th Canadian symposium on remote sensing.

7. McDERMOTT, P.D., 1986: Forensic Cartography. Photographs and Maps Go to Court. Proceedings of the American Society of Photogrammetry and Remote Sensing, Falls Church, VA.

8. O'DONOVAN, P., 1989: The Law and Remote Sensing Evidence. Proceedings of London Meeting on the remote sensing of oil slicks, London, England.

9. RANEY, R.K., 1991: "Theory of SAR". Presented to the United National Food and Agriculture Organization of the U.N.-ESA workshop on microwave remote sensing technology, Maspalomas, Canary Islands, Spain.

10. TRACEY, J.P., and M. KLEINHENZ, 1985: "Quantified thermal plume mapping using simultaneous spaceborne and airborne thermal infrared sensors". Presented at the 1985 International geoscience and remote sensing symposium, University of Massachusetts, Amherst, MS, 7-9 October.

11. TRACEY, J.P., and G.R. LAWRENCE, 1986: "Thermal Infrared Remote Sensing: One of Today's Solutions". Presented at the 1986 international geoscience and remote sensing symposium, University of Zurich-Irchel, Zurich, Switzerland, 8-11 September.

12. TUERKHEIMER, F.M., 1972: Legal Aspects of Water Pollution Detection Through Remote Sensing. Proceedings of the 1st conference on remote sensing of earth resources, Tullahoma, TN.

13. WHITEHOUSE, G., D. OUIHET, and G. FISHBURN, 1987: The Role of Remote Sensing in Flood Investigations. Proceedings of the 4th Australasian remote sensing conference. The Levels, South Australia.

SESSION 4: DISCUSSION

Session IV focused on the available tools that could be utilized respecting adequate verification of obligations of environmental arms control. One of the tools discussed was the use of satellite imagery and it's possible significance in an international court. The fact that it would still be hard to prove intent would make it difficult to use satellite imagery as an effective tool.

It was observed that mechanisms for deterring a breach of the ENMOD Convention must be found. The subjective element of intent is the biggest weakness of the Treaty. The use of Resolution 687 to establish liability does not resolve the issues of legal responsibility, (ie. the type of violation, or the legal determination). Even though the Security Council's assertiveness has increased tremendously following the Gulf War, there is a danger that if this assertiveness accelerates too fast, it could create a cleavage between the Developed and Third Worlds.

The use of satellite imagery has it's definite applications and limitations, one participant pointed out. For example, to monitor a known suspicious activity within a specified geographical area on a regular basis is fairly straightforward. However to randomly image all areas, searching blindly for an act of breach of a treaty, would be far too expensive. For precisely that reason, the use of collateral information based on ground-based or other sources is essential to make the most effective use of overhead imagery. The requirement of a central organization such as the United Nations in conjunction with the International Atomic Energy Agency would be essential in not only establishing policies and priorities as to where to direct imaging satellites geographically, but also to help alleviate the costs of such imagery by contributions from member United Nations States.

Presently such satellite imagery as NOAA and LANDSAT are being utilized by many countries to monitor such activities as crop monitoring and agriculture. There is a large database of satellite imagery and much international experience in using this imagery. This experience might make such a regime acceptable as a means of monitoring ENMOD related activities.

Satellite imagery could act as a deterrent by increasing the probability of being caught. It is unlikely, however, that satellite imagery will provide a means of catching people before they actually do something.

It was also pointed out that due to the possibilities of environmental catastrophes, the significance of ENMOD has increased. The Global Environmental Monitoring System of the United Nations Environment Programme is utilizing airborne, satellite and ground-based sensing on a global scale. A possible linkage between ENMOD and GEMS might be the environmental vulnerability of potential hot spots of violence or hostility. A technical risk assessment for ENMOD making use of technical data from GEMS could be developed.

One participant suggested that the United Nations is actively looking for ways to augment its fact-finding missions. The Secretary-General's fact-finding programs have very few tools of adequate use to them. What is required is a mechanism for the collection of data and well established priorities and policies by the Security Council in order to make effective use of such tools for monitoring ENMOD related activities. In this way, accountability by the perpetrators can be established. Much

has changed in terms of aggressive assertiveness by the Security Council, and initiative and a willingness by the UN to establish an effective mechanism, such as experienced by the United Nations Special Commission, is the principle method of implementing the purpose of the ENMOD Convention.

SESSION 5

GENERAL COMMENTS AND DISCUSSION

Chairperson: Ron Sutherland

SESSION 5

GENERAL COMMENTS AND DISCUSSION

Prof. Sutherland provided a summary of what was discussed so far and could be useful for the Geneva Review Conference. He stressed the interdisciplinary backgrounds of participants — ranging from diplomats, policy makers and verification experts, to lawyers and marine scientists, physicists, chemists, toxicologists and engineers — a mixture of great value to this workshop.

Prof. Sutherland identified the major problem of ENMOD as finding a means to protect the environment in times of armed conflict. The ENMOD Review Process has technical, legal and policy dimensions. Article II is ambiguous with respect to the definition of "deliberate manipulation of natural processes", and Article V — the "consult and cooperate" mechanisms, as well as the Security Council complaint and investigation process — need greater attention. Specific problems of verification identified include:

- the definition of the threshold for "widespread, long-lasting or severe" effects,
- the appropriate finding of facts (ie. whether environmental modification occurred, what techniques were used, and to what extent ENMOD could both be covert and successful), and lastly
- the technical assessment of the risks (ie. danger to the environment), military utility, remote sensing possibilities, relationship with other legal instruments concerning armed conflict, and the necessity of amendments.

In the general discussion following Dr. Sutherland's overview several themes emerged. It was pointed out that because the ENMOD Convention is an arms control agreement and not humanitarian law, it applies in peacetime, unlike some of the legal rules respecting war and the environment that had been discussed at the Workshop. Hostile action was required for the application of the ENMOD Convention but not necessarily armed conflict. Several participants emphasized the importance of hostile intent with respect to ENMOD compliance judgements: severe, widespread or long-lasting damage to the environment was not alone sufficient; hostile intent must also be demonstrated. Some felt that such hostile intent would be evident given the circumstances surrounding any incident. It was also pointed out that military activity can not be equated with hostile use or intent because all military uses are not, by definition, hostile. It is only with those military uses which are hostile that ENMOD is concerned.

The discussion also pointed out the differences between the ENMOD Convention and the process respecting the United Nations Conference on the Environment and Development scheduled for June 1992. A general view was expressed that it is inappropriate to seek to amend the ENMOD Convention in an effort to address broader issues respecting damage to the environment during armed conflict.

Discussion turned to the question of whether the requirement for consensus within the Consultative Committee of Experts, (which might be set up to address

questions about compliance with the ENMOD Convention), would hinder that body's effective action or agreement on compliance matters. It was suggested that such concerns could be alleviated if the human component in the verification process was reduced as much as possible through the use of technology. The expected Chemical Weapons Convention as well as Open Skies may have lessons for ENMOD verification, especially with respect to the synergistic effects of the use of several verification methods.

With the new activism of the UN Security Council, that body can now act as a sort of court of last resort for the purposes of compliance disputes with regard to agreements like the ENMOD Convention. It was pointed out, however, that some countries may still feel that the Security Council remains ineffective with respect to their interests, for example, because of the American veto with respect to Arab-Israeli disputes.

SESSION 6

LESSONS TO BE LEARNED

Chairperson: Ron Sutherland

THE ENMOD CONVENTION AND RELATED INTERNATIONAL AGREEMENTS: THE CHANGED SETTING IN WHICH THEY MUST OPERATE

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In assessing the success, the problems, and the potential of international agreements for protecting the environment from being used as a weapon of war or from undue long-lasting damage in the course of or as a result of armed conflict or deliberate hostile action, it is necessary to separate the issues addressed by the intent of such agreement, from the tools used to address those issues. Failure to separate the issues raised by acts of hostile use of the environment from the actions of compliance, verification and control can lead to artificial situations in which legal arguments as to the applicability of the agreement, or operational focus on the technologies and responsibilities for surveillance and verification on the one side become confused with the "laws of war" and the responsibilities of nation states on the other. When this happens, international agreements that purport to protect either the environment or non-involved people become out of touch with the realities of conflict and the operational decisions that must be made under stress by commanders in the field.

War is the last resort of quarrelling states or societies; and centuries of tragic experience have shown that nations or governments at war will not, and are not capable of, compromising their major objectives of victory or defensive survival out of consideration for the environment, rational management of resources, preservation of culture or the rights of civilians. Any political or international agreement that seeks to protect the environment must recognize this fact, and be designed to influence the destructive actions or the eventual effect on Nature without directly challenging the national objectives that come to the fore in times of conflict.

The following remarks attempt to touch on some of the points brought forward at this workshop under four main headings:

i) The changed national and international context respecting environment, the role of governments, and attitudes toward war, international organizations, and science;

ii) The role and limitations of international relations and formal agreements in this new situation;

iii) The ENMOD Convention in the 1990's;

iv) What issues might the ENMOD Review Conference consider.

The Changed Context

The world of 1995-2005 is different, in several ways, from the world of 1972-77, when ENMOD was developed. It is likely to become increasingly different in the future. Some aspects of this new context which are important to the operation and success of ENMOD, the Geneva Conventions, Non-Proliferation Treaties and similar well-intentioned mechanisms to protect people and the planet may be mentioned.

Environment and Environmental Issues

Attitudes toward the environment, and understanding of the significance of environmental issues, have evolved significantly since the 1970's when concerns were focused on local pollution and stewardship of resources. Today:

- In nearly all countries of the world, knowledgable and outspoken people are drawing attention to the factual evidence that the natural limits of Earth to provide living for the expanding population of humans are being approached or have been reached.

- There is a general public awareness in most democracies that time is running out for the "good life" that many have known and which most who have not known have been led to hope of achieving in the future. There is a broad awareness, if not an acceptance, that there is never likely to be enough natural resources or distributable wealth for all people to be able to live comfortably in an affluent style, no matter how well resources are managed.

- There is also a broad general awareness that the major problems of inadequate food, health, etc., are in large part environment-related, and that many are caused by or made worse by the actions of humans which degrade the environment and impair its productivity.

- There is widespread recognition that technologies, especially energy-intensive technologies, are major agents of environmental change. For much of the world, the environment in which people live has been adversely affected by the products and disturbances resulting from technologies and energy resources used by others, in distant areas.

- There is awareness, more in northern developed countries perhaps than in the low-latitude "south", that environmental changes and problems are integrated and connected; that most of the persistent and serious environmental issues, even if perceived to be local, become regional or global in their effects; and that the major environmental changes have nothing to do with national borders.

- There is also awareness, to a degree much greater than in the 1970's, that present-day economic and political systems and national entities have not been able to prevent environmental problems or to deal satisfactorily with them, but on the whole have helped to cause them on to make them worse.

Since 1978, "environment" has become an international entity in its own right. Protection of environment is defined as a legal responsibility in the Protocol I Addition to the 1949 Geneva Conventions Relating to the Protection of International Armed Conflicts (1991). President Bush of the USA has formally denounced "crimes against environment". In many countries, the Environment has become a political personality. Scientifically, the realization of "the environment" as an integrated entity has broad acceptance, and there is growing realization of the likelihood of a planetary organic unit, as conceptualized in the GAIA idea. This larger, integrated view of "environment", which includes people and their institutions, places a new dimension on international agreements related to the environment.

At the same time, intergovernmental activities -- UNCED, the Montreal Protocol to protect the ozone layer, the International Atomic Energy Agency, the Law of the Sea, and many others -- while addressing common environmental problems of the world, also emphasize to many citizens the enormity of world environmental problems and give rise to broad feelings of individual, national and international helplessness.

Changed Views of the Nation-State

The concept of what constitutes a nation is changing rapidly in public perception and diplomatic recognition and action. Happenings all over the world are questioning or challenging the traditional simplistic notion of a people with mainly a common history and language inhabiting a territory bounded by defined limits and forming a society under one government. Examples of the challenge and change of concept can be seen in the transition of the Soviet Union into the Commonwealth of Independent States; in the break-up of Yugoslavia; in the re-emergence of new nations and re-defined nationhood in southern Africa; in the discussions of a future united Europe; in Cambodia and Viet Nam and their neighbours; in Quebec within or without Canada; in Kurdistan; in Armenia; and elsewhere.

The changing social and political concept of a "nation state", inevitably colours the views and expectations of "state practices" in relation to the responsibilities and capacity for "national" and "international" action with respect to protection of the common shared environment. Parallel to the awareness of the integrated nature of our shared environment and its intimate relationship to local and regional economic activity, as emphasised to the Brundtland Commission and the United Nations Conference on Environment and Development, the fluid and uncertain concept of "what is a nation" offers to some states and societies the opportunity to "use the environment" for "national" purposes, or as a bargaining chip in international deals. The preparations for the Rio Conference (UNCED) have seen much of this.

Quite aside from the political and social evolution of the concept of a nation, it is clear that, in the modern context, the independence of action of any nation-state is inexorably compromised by the integrated environment. "National sovereignty" in the traditional sense can not extend to control of the environment.

Changed Situation Regarding Hostile Action and Warfare

What constitutes warfare, or a hostile action, are much harder to define than they were even 20 years ago. Clausewitz's First Rule of War: "Select and maintain the aim" is now much harder for any country or society to do. The "aim" is often no longer simple and clear, and "selection" may be meaningless; moreover, maintenance of the aim may be self-defeating.

In today's pluralistic and technically integrated word, the traditional spectrum of conflict: from rivalry, to competition, to inter-society interference and rebelliousness, to hostility and warfare, is no longer linear. The distinctions between sustained political hostility, undeclared war and condoned terrorism, massive or provocative "defense" preparations, and open armed conflict are becoming blurred in many parts of the world where the temptation to use the environment as a "weapon" may be strong. One may also ask, "what are arms?" Would Zebra Mussels, deliberately introduced to weaken an enemy, be "weapons" or "hostile use of the environment" under

the Geneva or ENMOD Conventions? In the 1970's these questions were easier to answer than they are today.

If warfare is the direct open violent expression of hostility between nations or societies, and hostility is the embodiment of longer-term or accumulated feeling of incompatibility or implacable resentment or enmity, then environmental issues themselves can be a major cause of long-term hostility and agents of war. Good examples are given by the long and tragic history of "water wars", centuries of conflict over rights to and use of rivers, extending at least back to the conflicts in Sumer 4000 years ago. Robert Mandel (1991) has made a useful classification of international river conflicts, which serves to illustrate the shades of meaning between rivalry, competition, conflict and warfare when an environmental resource is both a weapon and an object of national desire. In the modern situation, "environment" cannot escape being both a tool and a medium of conflict. Its use, and therefore in many instances its modification, can thus be a cause of hostility and an agent of hostile action. The basic environmental situations and disparities which, as shown by Mandel, are often the reason for conflict, are not subject to human management; but they are subject to human influence, and they may be developed as implements of warfare.

Expectations of Governments and International Agreements

Even as recently as 1972-78, at the time of the Stockholm Conference on the Human Environment and the signing of the ENMOD Convention, governments felt that they were the dominant actors determining the course of international events, and most citizens agreed, or expected them to take responsibility for the "condition" and direction of the world. The Stockholm Declaration on the Human Environment, NATO, the Warsaw Pact, and many other agreements or institutions were evidence of this. Today, neither governments or people are sure of the power of governments. The ability of national governments or international government institutions to control either national or international events is compromised by:

- multi-national corporations;
- the runaway economic system, in both capitalist and centrally-controlled economies;
- explosive growth in human population, mostly in poorer countries or in the poorer segments of society, placing the burden for social support on local municipal or regional institutions without concomitant tax revenue increases, leaving both national and local governments incapable of effective action;
- environmentally-determined social crises, e.g., Ethiopia, Sudan, Somalia, Namibia, whose governments cannot cope, and who therefore appeal to governments of other countries for aid, but at the same time resist "interference" by other governments in any activities that address the root causes of the problems. This situation reduces the freedom of government action of both the donor and the recipient;
- global warming, and global change, which is being documented with increasing scientific precision as a changing global condition that is beyond the

capacity of any single government to control in the short term, but whose long-term deterioration can only be prevented by resolute and sustained co-operated action by many governments in concord.

Government actions and inter-government arrangements can set the stage for economic and environmental actions; they can modify them to some extent, but rarely any longer can governments directly control the course or outcome. The loss of power of governments leads to cynicism about the effectiveness of government among many of the same citizens who have taken away or circumscribed the power of the government. In some countries this lack of citizen confidence is leading to a vicious circle of ineffectiveness.

People still expect governments to express principles, and to define the national and international interests of citizens. But they may not accept or follow what is expressed. An example is the high public expectations of government-run Environmental Assessment and Review, but the frequent unwillingness to accept EARP recommendations.

A major question of the role of governments was posed by Mr. Bryce: In time of stress, which principles do we abandon first? In time of war, would the people accept a government commitment not to harm the environment, or to use it as a weapon, at the cost of not winning the war?

People expect governments to be a surrogate for individual as well as national behaviour (e.g., in the recent war in the Persian Gulf, although efforts were made to separate the Iraqi government, as personalized by Saddam Hussain, from the Iraqi people, the country as a whole became the opponent, just as Germany did in World War II). A struggle against the government becomes a struggle against the people, even though the people may have had little to do with the choice of their government and no say in its policies. War has always been thus; the new factor is that in environmental matters, environments are also becoming interchangeable with the governments of the country.

A feature of the present decade is the increasing amount of international environment-related action that is being taken outside governments. Examples are: Greenpeace; other international environmental non-government organizations; refugee movements and the organizations helping them; and the environmentally constructive activities of international business groups and multi-national corporations. All of these actions help make national governments less dominant, perhaps even less important, with respect to the international (and thus national) environment.

On the international government scene, also, the major environmental influence may not any more be mainly with the agencies that have designated responsibility for the environment. It is probable that the UN Security Council, the United Nations Development Programme, and the World Bank have more direct influence on the state of the world environment than the major "environmental" agencies such as the United Nations Environment Programme and UNESCO. These developments also affect the expectations, and practical influence of, international agreements such as ENMOD.

Changes in Science, Technology

Science and technology and their applications have a continually increasing capacity to affect the environment. A competitive market system, driven by the demands of the rich and powerful in a situation of decreasing and more costly resources and dependent on increasing availability of technologically-produced energy and materials, will likely lead to environmental effects which are ever more severe and critical, unless significant restraining effects are applied on a large scale, and maintained for a generation or more. Up until now, the prospects for vigorous large-scale co-operative restraint have been poor at best.

At the same time, science has given all people and governments increased capacity to predict, to understand what is happening to the environment, and to identify the vulnerability of Earth as a life-support and economy-support system.

Our increased understanding of the situation is however, not matched with a concomitant capacity to act, to prevent, or to change our behaviour to avoid our own destruction. The gulf between the capacity of science and technology to use resources and deleteriously affect the environment on the one hand and our scientific ability to steer ourselves, our society or humanity at large toward long-term goals that will enhance the natural environment is widening, not narrowing. Our increased technical ability to detect changes and assess the consequences is not matched by ability to forestall the same changes.

An indication of our present technological dilemma is demonstrated by the fact that there is now, through remote sensing and associated techniques, the capability of detecting and monitoring very small changes in several hundred environmental characteristics anywhere in the world. But such techniques are expensive. Even in the face of a rapidly degrading environment, what is the value of the information that would be obtained, compared to the cost of surveillance? Who could afford continued world-wide or regional surveillance for environmental threats or degradation? Only the richest countries; - what is their obligation to the potential victims? What good is the availability of the means of obtaining this precise scientific information if there is no capacity to use it in a practical way or willingness to act on the information obtained?

Another aspect of developing science and technology that relates to verification of commitments to the ENMOD and related conventions has to do with the acquisition and use of information in conditions or threats of conflict. Is surveillance by satellite of environmental conditions in a "rival" country a hostile act? Science is increasingly developing techniques that use or slightly modify natural phenomena, such as magnetotelluric energy from distant tropical lightning strikes to aid communications and prospect for minerals. From these techniques it is but a step, in cases of military necessity, to manipulation of some aspects of the natural environment for hostile purposes.

The Role of International Agreements

In the past twenty-five years, there has been a proliferation of international agreements respecting the environment and the control of armed conflict or the threat of conflict. Examples pertinent to the verification of obligations respecting arms control and the environment include:

- The United Nations Principles on the Human Environment (from the Stockholm Conference, 1972);

- Protocols additional to the Geneva Conventions of 1925 and 1949 on protection of International Armed Conflict, including: Victims of International Armed Conflict (1977), Protection of the Environment (1991 - under negotiation);

- Partial Test Ban Treaty 1963, and other agreements respecting nuclear weapons in 1968, 1974, 1976, 1982;

- Conventions concerning: biological, bacterial and chemical warfare (1925 et. seg.) military action in Antarctica (1959); nuclear activities in Latin America (1967); nuclear explosions or military exercises on the moon (1979); nuclear activities in the South Pacific (1985);

- ENMOD 1978;

- Inhumane Weapons Convention (1981).

Each of these agreements has had a specific intent and narrow focus. A narrow, well-defined focus has been necessary in order to achieve international agreement through traditional legal negotiation methods, and to produce a text to which signatories could be held accountable. But it has become apparent that the proliferation of agreements has, in total, become piecemeal nibbling at what is an increasingly integrated and expanding problem. The large number of treaties and conventions, each separately negotiated, has resulted in inconsistency in scope and method of application, and, in some cases, contradictions in definitions.

Together, some critics have called the assembly of conflict-limiting and environmental protection agreements little more than statements of honourable intent. Those critics have stated that to make the agreements "real", there must be vigorous programmes of verification and surveillance, with public disclosure of breaches. Verification may be passive (including self-reporting and free access to observers) or active and intensive, including on-site inspections and monitoring devices. Some of the agreements, e.g. The Antarctic Treaty, make provision for this. Others do not. The success of verification of an international agreement depends upon compliance with an obligation to report, and identification of the authority, resources, and responsibility to take action.

Many students of international treaties (e.g. Goldblatt (1991)) have pointed out the shortcomings and limitations of piecemeal agreements to achieve environmental protection; and at the same time have drawn attention to the impracticability and undesirability of any umbrella or master agreement to which nations would agree to be held accountable. There thus remains the dilemma of how to bring about general environmental protection through commitment to specific narrowly focused actions.

Another characteristic of the present generation of international agreements is that, because in general they address broad problems through specific narrow actions, it is difficult to assess how effective they are in practice. What should be the criteria for effectiveness? Protection of the environment can of course be demonstrated in a material way if previously observed damage to an ecosystem is seen to have ceased, or improvement of some measurable physical or biological parameter, such as acidity of a lake or the number of songbirds, can be demonstrated. But it

often will be difficult to determine conclusively that a change in some environmental parameter, to make a more healthy environment or the reverse, was due in an important way to action taken as a result of a specific international agreement. And even though the circumstantial evidence may be compelling, it is probably even harder to assign the responsibility for environmental deterioration or damage to lack of action by a specific agent or country under an environmental protection agreement.

A good deal of the direct effectiveness of agreements to protect the environment is, however, not in the first instance physical or biological (although that is the ultimate objective), but psychological and educational. The agreements serve to affect the awareness, planning and assessment of government (including military) activities, as well as operations. The existence and contents of the agreements also affect public expectations, and values. These in turn affect investment. All such actions and influences are or can be demonstrations of the effect of international agreements to protect the environment in the event of international conflict.

The scope and operations of the various international agreements that consider the environment during conflict or military operations must be set against a changed international agenda in which environmental issues have moved from a marginal concern with health and amenities to one of common concern over resources and pollution, and then moved again to one of world-wide shared concern over societal and planetary survival, directly engaging heads of states. The progression from the 1972 United Nations Conference on the Human Environment, to the 1986 World Commission on Environment and Development, to the 1992 United Nations Conference on Environment and Development in Rio de Janeiro illustrates this evolution.

ENMOD in the Last Decade of the Millennium

The Effectiveness of ENMOD in 1992

Is the Convention on the Prohibition of Military or Other Hostile Use of Environmental Modification Techniques (ENMOD) merely one convention among many, or is it a background or umbrella that will enhance and serve many of the narrower and more specialized international agreements intended to protect the environment in time of war?

ENMOD, perhaps because it focuses on the active use of deliberate change of the environment as an act of war, and not only on protection of the environment, does capture public and general interest. It draws attention to the possibility that the environment itself, which often in the public and political mind is seen to be delicate and passive, could become an agent of war, with consequences more widespread and damaging than the war itself. It is probable that nearly all countries and governments support the objectives of the ENMOD Convention in principle, but some are not willing to compromise in advance their national freedom of action, especially at times of military action or stress of invasion. Therefore, only about 60 countries have ratified or signed the Convention.

There is a danger that the broad intent of ENMOD may become lost in the intricacies of legal interpretation of the text. There is a danger also that some who feel that the Convention is too all-encompassing may use disagreements on legal interpretation as a means to avoid firm application.

The public perception of the purpose of ENMOD appears possibly to be different from practical capability. Some of the public perception seems to be simplistic and

to expect that ENMOD would force combatants to give priority to environmental matters even in the stress of battle. When it is realized, in connection with recent conflicts, that although the Convention is a formal agreement that nations will not use deliberate changes in the environment as a weapon of war, severely and deliberately damaged environments have become in some cases the characteristic background for tactics on the fields of battle without any conspicuous reference to ENMOD at all, the Convention may become another international vehicle for public disillusion and cynicism. The agreement then could become not an international asset, but an embarrassment to governments.

The ENMOD Criteria in the 1990's

The criteria of environmental modifications to which the Convention will apply in the future warrant some consideration, in the light of issues and developments of the 1990's. Article I of the Convention prohibits use of environmental modification techniques for military or any other hostile purposes, if such use will have "widespread, long-lasting, or severe effects", and the Understanding to Article I defines those criteria in physical, biological, and economic terms. In the light of the modern need for legal interpretation, it is proper to ask whether a <u>defined threshold</u> of effects required to bring the Convention into operation will be an incentive to refrain from modification of the environment as a principle, or whether it might be used as an incentive for protagonists to use the environment for hostile purposes up to the defined threshold limit. Will the criteria be applied to each operation or military campaign, separately, or will the cumulative effects be counted? And, of course, there is the problem of who makes the judgement on the degree of severity or the degree to which the environmental change was a deliberate modification for hostile purposes.

A further problem appears to be that, as stated in the Convention, in most cases, whether or not the criteria have been exceeded can be determined only after the event. If this is so, how effective can the Convention be as a deterrent to <u>prevent</u> deliberate environmental modification? What will be the most effective role of the Convention in deterring actions that may lead to environmental damage, rather than promoting environmental modifications that could be effective in a military sense but only damage the environment "a little bit" to see if one can get away with it? An illustration of this problem is provided by the recent war in the Persian Gulf. Massive oil slicks were deliberately created to harass the Allies. It turned out, after the event, that the biological and ecological damage was less than originally feared; nevertheless, the <u>intent</u> to create a widespread and severe environmental effect as an act of war was certainly there. On the evidence available so far, it appears that in this case the criteria of the ENMOD Convention may not have been exceeded, as far as the individual oil spills in the Gulf are concerned; and this is mainly because of the vigourous marine dynamics of the Persian Gulf. But had an oil spill of the same magnitude been released in, say, the more sensitive waters of the Baltic Sea (which is roughly the same size and configuration), the biological and economic havoc would have been enormous and long-lasting. Should the Convention apply in one case and not in another, even though the deliberate action and the intent might have been the same — the only difference being the ability of the natural environment to cope with a human-caused insult?

The criteria for "hostile intent" also needs consideration or explanation in light of evolving ideas about war, conflict, and national or international opposition. Deliberate action in the course of a declared war is perhaps not very difficult to identify. But in the modern context, an increasing number of armed

conflicts are undeclared war. The temptation to interfere with an environmental condition to oppress an enemy or potential enemy is perhaps strongest in the case of undeclared "war", because the action can be tailored to local circumstances and does not involve the formal military operations that bring international attention and censure. A case in point is the destruction of Croatian water supplies by Serbian guerrillas. Judging from newspaper reports, this action appears to be severe environmental modification with hostile intent. Another case would be use of environmental stress to eliminate or control a "nuisance", perhaps exemplified by the driving of the Kurds of northern Iraq to the hills in mid-winter, and removing basic means of life support; although in this case it was not the natural environment that was modified as a hostile act but the forced exposure of people to hostile natural conditions. Would the Convention in any way apply in such a case?

One might also ask, would the Convention apply to deliberate environmental modification undertaken to prevent an enemy from arising or gathering strength in the future? Would it apply to the actions of the Roman Army in poisoning the fields around Cartage with salt? Was this an act of vengeance toward a defeated enemy, or prudence to prevent future wars? What about acts of pique, as seem to be the only explanation for setting fires to some oil wells in Kuwait during the retreat of the Iraqi army, when there was no apparent military advantage to be gained? It is clear that considerable judgement and latitude may be required to establish the bounds and characteristics of "hostile use" in the modern context.

What Issues Might the ENMOD Convention Review Conference Consider?

Because of the broad scope and widely expressed approval of the intent of the ENMOD Convention, the agreement might become the basis for an effective, flexible but practical international conflict resolution device, based on the widespread and justified political and public concern about what is happening to the environment.

To assess the potential for the ENMOD Convention in a larger international context, it would be useful to examine its scope and application not only with respect to other international agreements respecting the environment and armed conflict, such as the Geneva Convention and subsequent Protocols, but also agreements respecting the environment and international economic competition, many of which will be reviewed at UNCED.

Bearing in mind the issues with respect to "criteria" noted above, it may be useful to consider the possibility of enlarging the Convention by successive additions and amendments to make it more realistically applicable to the relationships between environment and hostility that pertain today than is possible with only the text designed for the simpler conditions of the 1970's. An instructive example is the progressive evolution of the 1969 Antarctic Treaty (originally a simple international co-operation and peace-keeping agreement) into the Antarctic Treaty System of today, in which the original text has not been changed but which through "adjustment by amendment" has become an effective yet flexible conflict resolution and environmental management mechanism.

It would be useful, perhaps, for Review Conference to examine the preamble to the Convention in the modern context. The wording of "deliberate" as distinct from "incidental" modification of the environment, assessment of severity of effect, degree of damage, establishment of proposed thresholds or definition of environmental catastrophe need consideration. It may be useful to consider the need to have a baseline of normal conditions against which the degree of environmental modification

could be assessed; the United Nations' Global Environmental Monitoring System (GEMS) and Global Resource Inventory Database (GRID) could here perhaps be linked to the Convention. It would be useful to look openly at the ENMOD Convention in the context of the growing attention, in United Nations agencies and elsewhere such as OECD and NATO, given to the concept of "environmental security"; at the evolution of ideas with respect to the Law of the Sea; and with respect to international actions related to the United Nations Charter on Human Rights.

Verification

The issue of verification, of examination to determine compliance with the provisions of the Convention in principle or in achieved effect on the environment, is bound to be an important component of the forthcoming ENMOD review. A major problem, in the context of the mid-1990's, will be not only to detect deliberate action to modify the environment, but also to detect and identify situations that could lead to hostile use of the modified environment. In some respects this problem amounts to recognition of accidents waiting to happen; and in the conflict-prone and environmentally-stressed world of today there are many places where a small political or environmental event could escalate into a situation where there is temptation to use deliberate environmental modification for hostile purposes. Ironically, international aid for peaceful socioeconomic development may exacerbate the potential for hostile use of environmental modifications. A case in point, for illustrative purposes only, is the situation in Sudan and southern Egypt, where massive modification of the arid natural environment is being undertaken with international aid. A slight change in the natural climate could so severely stress the delicate socio-economic-political situation in this region that historic and still present animosities could flash into conflict; and "water wars" of the type known in the region for five thousand years, but intensified by modern technology, are a possibility. Can the ENMOD Convention be of any value in such a situation?

Another aspect of verification of compliance or non-compliance in the modern context is the appropriateness of collective -- that is, open to the world and shared among those concerned -- as distinct from individually-gathered or agency-controlled information and evidence. What is the place of espionage and private informers with respect to modification and impending hostile use of the environment? At the other end of the verification scale, what should be the chain of authority and decision-making that decides upon the programmes of orbiting satellites so that they will gather information pertinent to ENMOD, and to whom and according to what specifications is the information to be reported? Is satellite surveillance to be the prerogative of NASA and the European Space Agency?

What should be the role and responsibility of the United Nations Environment Program - Global Environment Monitoring System? All such surveillance is costly, not only obtaining of the imagery, but interpretation of the data, maintenance of archives, and communication of the results of the interpretation to those who could act on it. Who should pay for such a system? This is not a case like "polluter pay" where non-compliers can be requested to carry the costs, for when the system is fully successful there will still be expense but no non-compliers.

Related to cost and responsibility is the issue of research and development of surveillance and verification technologies -- laser fluorosensors, enhanced imaging data processing, etc. Where will the resources come from and on whose authority?

Countries should not take a stand on improvement or strengthening of the Convention unless they are prepared to do their part technically in those areas where they have a contribution to make.

One can also ask, what is the role and what are the rights of small nations and societies with respect to the verification of whether their larger rivals are complying with the Convention? What about minorities in a country, not recognized by their government as separate nations, who in some parts of the world feel most vulnerable to the threat of environmental modification being used against them? The Kurds in Iraq are an example. How would their reports of violation of the Convention be handled internationally?

Capacity to Take Preventative Action or to Assign Responsibility

A very important aspect of the future effectiveness of the ENMOD Convention, which is likely to come under discussion at the Review has to do with the mechanism for taking action when non-compliance has been established. Such action could range from public censure to a number of more concrete decisions; but it should be taken in the name of the United Nations as a body. Article V of the Convention requires states to co-operate in the implementation of the Convention through the UN Consultative Committee of Experts and the UN Security Council. As this appears to be the first instance in which the Security Council has been given direct responsibility for implementation of an international agreement with respect to environmental matters, it might be a helpful and progressive step to consider some draft environmental guidelines with respect to the ENMOD criteria that could be of assistance to the UN Central Agencies.

The capacity to take action in the event of hostile use of environmental modification applies not only to action to expose and censure or stop the perpetrator, but action to protect and aid the victims, and to reduce environmental damage or long-term consequences. For ENMOD to be truly effective, it must be linked with or supported by existing Search and Rescue organizations and environmental clean-up agencies. At the same time, it must be free from and unencumbered by the operational aspects of the aftermath of hostile use of the environment. It must be primarily an international tool that is devoted directly to prohibition or control of hostile use of environmental modification. Consideration might be given to the problem of linking ENMOD with existing environmental and operational organizations and at the same time remaining focused on its principal purpose.

The Ultimate Aim

The ultimate aim of the ENMOD Convention is to improve the environmental and societal security of the world by bringing a collective responsibility for the Earth into the narrower but often more urgent context of violent quarrels between nations and groups of humans. It strives to do this by obtaining commitments from governments, in advance of open conflicts, that they will not, in the event of conflict, use or abuse the environment which we all share, as in agent in that conflict. The entering into such an agreement, while easy to do in absence of conflict and perhaps very hard to keep amid the exigencies of war, is itself a significant confidence-building exercise and a step toward collective security in the political sense. It also should be a step toward collective responsibility for the security of the environment itself.

The ENMOD Convention is an important and so far successful but quite modest, and in some respects inadequate, instrument in this field. If it is to continue to be effective, it must be placed in the larger context of international and inter-society conflicts, and be relevant to the increasingly serious environmental issues of today. The forthcoming Review Conference provides an opportunity to examine whether ENMOD is a suitable instrument around which to build this larger function, or whether something different is needed.

In a perceptive series of essays, Matthias Finger (1992) has examined the relationships between environment and military actions and incentives. His analyses have lessons for ENMOD. The basic incompatibility between military objectives, which are to give priority, above all else, to entrenchment or consolidation of a pre-defined authority or power structure, and environmental issues and objectives that recognize situations and forces not related to national borders or human institutions of authority, means that any instrument that seeks to limit modification of the use of environment as a military instrument, if successful, will inevitably reduce and change the goals and priorities of conflict and military actions. If it is not successful, the military activities will increasingly hold the environment hostage to military priorities, no matter what the environmental cost and the self-destructive costs to the military and to national goals themselves. The issues opened up by the ENMOD Convention and the review of its applicability in the world today are thus much larger than whether a fifteen-year-old convention is workable in legal and political terms -- or even worth keeping -- today. They are issues of the place of humankind and human political institutions in the natural world and the world of nations, and of the ability of both to sustain us all.

References

Finger, Matthias, 1992. New horizons for Peace Research: the Global Environment. in Kakomen, J,. ed. The Concept of Security, Peace Research Conference, Gronigen.

Goldblatt, Josef, 1991. Legal Protection of the Environment Against the Effects of Military Activities. Bulletin of Peace Proposals, vol. 22, (4), p. 399-406.

Mandel, Robert, 1991. Sources of International River Basin Disputes. International Studies Association Meeting, Vancouver, B.C., 42 p.

LEGAL AND POLITICAL LESSONS

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Fred Roots has just provided us with some sage advice concerning "Lessons for the ENMOD Review Conference". I will consequently deal more generally with protection of the environment in time of armed conflict and international law, including but not limited to the ENMOD Convention.

Our discussions of the past few days have amply demonstrated that the Gulf war served as catalyst to examine applicable international law in this area and see if it needs strengthening. Following my initial presentation on "The Use of the Environment as an Instrument of War in Occupied Kuwait", Philippe Kirsch aptly summarized the results of this examination by saying that the law is weak since, if it is contained in a treaty, it suffers from insufficient participation of States and, if it is found in customary international law, it is hampered by the insufficiency of its enforcement mechanisms. This kind of weakness is not particular to this branch of international law, which is what States say it is because it is based on consent. Self-interpretation by States of international law is the norm because the compulsory jurisdiction of international courts, such as the International Court of Justice, is rarely accepted. As a result States are often judge and party in their own case.

These weaknesses and the obstacles they create are not easily overcome and may explain the tendency of States pointed out by Jason Reiskind to convene conferences to look like they are doing something when in fact they are not. Conferences can nevertheless be useful, if not essential, to shed light on an area as complex and uncertain as the one before us. In this connection I find very telling the "preliminary" character mentioned by Philippe Kirsch of the meeting of experts convened by the International Committee of the Red Cross, 14 months after the end of the Gulf war and following three international experts meetings (not counting this one) and two intergovernmental ones.

At this point in the debate I must say I share Philippe Kirsch's agnosticism: while a Fifth Geneva Convention such as proposed in London is clearly a non-starter (partly because of the uneasy marriage it attempted between Hague law, Geneva law and environmental law), I find it difficult to accept that all is well and that nothing can be done. What can be done is not necessarily restricted to the creation of new law, but its precise definition depends on an identification of priorities, in other words of what should be done. It seems to me that not enough reflection was accorded to this question during our discussions and that more will no doubt be required.

Peggy Mason provided us with a good start when she said that if the goal is preventing a recurrence of Iraqi behaviour in occupied Kuwait (and I would submit that this is at least one of the goals which should be pursued), we must focus on punishment to deter future aggressors, including environmental aggressors. Jason Reiskind drew attention to mechanisms which are already available to mete out such punishment, in particular the possibility of war crimes trials based on Iraq's violation of article 147 of the Fourth Geneva Convention (which seems strangely to have escaped most expert scrutiny so far). Given that the reasons which previously

militated against such trials, i.e. the risk of making a martyr out of Saddam Hussein and the hope that he might gracefully bow out, seem less relevant today, this may be worth looking into provided that the alleged criminals come into the custody of a State with both the jurisdiction and the political will to try them.

Several other possible avenues short of legislative action were mentioned, ranging from greater use of the Secretary General's powers under article 99 of the United Nations Charter to wider acceptance of the competence of judicial and investigative bodies such as International Court of Justice and the International Fact-Finding Commission under article 90 of Protocol I. These avenues all seem worthy of being followed, recognizing however that in so doing we may run up against the same problem as in drafting international agreements: you can bring a horse to water but you can't make it drink. More concretely, you can't force the Secretary General to act under article 99, you can't force the Security Council to act on the Secretary General's recommendation if he does, you can't force States to accept the competence of the International Court of Justice and the International Fact-Finding Commission, just like you can't force States to adhere to international agreements.

Peggy Mason suggested a second answer to the question of what should be done when she spoke about detecting violations through verification. This subject of verification, which figured prominently in the title of our workshop, was much less prominent in our discussions until this morning. Common ground nevertheless seemed to emerge over the last two days on a number of points:

a) In general, verification deters violations because violators don't want to be exposed.

b) This kind of deterrence may not work on an irrational actor (as some would argue is the case of Saddam Hussein).

c) Even in such circumstances verification is still useful for the calculation of damages and eventually of reparation.

d) Verification requirements will vary from one treaty to the next. In this respect there is, for example, an important difference between the draft Chemical Weapons Convention, which prohibits the use, development, production, acquisition, stockpiling, retaining or transferring of such weapons, and the ENMOD Convention, which prohibits only use.

e) Verification requirements will also vary according to the relevant element of intent. As we have seen this element can be subjective only as in ENMOD (" military or any other hostile use") or both subjective and objective as in Protocol I ("intended to cause" and "may be expected to cause"). The latter variation is in my view better because bad faith and irrationality are less likely to provide the basis of a possible defence against a breach of treaty accusation.

All of the above was written on the basis of the first two days of our discussions. This morning I consequently asked Ron Cleminson not to say anything relevant from a legal or political point of view because my conclusions were already written and too long. Fortunately for me, although Ron said a lot that was politically very relevant, he summarized his conclusions himself quite neatly:

- new concepts are required;
- a package approach is essential;
- tasks must be defined;
- the package must be tailored accordingly; and
- technological support makes each on-site inspector more effective.

The role of remote sensing in verification was highlighted today but so were the limitations of remote sensing for purposes of detecting violations of international agreements protecting the environment in time of armed conflict, which have to do with cost effectiveness and technical capability. For example, as Jeff Tracey explained, cloud seeding is not verifiable and overhead remote sensing cannot prove the origin of flooding, although it can provide leads for on-site inspection.

A subsidiary question to what should be done is how we should go about it. Here again there was widespread (and hopefully long-lasting) recognition of the indispensability of credibility and realism. As Sandy Bryce reminded us, there is no point in writing rules you're not prepared to defend in times of high stress such as armed conflict. Jason Reiskind put it even more starkly when he said that a military commander will not give up a battle, much less the defence of his own country, in order to protect the environment. A number of concrete requirements flow from this general need for realism.

First, caution must be taken to avoid the risk of inadvertently weakening the legal value of existing provisions, which arises in two ways:

a) any attempt to reinforce existing law which takes the form of ostensibly new rules could cast doubt on the binding character of the earlier rules, especially for those States which would not be bound by the new ones, and

b) the same problem arises in case of failure of such an attempt, particularly if certain States explicitly refuse to recognize the binding character of existing rules.

As we have seen, this type of problem is neither unprecedented nor insoluble in international law: it was successfully surmounted in the case of article 3 bis of the Chicago Convention on International Civil Aviation and a clear distinction was made for this purpose in the Munich recommendations between measures directed on the one hand towards increasing the effectiveness of existing law and on the other towards further development of the law.

Second, the need for realism requires that we pay due attention to the attitude of key States, in particular the United States of America, in what for the moment appears to be a much more unipolar world than a multipolar one. The importance of the United States position has cropped up in a variety of ways throughout our discussion. One way in which it hasn't, perhaps because of lack of time, is the fact that the United States was and probably remains opposed to the objective standard of care characteristic of Protocol I, which prohibits methods and means of warfare which may be expected to cause widespread, long term and severe damage to the environment. In a 1985 article generally considered to be a declassified version of the confidential study of the Joint Chiefs of Staff on which the United States based its decision not to ratify Protocol I, Commander Guy Roberts argued that this objective

standard would enable war crimes trials to be held in all cases where the environment is the victim of collateral damage due to military operations. While some may consider this view to be excessive, and I certainly do, it is nonetheless a factor which must be taken into account.

Another illustration of the importance of the United States position was provided by Jason Reiskind when he said that it greatly influenced the legal basis for the determination of Iraqi liability adopted in Security Council resolution 687. As Jason explained, there are three possible bases for such liability: Iraq's violation of the prohibition on aggression, requiring compensation of any damage resulting from it; its violation of customary international law as reflected in the Nürnberg Principles; or a violation of one or several provisions of the Geneva Conventions of 12 August 1949. This deliberate vagueness is the result of having the Security Council make legal determinations, as opposed to the International Court of Justice. Such a situation is made possible by what I referred to earlier as the primacy of self-interpretation by States of the norms of international law applying to them, a primacy which it tends to reinforce. Individual countries may not want to tie their hands to any particular interpretation of applicable rules of international law and may prefer to keep all their options open for the future. Personally I would submit that this is not in the interest of the rule of law in international relations or of the international community as a whole.

A third example of the importance of the United States position was indirectly provided by Jason Reiskind when he indicated satisfaction with the fact that the United States appears to have come around on paragraph 9 of the Ottawa Conference Chairman's Conclusions. After stating that the application and development of the law of armed conflict have to take account of the evolution of environmental concerns generally, this paragraph declares that the customary laws of war, in reflecting the dictates of public conscience, now include a requirement to avoid unnecessary damage to the environment. Whether the United States opposes or supports this concept or any other concept which might come into play during the course of efforts to improve the protection afforded to the environment in time of armed conflict, this example reinforces once again the fact that we cannot afford to ignore its views.

Third, the need for realism also requires that account be taken of the position of other key States and of the impact of other key issues. I refer here in particular to the position of France and to the issue of the applicability of Protocol I to nuclear weapons. Like the United States, France is not a party to Protocol I, which contrary to the United States it did not even sign. France announced its intention not to become a party in 1984, invoking "the absence of consensus between signatories to Protocol I concerning the exact scope of obligations assumed by them in matters of deterrence". This rather convoluted formulation was the result of repeated but unsuccessful French attempts to obtain a clear answer to the question of whether of not Protocol I applied to nuclear weapons, since several of its provisions were likely to have an impact on France's nuclear deterrence strategy, based on the threat of massive anti-city reprisals. This is particularly true of articles 35(3) and 55, since it is a priori difficult to argue that such a use of nuclear weapons would be excluded from the prohibition on "methods or means of warfare which (...) may be expected to cause widespread, long term and severe damage to the natural environment".

This is why, in becoming parties to Protocol I, Germany, Belgium, Canada, Spain, Italy and the Netherlands, none of which possesses nuclear weapons but all of which are members of a military alliance whose deterrence strategy rests on the threat of their use, made interpretive statements to the effect that the Protocol applies only to conventional weapons. The United States and the United Kingdom, which are not parties to Protocol I, made similar statements upon its adoption which where officialized when it was opened for signature. Interestingly, neither China nor the USSR, as it then was, the only two nuclear weapons parties to Protocol I, felt the need to make any such statement at the time of ratification. France, for its part, is of the view that the preparatory work of Protocol I reveals an ambiguity on the question of whether or not it applies to nuclear weapons, which interpretive statements alone cannot clarify. It consequently considers fragile the position consisting in reliance upon such statements to affirm the legality of the use of nuclear weapons under Protocol I.

The organizers of the Ottawa Conference were acutely aware of this controversy and determined to avoid getting dragged into it, as illustrated by the title of this Conference of Experts on the Use of the Environment as a Tool of Conventional Warfare, and it seems that they succeeded in their efforts to do so. Nevertheless, as illustrated by the Sixth Committee debate on the relevant agenda item proposed by Jordan at the last session of the United Nations General Assembly, it is impossible to exclude nuclear weapons from a discussion of environmental protection in time of armed conflict in a multilateral intergovernmental setting. The danger is that an excessive focus on the issue of nuclear weapons would be the surest way of condemning such a discussion to failure. We must consequently recognize that this issue will inevitably arise while attempting to tread as lightly as possible when it does -- not an easy balancing act, but a necessary one.

Fourth, the need for realism requires a clear understanding of the different approaches which can be taken to develop new law, in the event that such a development is deemed appropriate. As pointed out by Philippe Kirsch, three approaches are possible. A totally new instrument can be elaborated, but then extensive informal consultations are essential to avoid the risk of diluting existing law or of having the initiative highjacked by the addition of unacceptable proposals. Alternatively, we can build on existing instruments through statements of understanding, annexes, protocols, etc. This option is less risky than the first but still entails a lengthy process.

Finally, we can use the Security Council as a short cut. This approach is the fastest one to legislative development because it mobilizes a restricted political forum with the greatest possible authority. The Security Council can decide that certain things are prohibited because they are contrary to international peace and security. The fact that it devoted a full third of its 31 January 1992 Summit Declaration to arms control and disarmament means that it will no longer be just a bystander in this area as it tended to be in the past. However, in contemplating this option we should be mindful of two important facts. On the one hand, the Security Council's assertiveness is rapidly increasing over time and it can do things today that were inconceivable only six months ago. On the other hand, any attempt to artificially accelerate this process runs the risk of creating a North/South split. The West should therefore be careful not to be too pushy and should exercise moderation to avoid a Third World backlash. Philippe Kirsch pointed out that this danger is inherent in current efforts to impose sanctions on Libya as a result of the Lockerbie and UTA incidents.

I would like to conclude with a few personal remarks on factors which I believe are relevant to the question of whether or not new law is necessary to ensure better protection of the environment in time of armed conflict. The answer to this question depends to a certain extent on how one envisages the role of humanitarian law in international society and on one's expectations concerning the possibility and desirability of developing that branch of the law.

Personally I see humanitarian law as the expression of a will to "humanize war", to make its effects less painful by circumscribing to the maximum possible extent the material and human destruction which are in its very nature, limiting them to what is strictly necessary to attain the military objectives of those responsible for conducting it. This law truly responds to "the dictates of public conscience" and will consequently evolve alongside them. It is significant in this connection that its development in the twentieth century runs parallel to that of legal restrictions on the use of force in international relations.

In the 1970s the dictates of public conscience extended to the environment and resulted in the adoption of the ENMOD Convention and articles 35(3) and 55 of Protocol I. Fifteen years later, public conscience is not less demanding in environmental matters, quite the contrary. This is why the oil spills and oil fires provoked by Iraq in Kuwait made such an impression on it. It is also why governments and non-governmental organizations took the initiatives we have been discussing, which all sought to express, each in its own way, the "never again" reaction instinctively felt by the millions of TV viewers around the world who followed in real time the most extensively covered war in history.

As Philippe Kirsch reported, it was said at the London Conference that the history of humanitarian law is made of sporadic progress during "legislative moments", by definition relatively brief, when legal advances are possible in the aftermath of a prominent war in which the victorious side was the victim of belligerent practices that fell outside its views of the canons of military necessity. Doubts were also expressed in London as to whether we really have entered such a "moment", given the necessity of first examining existing law and the danger of rushing to legislate on the basis of a single recent event. As long as the debate continues and no decision is taken on the appropriateness of completing the law on environmental protection in time of armed conflict, it remains theoretically possible to do so. It is clear that the chances of this materializing diminish as time goes by and as the conflict at the origin of the "moment" recedes in the collective memory.

If such a legislative development remains for the moment possible, is it nevertheless desirable? As I stated earlier, it is still too soon to give a definitive answer, since the international community has barely started to examine the extent to which the current state of the law responds to its needs and it is not yet clear that agreement is possible to fill in any eventual gaps. Subject to the final result of this examination, I am personally inclined to think that such a development is indeed desirable. It seems to me that we should seize the opportunity provided by the damages inflicted on the environment in Kuwait to limit a little bit more the margin of manoeuvre of political leaders and military commanders when they are engaged in an enterprise of destruction. In this way we will be able to increase the place given to the dictates of public conscience and limit that of the necessities of war, which is the very purpose of international humanitarian law.

References

1. The author was in charge of environmental law from 1983 to 1985 and Head of the UN, Human Rights, Peace and Security Section in 1987 and 1988 in the Legal Operations Division of the Department of External Affairs. The opinions expressed here are however his own and do not necessarily reflect those of the Government of Canada.

SCIENTIFIC AND TECHNICAL LESSONS

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International disagreement and general inertia resulted in uncertainty and lack of action after the Gulf War. In order to be able to accuse any nation of violating the ENMOD Convention, one has to have proof that long-term damage to the environment occurred.

Ron Cleminson summarized, earlier, some of the technical details, such as:

- remote sensing, by satellite, including images of thermal readings, etc.;
- low-altitude photographs;
- use of airborne sensors of various types;
- ground-based monitors, including remote sensors; and
- collateral analysis of data from various sources.

All these methods may be effective, particularly when used in concert, but we have to consider the benefits and the costs. Cost savings may be accomplished by informing scientists and engineers of specific requirements and tasks, so that they might come up with the appropriate instruments.

However, whenever data are collected, one has to have baselines or historic data, to compare with. For instance, we need:

- environmental baseline data, such as recordings of temperatures and their fluctuations, precipitation and drought data;
- health baselines; maybe WHO could provide these, or international workshops could try to assemble such information; and
- predictive modelling of events like plume modelling and dispersion from oil fires; distribution of chemical compounds released as a cloud, etc.

While doing all of this, we should not forget what Fred Roots said: "Nature has its own agenda." Periodic climate changes have come and gone, so have diseases, and one has to be careful not to jump to premature conclusions.

In order to get a better appreciation of all these potential requirements, one could establish "think-tanks" that should periodically review and summarize such aspects. These "think tanks" should be of an interdisciplinary nature, to force scientists, and eventually political scientists and policy makers, to communicate. Governments could press for such action, and sponsor such gatherings on a national and international basis.

Finally, it is certainly worthwhile to spend some time on clarification of the terminology and definitions. Dr. Sutherland wrote about this on his overhead, under the heading of Verification Problems:

Threshold provision: "widespread, long-lasting or severe"

Appropriate Finding of Facts:

- has environmental modification occurred?
- what technique(s) were used?
- thresholds:
    - widespread, 100 sq. km?
    - long-lasting, months/season?
    - severe, how severe?

SESSION 6: DISCUSSION

In the ensuing discussion it was pointed out that a significant amount of work during the Review Conference is required by experts groups focusing on specific questions. For example, during the Biological and Toxins Weapons Convention, it was the non-governmental organizations that brought forward several specific proposals for consideration. Out of ten proposals put forward, three were adopted by the Conference. The point to consider here is the importance of a tremendous amount of preparatory work required before any proposal could be seriously considered for incorporation into a Review Conference.

One criteria that has not been well defined within the ENMOD Convention is the definition of a quantitative measure of "severity". The severity of an environmental catastrophe directly influences whether it can be deemed an "environmental modification technique". The problem of a literal interpretation of the Convention was also discussed. For example, if an aqueduct was diverted or destroyed, would this represent a manipulation of a natural process. An aqueduct is not natural and a manipulation of the natural process occurred when the aqueduct was built originally. Is a natural process still being manipulated as a result? An argument could be made that the destruction of an aqueduct could ultimately result in the changing of the natural ecological process of the irrigated land.

The discussion turned to the question of whether defoliants should be considered as a method of environmental modification. Examples of the use of defoliants in time of war include their use by the British in Malaysia to destroy rice crops, and their extensive use by the United States in Vietnam. During the adoption of the ENMOD Convention, the United States and the Soviet Union considered the use of defoliants as not included under the definitions of the Treaty.

The issue of the use of outer space as an area where the environment can be modified was also addressed. It was recognized that any occurrence in outer space would be considered "widespread, long-lasting or severe". Specific examples of modification techniques in outer space such as nuclear explosions and debris were introduced into the discussion. The key issue here was whether these methods were considered as a hostile act. The dividing line between the ENMOD Convention and other treaties is the means of destruction, damage or injury in outer space.

It was suggested that the Review Conference might consider using illustrative examples rather than definitive statements as a method of defining whether something is a manipulation of a natural process.

SESSION 7

WORKSHOP REVIEW

Chairperson: Ron Sutherland

WORKSHOP ON VERIFYING OBLIGATIONS RESPECTING ARMS CONTROL AND THE ENVIRONMENT: A POST-GULF WAR ASSESSMENT

WORKSHOP REVIEW

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Introduction

This Workshop brought together a group with diverse skills to examine problems of arms control and the environment with particular concentration on the Environmental Modification Convention of 1977 (Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques) because of the forthcoming review in September 1992 and also the Geneva Protocol I of 1977 (Protocol I Additional to the Geneva Conventions of 1949 and Relating to the Protection of Victims of International Armed Conflict) in so far as it is concerned with the environment; these are articles 35.3, 55.1 and 2 and 56.

The text of the relevant articles is as follows:

35.3 It is prohibited to employ methods or means of warfare which are intended, or may be expected, to cause widespread, long-term and severe damage to the natural environment.

55.1 Care shall be taken in warfare to protect the natural environment against widespread, long-term and severe damage. This protection includes a prohibition on the use of methods or means of warfare which are intended or may be expected to cause such damage to the natural environment and thereby to prejudice the health or survival of the population.

55.2 Attacks against the natural environment by way of reprisals are prohibited.

56.1 Works or installations containing dangerous forces, namely dams, dykes and nuclear electrical generating stations, shall not be made the object of attack, even where these objects are military objectives, if such attack may cause the release of dangerous forces and consequent severe losses among the civilian population. Other military objectives located at or in the vicinity of these works or installations shall not be made the object of attack if such attack may cause the release of dangerous forces from the works or installations and consequent severe losses among the civilian population.

Articles I, II and V of the ENMOD Convention were determined to be of most interest to the discussion and the text of these articles is given below:

Article I.1 Each State Party to this Convention undertakes not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party.

I.2 Each State Party to this Convention undertakes not to assist, encourage or induce any State, group of States or international organization to engage in activities contrary to the provisions of paragraph 1 of this article.

Article II As used in article I, the term 'environmental modification techniques' refers to any technique for changing -- through the deliberate manipulation of natural processes -- the dynamics, composition or structure of the Earth including its biota, lithosphere, hydrosphere and atmosphere, or of outer space.

Article V.1 The States Parties to this Convention undertake to consult one another and to cooperate in solving any problems which may arise in relation to the objectives of, or in the application of the provisions of, the Convention. Consultation and co-operation pursuant to this article may also be undertaken through appropriate international procedures within the framework of the United Nations and in accordance with its Charter. These international procedures may include the services of appropriate international organizations, as well as of a Consultative Committee of Experts as provided for in paragraph 2 of this article.

V.2 For the purposes set forth in paragraph 1 of this article, the Depositary shall, within one month of a receipt of a request for any State Party to this Convention, convene a Consultative Committee of Experts. Any State Party may appoint an expert to the Committee whose functions and rules of procedure are set out in the annex, which constitutes an integral part of this Convention. The Committee shall transmit to the Depositary a summary of its findings of fact, incorporating all views and information presented to the Committee during its proceedings. The Depositary shall distribute the summary to all States Parties.

V.3 Any State Party to this Convention which has reason to believe that any other State Party is acting in breach of obligations deriving from the provisions of the Convention may lodge a complaint with the Security Council of the United Nations. Such a complaint should include all relevant information as well as all possible evidence supporting its validity.

V.4 Each State Party to this Convention undertakes to co-operate in carrying out any investigation which the Security Council may initiate, in accordance with the provisions of the Charter of the United Nations, on the basis of the complaint received by

the Council. The Security Council shall inform the States Parties of the results of the investigation.

V.5 Each State Party to this Convention undertakes to provide or support assistance, in accordance with the provisions of the Charter of the United Nations, to any State Party which so requests, if the Security Council decides that such Party has been harmed or is likely to be harmed as a result of violation of the Convention.

The Workshop examined some of the legal and technical aspects of the above international laws and found it difficult to determine the possible application of ENMOD to the Gulf War. It seemed clear that the local environment had been effected detrimentally by the deliberate setting of oil fires well beyond the realms of military necessity and that the deliberate release of oil into the Gulf fell into the same category, but the terms "widespread, long-term and severe" in Protocol I and "widespread, long-term or severe" as used in ENMOD particularly when taking the documentation on "threshold" into account made a clear breach difficult to demonstrate.

ENMOD Review Process

In the light of the above, it was agreed that the upcoming Review Conference will likely address the following:

- Article II and the terms, "environmental modification techniques", "deliberate manipulation of natural processes";

- Article V and the role of the Consultative Committee of Experts and the mechanism of complaint and investigation.

The Review Conference might stress the importance of strengthening the verification process for the ENMOD Convention and rely, to some extent, on prior experience of the Biological and Toxin Weapons Convention (BTWC) where there was agreement to first develop confidence building measures (CBMs) that could eventually form the basis for a more formal mechanism. It was noted that UNEP might play a similar role to that initially envisaged for WHO in the BTWC.

To this end it might be appropriate to concentrate on a way to determine "findings of fact", namely:

- Has environmental modification occurred?
- What techniques, based on present scientific knowledge, could be used?
- Could the notion of "threshold" be clarified and better defined?

It was considered that this could best be done by a technical assessment of risks that used the following concepts:

- Danger to the environment;
- Military utility;
- Feasible ENMOD techniques;
- Unacceptable military targets;

- Remote sensing capabilities; and
- Relationship with other legal instruments.

The final discussion centred on the development of illustrative lists; these might describe events that were possible and also be able to demonstrate a verification process. The list might include:

- Forest fires and remote sensing;
- Oil fires and remote sensing;
- Misuse of herbicides;
- Water diversion;
- Electromagnetic pulses; and
- Introduction of new species.

These could be further evaluated and a decision made as to whether working papers be developed around such themes.

LIST OF PARTICIPANTS

WORKSHOP ON VERIFYING OBLIGATIONS RESPECTING ARMS CONTROL AND THE ENVIRONMENT: POST-GULF WAR ASSESSMENT

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