Journal of Coastal Conservation 1: 63-76, 1995

Maritime oil spills - Environmental lessons and experiences with special reference to low-risk coastlines

Ritchie, W.

University of Aberdeen, Regent Walk, Aberdeen AB9 1FX, Scotland, United Kingdom;
Tel. 44 1524 65201; Fax +44 1524 36841; E-mail: W.RITCHIE.@LANCASTER.AC.UK
Present address: Vice-Cancellor's Office, Lancaster University, Lancaster LA1 4YW, United Kingdom

Abstract. Oil spill contingency plans are available for most coastlines but the amount of useful environmental data is variable. The information should be held on a GIS base. High risk areas should be identified and the pre-existing store of environmental knowledge should be commensurately extensive and should be available in considerable spatial detail. Contingency plans still depend on basic lists of coastal types as defined by static, sediment based shoreline characteristics. There is a lack of dynamic, process information. The *Braer* oil spill of 1993 provides a case study of the application of sound coastal geomorphological and ecological data to impact assessment. Monitoring of the ecological effects of this massive oil spill reinforces other research which indicates that most coastlines can recover naturally from oil spills, and that oil spill clean up techniques may not necessarily benefit rapid shoreline recovery. Although pre-existing environmental information is important, the key decisions must be taken quickly and are frequently judgmental and, therefore, place a premium on gathering appropriate scientific expertise to the site of the spill as soon as possible and with sufficient powers to affect both the oil spill response, to initiate early surveys of damage and to facilitate the initial monitoring programme.

Keywords: *Braer* oil spill; Contingency planning; Coastal information base; Shoreline recovery.

List of Acronyms:

CONCAWE	Oil Companies' International Study Group for Conservation of Clean Air and Water;
CRISTAL	Contract Regarding A Supplement to Tanker Liability for Oil Pollution;
ESGOSS	Ecological Steering Group on the Oil Spill in Shetland;
FEPA	Food And Environment Protection Act (on Fig. 1 this box defined area from which no food products, especially fish of all types could be harvested);
GIS	Geographic Information System;
IOPCF	International Oil Pollution Compensation Fund;
ITOPF	International Tanker Owners' Pollution Federation;
MEHRAS	Marine Environmental High Risk Areas;
SCAT	Survey Clean-up Assessment Team;
SPA	Special Protection Area;
SSI	Site of Special Scientific Interest;
TOVALOP	Tanker Owners' Voluntary Agreement for Liability For Oil Pollution.

Introduction: the oil spill and the development of contingency plans

Major coastal oil spills are similar to other natural and man-made incidents that lead to environmental damage, adverse commercial and economic impacts and, sometimes, loss of property and life, in so far as during and after the event there is public clamour that "this must not happen again". More realistically, the probability that "this will happen again" is recognised and various procedures and arrangements are made to reduce the severity of unavoidable adverse consequences.

Reactions to coastal oil spills range from major international political decisions (e.g. The International Convention on Oil Pollution Preparedness, Response and Co-operation [OPRC] Convention in 1990) to the development of local-scale contingency plans. Beneficial changes include national and international legislation to ensure that adequate compensation is paid to injured parties. At the level of a nation state, effective professional and technical organisations have been established to deal with oil clean up, normally within predetermined territorial restrictions. Oil spill prevention and clean-up are ultimately responsibilities of local and regional government agencies but in specific locations, normally close to the shoreline and especially where these are oil based activities, the oil industry or a harbour authority plays the major role. Offshore; e.g. beyond a specific distance, it is always the responsibility of a national agency such as the Coast Guard to respond to major oil spill incidents. Port and harbour areas are likely to have their own detailed clean-up and other types of oil spill contingency plans, but oil spills in the open sea may use different techniques, including some use of spraying with approved chemical dispersants.

The *Torrey Canyon* oil spill in the English Channel in 1967 is often regarded as the key incident for international improvement. It led to the creation by the ITOPF (the International Tanker Owners Pollution Federation Ltd) of TOVALOP, and later, the cargo owners founded CRISTAL in 1971. Both TOVALOP and CRISTAL relate to issues of liability and compensation arrangements. Most European countries accepted the need for a national organisation to be ready to counter major oil spills. In Britain, this agency is the Marine Pollution Control Unit (MPCU). In France, after *Amoco Cadiz* in 1977, the major role is played by the French Navy. In the Netherlands, control both offshore, along the coast and inland, rests with the State Waterways Board (Department of Public Works and Water Management). For other European countries similar agencies are specified, and these are summarised in Table 1 which is abstracted from Archer & White (1989). In the USA the picture is less clear and several agencies appear to be involved, including the oil industry itself, the US Coast Guard and the Environmental Protection Agency. The relationship between Federal and State Agencies adds managerial complexity. Indeed, after analysing the aftermath of the *Exxon Valdez* incident in 1989, it remains to some extent unclear how the response to a major oil spill on the coastline of USA would be managed. It is interesting to note that a background paper to the Congress of the United States entitled "Coping with an Oiled Sea" (Anon. 1990) contains the following: "The current US approach to fighting major oil spills, unlike the approach of some European countries is more democratic than authoritarian. Democratic decision-making, however, may not be as appropriate for making decisions in emergency situations where speed is essential". This observation is valid to most aspects of decision-making and is not confined to major oil spills but the speed and circumstances of most oil spills - often at night and often in bad weather - necessitates rapid decision-making procedures. In general, democratic procedures during most oil spills will be inherently slow and therefore inefficient. Experience has shown that the most effective response is by a single on-scene commander with unquestioned authority to act quickly but with adequate consultation. This consultation process is not primarily with 'interested' parties but with pre-determined expert advisors. Effective countermeasures and actions to minimise environmental damages are improved greatly if there is a pre-existing store of information in an accessible form for the coastal zone.

Environmental information needed for contingency responses

Most major oil spills have revealed various degrees of inadequacy in the availability of essential information. These inadequacies include basic chart and map data, tidal, current and wave characteristics, shoreline types, bathymetric information, ecological and habitat databases. (Poor logistic capability, shortage of equipment, absence of qualified personnel and other operational failures have also been recorded but are not discussed in this paper.) From an environmental perspective, it is generally correct to record that most of the shortcomings that relate to physical environmental factors have been rectified most effectively and efficiently near major oil ports and installations where, statistically, most oil spills are likely to occur. Further, the normal day to day operation of the terminal or port necessitates the ready availability of hydrographic, weather and other information. In the past, information on shorelines types and habitats were the most common deficiencies. Even close to oil terminals or ports, coastal information has sometimes been absent or at best superficial. Nevertheless, more recently, appropriate shoreline data have been obtained and put into readily accessible and user-friendly maps and many plans have now moved onto a GIS format. The major advantages of using GIS were manifest during the *Exxon Valdez* oil spill when massive quantities of spatial data were assembled on PC based systems. The ability to update information and to interrogate relationships between different layers of information are prime advantages of GIS. The ability to enlarge or reduce the area of concern is another valuable asset. The amount of information that is available for coastlines near major oil terminals or in busy waterways such as major estuaries has been obtained by concentrating survey resources on the relatively small areas at risk. The oil spill contingency plan for Sullom Voe Terminal in Shetland (Fig. 1), for example, although not as yet transferred to a GIS format, is a model of such environmental and ecological information but almost all major oil port and terminal areas and most major commercial estuaries in Western Europe now have this type of shoreline database which includes additional information such as accessibility, seasonal populations of wildlife, shoreline materials, exposure and energy conditions. (It is interesting to note that for Sullom Voe the oil spill contingency plans were greatly improved after the *Esso Bernicia* fuel oil spill in 1978.)

In most contingency plans, special attention is given to shoreline geomorphology which can be simplified into a description of materials, gradients and littoral dynamics. The need for this information derives not so much from the assessment of environmental impact or the scientific measurement of ecological recovery (where this information is essentially the description of habitats) but primarily from the situation where almost all oil spill clean-up techniques derive from the concept of shoreline vulnerability and fragility. Indeed, in some form or other, most oil spill plans embody the CONCAWE classification (as exemplified by Table 2). The main inadequacy of this geomorphological classi-

Table 1. Summary of oil spill response arrangements.

Country	Central government departments primarily involved	Responsibility for clean-up: At sea	Responsibility for clean-up: On-shore	Policy for clean-up at sea	Clean-up resources
Belgium	Ministry of Defence Ministry of Interior	Navy	Coastal municipalities; Civil Defence Corps	Dispersants applied from vessels	Limited mainly to dispersants and spraying equipment
Denmark	Ministry of Environment	National Agency for Environmental Protection (N.A.E.P.)	(N.A.E.P.) Coastal local authorities; Civil Defence Corps	Containment and recovery almost exclusively although provision for limited use of dispersants	Specialised vessels equipped with booms and skimmers. Also equipment and materials for shore clean-up in district stockpiles
France	Secretary of State for the Sea Ministry of Defence Ministry of Interior	Maritime Project (Navy)	Coastal communes; Commissioner of the Department	Containment and recovery preferred but dispersants used in designated areas	Extensive stocks of specialised equipment and materials in regional stockpiles. Also strike teams and aircraft for dispersant spraying
Germany	Ministry of Transport	Federal Board of Waterways and Navigation; Coastal states	Coastal states	Containment and recovery preferred but dispersants also used in North Sea	Specialised vessels, booms, skimmers, spraying equipment and dispersants
Norway	Ministry of Environment	State Pollution Control Authority/Maritime Directorate	Coastal community and inter-community areas	Containment and recovery almost exclusively, but will consider dispersants if mechanical means are ineffective	Extensive stocks of specialised equipment and trained response teams at 12 regional centres
Sweden	Ministry of Defence	Coast Guard Service	Municipal fire brigades; Provincial authorities	Containment and recovery preferred although dispersant application permissible under certain conditions	Large fleet of vessels equipped for anti-pollution work. Extensive sticks of clean-up equipment in some 30 coastal sites
United Kingdom	Department of Transport	Marine Pollution Control Unit of Maritime Directorate	Marine Pollution Control Unit of Maritime Directorate; Coastal local authorities	Aerial application of dispersants; containment and recovery where applicable	Seven dedicated spraying aircraft, vessel-mounted spray gear and extensive stocks of dispersant; also containment and recovery equipment and equipment for shore clean-up in three regional stockpiles
the Netherlands	Ministry of Transport and Public Works	North Sea Directorate of State Waterways Board	Coastal provincial and municipal states	Containment and recovery exclusively	Specialised vessels, including combined dredgers/oil combating ships equipped with oil recovery equipment. Other vessels for deploying booms. Other equipment held by salvage and private contractors

[Abstracted from Archer, N.J. & White, I.C. (1989), ITOPF, London].

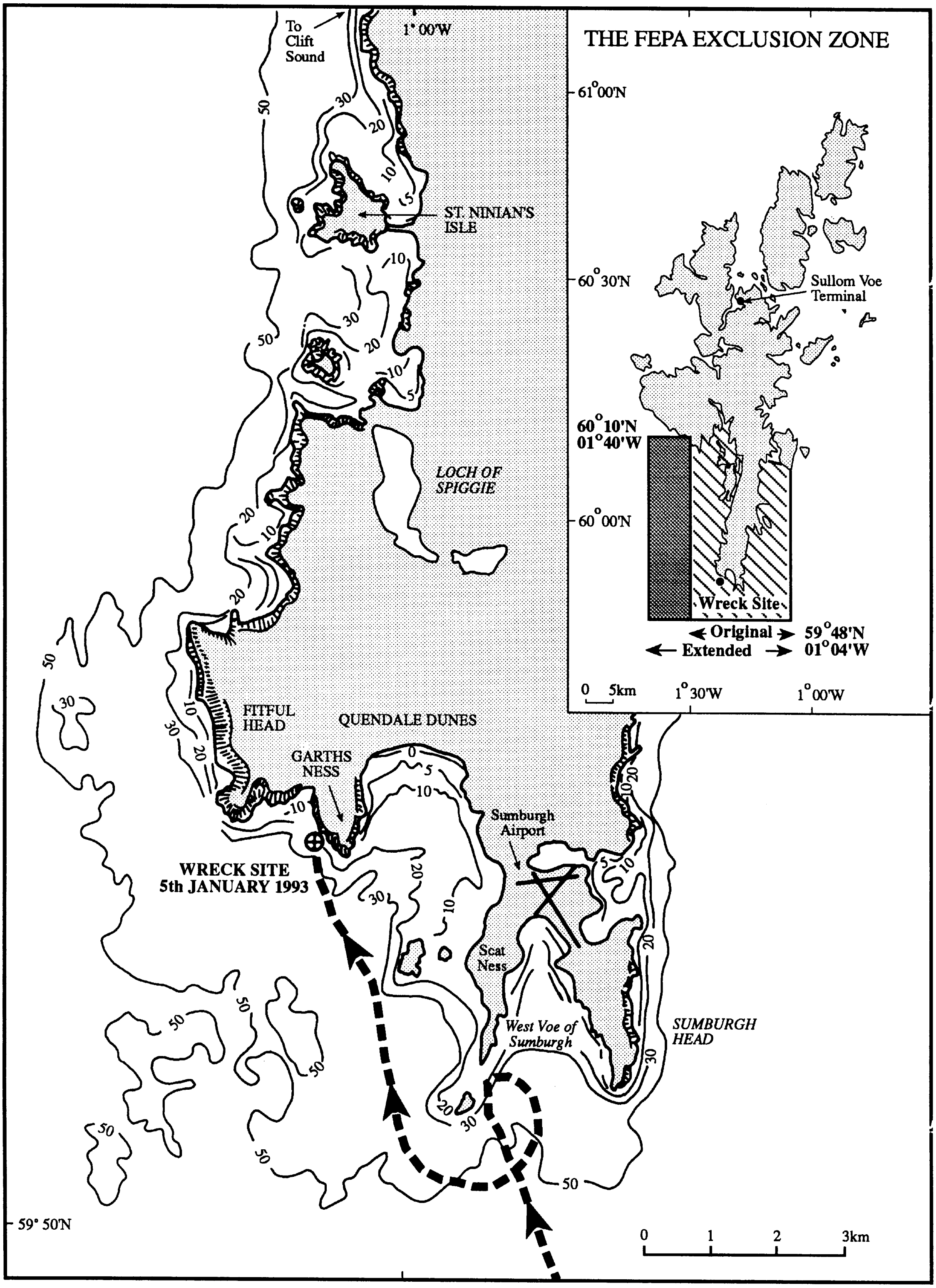
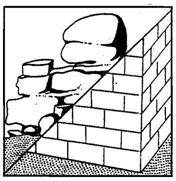
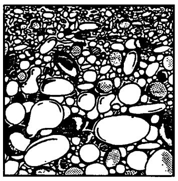
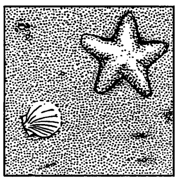
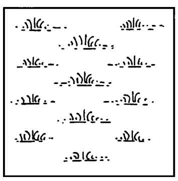


Fig. 1. Track of the *Braer* and location of impact on coast of south Shetland.

Table 2. Behaviour of oil on some common types of shoreline.

	Type and Size Range	Comments
	Rocks, boulders and man-made structures > 250 mm	Oil is often carried past rocky outcrops and cliffs by reflected waves but may be thrown up onto the splash zone where it may accumulate on rough or porous surfaces. In tidal regions, oil collects in rock pools and many coast rocks throughout the tidal range. This oil is usually rapidly removed by wave action but is more persistent in sheltered waters.
	Cobbles, pebbles and shingle 2 - 250 mm	Oil penetration increases with increasing stone size. In areas with strong wave action, surface stones are cleaned quickly by abrasion whereas buried oil may persist for some time. Low viscosity oils may be flushed out of the beach by natural water movement.
	Sand 0.1 - 2 mm	Particle size, water table depth and drainage characteristics determine the oil penetration of sand beaches. Coarse sand beaches tend to shelve more steeply and dry out at low water enabling some degree of penetration to occur particularly with low viscosity oils. Oil is generally concentrated near to the high water mark. Fine grained sand is usually associated with q flatter beach profile remaining wet throughout the tidal cycle so that little penetration takes place. However, some oil can be buried when exposed to surf conditions for example during a storm.
	Mud (mud flats, marshes, mangroves) < 0.1 mm	Extensive deposits of mud are characteristic of low energy environments. Little penetration of the substrate by oil occurs because the sediment is usually water-logged but oil can persist on the surface over long periods. If the spill coincides with a storm, oil can become incorporated in the sediment and persist indefinitely. Animal burrows and plant root channels can also bring about oil penetration.

(Abstracted from Response to Marine Oil Spills ITOPF 1987 3rd Edition p iv 4.)

fication is the absence of dynamic process factors. Fragility and vulnerability are not synonymous since the techniques and prioritisation of preventing oil impact onto the coast as determined by the latter include an estimate of the likelihood of oil impact; fragility is an absolute concept, albeit qualitative.

As an example of the importance of the shoreline types as the prime determinant in both the evaluation of damage and the specification of the cleaning techniques to be used after oil has impacted the coast, consider the development of SCAT teams during the *Exxon Valdez* oil spill. The prime duty of a SCAT team is identified by its full title - Shoreline Clean-up Assessment Teams. They provide reasonably standardised, rapid and systematic assessments of both the shoreline and the extent and characteristics of the stranded oil. The team consists of a coastal geomorphologist, a biologist and (in Alaska) an anthropologist/archaeologist along with a technical clean-up expert. In other areas, the composition of the team might vary. The methodology is little more than the use of standardised checklists and rigorous use of predetermined descriptive terminology. The concept was not new but the scale of operation in Alaska was huge. As reported by Owen & Teal (1990), SCAT teams covered 5500 km of coastline in 4 months. The fact that this huge effort was required is only partly explained by the need to assess the amount and type of oil that actually stranded but it is a reflection on the understandable lack of detailed knowledge of the pre-existing ecological, geomorphological (and in Alaska) cultural status of the shoreline. It should also be noted that the *Exxon Valdez* oil spill was of 37 000 tonnes and threatened over 5000 km of coastline whereas the *Braer* oil spill in 1993 was 85 000 tonnes and only impacted 120 km of coastal areas. Nevertheless, the underlying concept of a SCAT response is valid but the number of teams and the rate of geographical deployment will vary according to the length and nature of the impacted shoreline.

The extreme differences between the tonnage spilled and the length of coastline under threat as exemplified by the *Exxon Valdez* and the *Braer*, emphasise the critical need to appreciate the scale of oil impact. Oil strands on particular shorelines at the scale of metres;

clean-up and oil recovery takes place at the same painstaking level; booms, skimmers, water and steam jets and other devices are rarely deployed in lengths more than tens of metres long. Thus, the level of information required must be at this large-scale; in cartographic terms 1:10 000 or 1:5000 or better; that is at a scale of depiction where tens of metres can be shown and is not so generalised as to be meaningless. Without the power of GIS systems to expand both the scale of presentation and the amount of on-screen reference data, this large scale is only practical when compiling pre-spill environmental data for coastlines measured in tens of kilometres, eg, near oil terminals or major ports or in other special areas such as coastlines which border constricted sea lanes.

A most recent report, the thorough Canadian Coastal Environments: Shoreline Processes and Oil Spill Clean-up by the Environmental Protection Agency (Anon. 1994a), epitomises the problem of the scale of information presentation. The coastline of Canada is 250 000 km long, and in this Report, the process of description begins with major regional subdivisions, e.g. British Columbia, Gulf of St. Lawrence etc. and these very large geographical units are subdivided further. The baseline information is derived from extensive original surveys often done by aerial photographic or video classification techniques, supported by comprehensive literature reviews, but it is inevitably generalised. To overcome some of the problems of the impossibly large scale of description, this Canadian Report begins with an account of the essential principles of physical geomorphological processes and coastal dynamics including regional processes, materials and seasonal shoreline changes and it should be possible to apply these basic principles to derive an initial analysis of the geomorphological nature of any specific shorelines as a first level of understanding of the likely impact of oil on the littoral environment. This section is followed by a general account of the fate of oil in relation to different shoreline types. In the final 150 pages of the report, the entire coastline of Canada is divided into approximately 40 sections and each section is described briefly in geomorphological terms. It is not the purpose of this paper to review this major national report, but it is important to use this example to recognise the need to produce a cascading sequence of progressively more detailed coastal and ecological information to assist oil spill contingency planning, response systems and subsequent rehabilitation. The production of similar national coastal reports from different parts of the world is now widespread and can be interpreted as a first stage response to the inadequacy of information and the experiences gained from earlier oil spills.

In the context of an oil spill, the task of acquiring detailed relevant pre-spill information for entire national coastlines is often impossible and unnecessary. What requires to be added is a reasoned statement of the statistical probability of an oil spill occurring at or near a particular stretch of coastline and this assessment of vulnerability should define the level of survey effort. It is the duty of the oil industry, tanker operators and maritime transport and navigation authorities to produce probability maps for the incidence of oil pollution so that the effort of environmental scientists and government agencies can be concentrated on the zones at greatest relative risk. There is however currently and coincidentally a separate urgency to increase the knowledge-base of shoreline information from coastal states world-wide. This coastal information should include data which goes beyond simple listing but attempts to assess the importance of particular habitats or numbers of species at both national and international scales. This demand arises from the adoption of AGENDA 21 at the World Environmental Congress in Rio in 1992. Essentially an important component of AGENDA 21 from the United Nations Conference on Environment and Development invites coastal states to undertake research on a series of crucial coastal problems, including: eroding zones, pollution sensitive areas and details of physical and biological processes. In another section, AGENDA 21 emphasises the need for periodic assessment of trends including updated predictions of the effects of all types of emergencies and the direct impact of human activities on existing coastal and physical infrastructures. This convergence of interest between the particular problems associated with the oil industry and the general recognition of various types of adverse pressures on world coastlines should be welcomed since the acquisition of relevant information now becomes multipurpose and the justification for national resources to be made available in order to work towards common goals is enhanced significantly.

On the assumption that coastal environmental information must be the major component in all types of pre-spill planning, actual clean-up and recovery procedures and post-spill recovery monitoring, this broad review of some previous oil spills reveals two contrasting situations:

Scenario 1: Environmental information is available in considerable detail for relatively small coastal areas such as estuaries, ports and harbours, and areas adjacent to various types of oil facilities. The data are well co-ordinated and readily available as part of contingency plans. Increasingly the data is held on a Geographical Information System (GIS).

Scenario 2: For areas that are thought to be at low risk

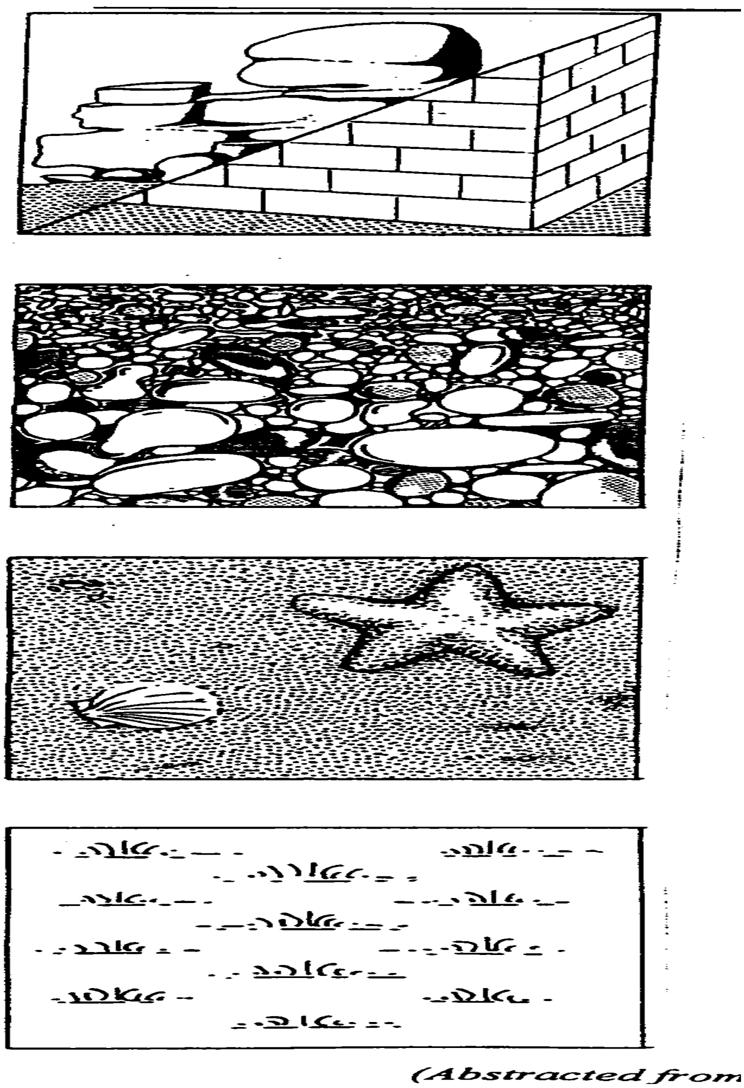


Fig. 2. The wreck of the *Braer*.

or where the responsible agencies have not implemented national contingency planning programmes the level of environmental information is almost non-existent, fragmented or extremely generalised. The data tend to be uncoordinated and in the event of a major oil spill would need considerable time and effort to bring together.

Lessons from the *Braer*

These two scenarios are oversimplified and, as exemplified by the *Braer* oil spill in 1993 in Shetland, where the incident occurred in a relatively low risk coastline, in an area with a well-prepared oil spill contingency plan (albeit less detailed than the plan for the higher risk situation further north at the major oil terminal of Sullom Voe), and in a coastal environment with, fortuitously, considerably above average pre-existing environmental and ecological data, future oil spills could occur in situations that lie between the two scenarios as described above, i.e., with an uneven mixture of relevant environmental data. The *Braer* oil spill (Figs. 1, 2, and Table 3) can therefore be used as a case-study for wider lessons, not only to evaluate the requirement for coastal environment information, but also to examine the extension of the initial assessment of the impact of oil into the equally important topic of subsequent monitoring of damage recovery.

Table 3. Major oil spills from tankers.

Tanker	Year	Cause	Tonnes oil spilled
Atlantic Empress	1979	Collision of two tankers off Tobago	300 000
Castillo de Bellver	1983	Fire aboard ship off Cape Town	250 000
Amoco Cadiz	1978	Ran aground off Brittany coast	227 000
Torrey Canyon	1967	Ran aground off Land's End	119 000
Sea Star	1972	Collision in the Gulf of Oman	115 000
Othello	1970	Collision in Tralhavet Bay, Sweden	100 000
Urquiola	1976	Ran aground near La Coruña, Spain	100 000
Hawaiian Patriot	1977	Fire aboard in northern Pacific Ocean	99 000
Braer	1993	Ran aground off Shetland Islands	84 700
Aegean Sea	1992	Ran aground near La Coruña, Spain	75 000
Exxon Valdez	1989	Ran aground in Alaska	37 000

The *Braer* oil spill in January 1993 on the south coast of Shetland resulted in 83 700 tonnes of Norwegian Gullfaks light crude oil being spilled into the turbulent, gale-tossed seas of this group of islands with its rich marine resources and potentially fragile coastal and nearshore ecosystems. The pollution incident, the response by the MPCU and the Joint Response Centre which was set-up in Shetland from the first day of the spill have been described fully elsewhere (e.g. Harris 1995, which also includes an account of aerial spraying of dispersants on oil on the sea over a three-day period). The nature of the high energy, exposed rocky Atlantic coastlines (Fig. 3), the adjacent sand beaches and the low energy sheltered voes to the north-west and the importance of wave and current action over the 12 days of the spillage are described by Ritchie (1993). In general, however, the unique combination of a mainly reflective, high energy rocky coastline, light crude oil and almost 12 days of continuous gales and hurricane force winds (with correspondingly high incident wave energies) led to the almost complete dispersal of oil into the turbulent sea. There was almost no stranding of oil. The impact on most natural coastal environments and dependent ecology was negligible but the economic impact on various types of fishing, and especially salmon farming was considerable (Fig. 4).

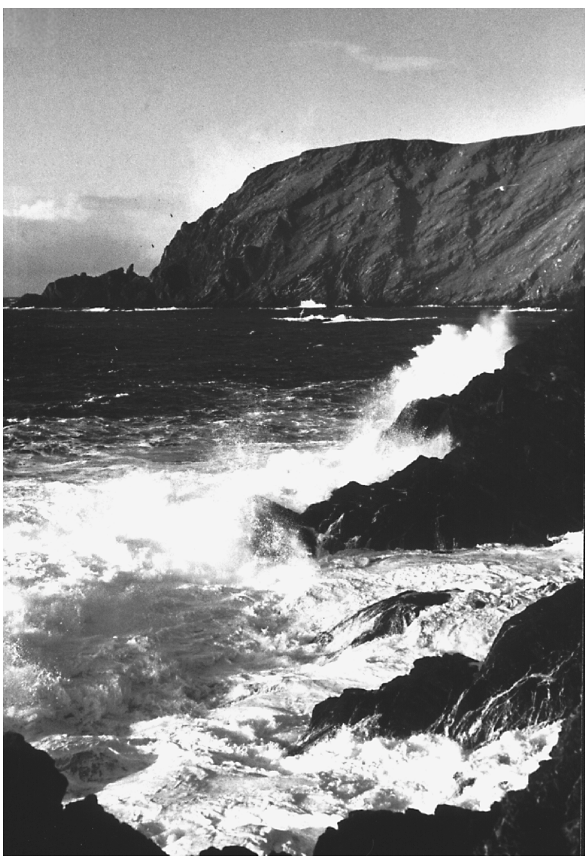


Fig. 3. Garths Ness (foreground) where the *Braer* ran aground with Fitful Head (a typical west coast shoreline type) in the distance.

The fate of the oil after it had been dispersed into the water column and carried northwards and southwards by currents and taken to offshore basins of fine sedimentation in relatively deep water where some quantities of oil remain to this day is described in detail in Chapter 3 of the ESGOSS Report (Anon. 1994b). Although these currents were driven by tidal forces it appears likely that both wind and wave forces were also important. Similarly, the reflective nature of most of the cliff coastline of south-west Shetland might also have contributed to the direction of the movement of the oil, in suspension, in these transporting water masses by creating a large-scale 'backwash' effect.

In January 1993 the opportunity to derive valuable advice from the oil spill was recognised by HM Government and two committees were created:

The Donaldson Committee[1], whose terms of reference were:

The task of the Inquiry has been to identify what more can be done to protect the UK coastline from pollution from merchant shipping.

The Ecological Steering Group for the oil spill in Shetland (ESGOSS) whose terms of reference were:

To monitor environmental work arising from the incident and to provide a focus for liaison and advice;

[1]Note: although created as a consequence of the *Braer* oil spill, the terms of reference of the Donaldson Inquiry extended to the whole of the coastline of the UK and included all noxious and hazardous substances.

Fig. 4. Typical moored salmon farms in the sheltered voes of West Shetland. Approximately 20% of the industry in Shetland was temporarily destroyed by comparatively small volumes of oil in the water which were carried northwards by waves and currents.

To assess the impact of the incident on the ecology of the Shetland Islands;

To develop urgently the best strategies in the short and longer terms for dealing with the implications of the incident as they affect the ecology of the Shetland Islands and to report to the Secretary of State for Scotland on these at an early date;

To oversee special studies for monitoring the impact on the subsequent recovery of the environment in order to advise the Government of the lessons to be learned which could be applied more widely, whether in the United Kingdom or elsewhere.

Some of the principal conclusions (excluding those that relate to safety arrangements on board and controversial issues such as the advantages of double-hulled vessels)of the Donaldson Enquiry are given in Table 4 and it is clear that these recommendations are addressed principally to matters of safety and to navigation in order to minimise pollution and ecological impact. Nevertheless, the concept of MEHRAS (Table 4) accords closely with the principle of obtaining sufficient coastal information to produce the necessary classification system. Thus the conclusions and recommendations fall into the category of prevention rather than mitigation and, in the context of this paper which has an environmental focus, need not be considered further. In contrast, the underlying assumption of the ESGOSS Report is that an oil spill will occur somewhere, sometime in the future and the experiences of the *Braer* as they relate to environmental impact assessment and to ecological monitoring of coastal areas should be incorporated in future planning for such an unfortunate event.

Discussion: Environmental lessons as derived from the *Braer* oil spill

Environmental and ecological impact

The prime environmental lessons relating to ecological monitoring are set-out below in a verbatim extract from the ESGOSS Report (pp. 145-147). These question the previously strongly held view about the severity and lasting effects of oil pollution on coastal habitats and bear upon current discussion on the value of the ‘do nothing’ option which, as exemplified by the *Argo Merchant* oil spill off Nantucket in 1976, can be the correct choice if wave, wind and other marine conditions are favourable. As exemplified by the *Braer*, the type of oil is also of utmost importance.

- *The ecological effects even of major oil spills are mostly short-lived, and their effects on populations of wild creatures and plants mostly small in relation to the often great population fluctuations occurring from purely natural causes.*

Table 4. Some conclusions and statements from the Donaldson Inquiry.

- The root cause of virtually all the pollution with which we are concerned is human failing.
- Maritime transport, like aerial transport, is essentially international in character. The UK is as much threatened by passing traffic as by ships destined for our ports.
- A striking feature of ships, as compared with aircraft, is their relative anonymity whilst en route. This is a positive incentive for wrongdoing, whether in the form of deliberate discharges or negligent operations.
- MEHRAS should be established (Marine Environmentally High Risk Areas). The average Master of a vessel neither knows, nor has the means of knowing, that the nature of the shoreline is such that if his ship grounded, there could be a risk of exceptional damage which might expose his owners and insurers to substantial liabilities. We recommend that this be remedied. MEHRAS would be established where there was both a significant concentration of shipping and a high risk of environmental damage.
- MEHRAS would feature not only in the Seaway Code but also be marked on Admiralty Charts.
- We have examined with care the UK facilities for cleaning-up oil spills. They are impressive. Criticism has also been directed at the UK's unique and expensive capacity of spray dispersants from the air, but we have come to the conclusion that the special character of our coastline justifies its retention.

(*As abstracted from the Report of Lord Donaldson's Inquiry into the prevention of pollution from merchant shipping.)*

- *The resilience of ecosystems and of plant and animal populations to disturbance, including pollution by oil, and the usually rapid recovery after disturbance, should not be underestimated.*

- *The essentially short-term nature of the environment effects of marine oil spills has been highlighted by many individuals and bodies, including the Royal Commission on Environmental Pollution (1981) in the UK, the National Research Council (1985) in the United States and by the United Nations Group of Experts on the Scientific Aspects of Marine Pollution (1977). Key generalisations drawn from such reviews are that crude oil loses most of its toxicity within a few days of being spilled at sea, that mortality of marine organisms declines rapidly thereafter, that sub-lethal effects are of little or no long-term significance, and that recovery of marine ecosystems is usually quick, particularly when there are nearby sources of organisms to replace the losses.*

- *The capacity for rapid recovery of terrestrial, freshwater and marine ecosystems reflects the fluctuating character of natural systems. Environments are often markedly unstable over time, reflecting the fact that natural states of flux, often gross flux, rather than stability. Within the sea, this dynamic state has been shown for all sectors which have been studied, from the intertidal to the communities of soft and hard sea-bottom substrata, to pelagic fish and the abundance of plant and animal plankton species on which they ultimately depend.*

- *The observed resilience of ecosystems on land and at sea to oil pollution is probably in part attributable to the natural and ubiquitous presence of hydrocarbons in the environment, because of their synthesis by organisms. Indeed, it should not be forgotten that petroleum hydrocarbons are merely fossilised biogenic hydrocarbon, and that natural seeps of petroleum hydrocarbons occur both on land and on the sea bed. For both these reasons, it is not surprising that many species of microorganisms exist which can biodegrade oil, and that in all ecosystems studied to date a microbial biodegradation capacity has been found.*

- *It is easy to overestimate the ecological effects of an oil spill. Even the amount of oil released to the environment is not always well known.*

- *A common feature of marine oil spills is the lack of antecedent biological data to use as a baseline for subsequent monitoring. As a result, it is rather easy to infer 'effects' caused by oiling when this may not be the case. For example, following an accidental release of diesel oil from the north coast of Scotland most of the limpets in the impacted area were found to be dead (Bowman 1978). This would almost certainly have been regarded as a classical case of oil spill damage if this area had not been regularly monitored, so that it was known that the limpets were already dying as a result of exceptionally high summer temperature at the time of the oil spill.*

- *Any oil spill is environmentally damaging, and will be distasteful and distressing in a civilised society. Moreover, there is always a need for some caution in comparisons, since circumstances do alter cases; and the Braer spill had special characteristics, such as heavy pollution of sediments, which would apparently be capable of leaving longer-term effects - even though no evidence of these has been found. However, it has been the consistent experience that natural ecosystems quickly recover from non-chronic oil pollution, and that the actual damage done by oil spills has never been as bad as the public had feared (*Fig. 4*).*

Some of these conclusions, especially in relation to the necessity of undertaking oil clean-up and remediation on different types of coastline, have been reinforced by a careful analysis of the after-effects of clean-up on 34 major oil spills since 1970 and 17 experimental oil spills, also since 1970. In a milestone paper (Sell et al. 1995) the following conclusions are reached, i.e.:

• *Irrespective of the type of clean-up operation, ecological recovery of shore strata follows natural time scales of up to three years for rocky shores and up to five years for saltmarshes.*

• *Clean-up often has a marginal or negative influence on these time scales, so there is little scientific justification for shore treatment especially on rocky shores.*

• *Clean-up may be justified by socio-economic factors relating to tourism, recreation, aquaculture, fishing, visual amenity and effects on some birds and annuals.*

• *In exceptional cases, e.g., where oil has formed heavy, smothering deposits or toxic subsurface deposits, there are grounds for some clean-up.*

• *Non-intervention in many cases would be the more effective means of ensuring recovery in high-energy environments where the natural degradation and removal of oil would be relatively rapid.*

• *Predicted results of the affects of clean-up or the 'leave alone' option on saltmarshes are more variable. The colonisation was accelerated when bulk surface oil was removed.*

Thus the resilience of natural systems is reinforced but there are certain thresholds which, if exceeded, preclude recovery in any reasonable timescale. Further, the combined outcome of the conclusions of the ESGOSS Report and the research undertaken by Sell et al. (1995) is that the early use of such terms as 'environmental disaster' or 'ecological nightmare' are usually premature and unnecessarily emotive. Environmental scientists have a responsibility to ensure that there is balanced reporting of oil spill incidents and that understandable fears in the minds of the public and especially those living close to the incident are not aggravated. Equally important, a balanced assessment will ensure that various types of clean-up and remedial effort are not applied according to some preconceived bias or to specific high profile life forms or habitats when experience has shown that these ultimately might be of minor scientific importance. Indeed one might dare to pose the question that many clean-up operations are guided more by the perception of specific public and single issue conservational criteria rather than a balanced comprehensive assessment of the most likely short and long term adverse environmental changes. Nevertheless, issues such as economic damage (Fig. 4) and risks to human health must take priority.

Environmental management and co-ordination of monitoring efforts

In relation to environmental management, some of the main recommendations on the response to any future oil spill are quoted from the ESGOSS Report, with minor changes, below:

• *The precise impact of an oil spill is never self-evident. There will always be a need for survey work to establish its extent. The need for such assessment is particularly acute at the beginning of the spill, when its character and extent, and the kind of work which may be pursued later on, are unknown. Monitoring organisations need to bear this need for urgent response in mind in their contingency planning, including adequate flexibility in resource provision.*

• *It will be useful to bear in mind:*

— *Tracking the progress of the spill will be the first priority. The capacity to carry out aerial and other surveillance is essential. There should also always be arrangements to take sea water samples as soon as a major oil spill occurs. It will always be useful to model the movement of a spill but improved models for the movement of spilled oil in water should be a priority for research funding.*

— *There will usually be a need to carry out emergency survey work in areas which may be affected by a spill, so as to fill in gaps in available baseline information on the local ecology, and validate information on it which is already to hand.*

— *There may be sites with specific ecological and environmental designations and work may be needed to safeguard these or to assess risks to species or habitats for which the sites were designated.*

• *Oil spill contingency plans should make provision for an appropriate agency to assume responsibility for setting up a local wildlife response team.*

• *Digitisation of coastal sensitivity maps and other sources of relevant data should be expedited.*

Part of the terms of reference of ESGOSS included the need to incorporate the findings of studies of other major oil spills and both the ecological and environmental

MAXIMUM EXTENT OF SURFACE OIL (Jan 93)

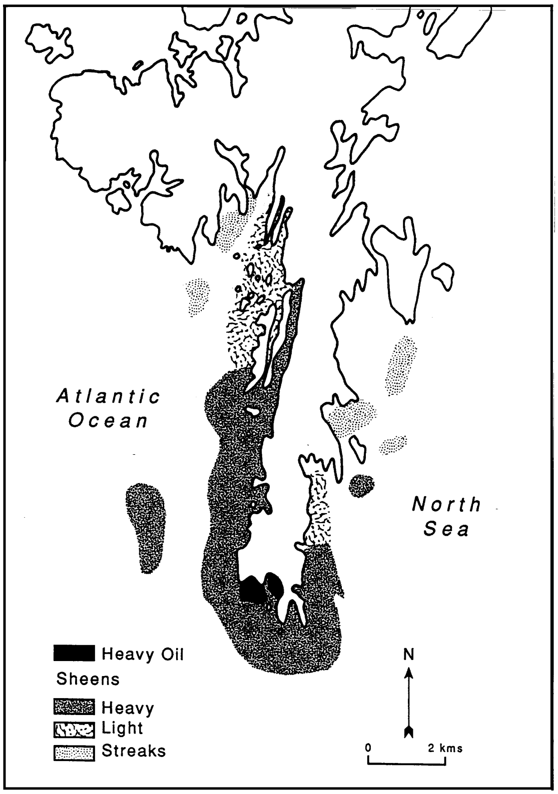


Fig. 5. The maximum extent of any form of surface oil movement during the *Braer* oil spill. Sheens represent very small quantities of oil on the surface of the sea.

management recommendations as listed above draw upon previous surveys and reports. It is important to emphasise that there are some common questions that recur in all oil spills. Some are incident-specific and other are generic and the answers could be pre-determined. Those that are incident-specific are: What are the characteristics of the oil, eg, viscosity, evaporation rate etc.? What is the level of energy in the sea at the time of spillage? What clean-up techniques are being used? How important is the time and season of the spill? What is the precise geomorphic nature of the shoreline?

Others are pre-existing and generic: Where are the sensitive coastal habitats and how high is the risk of serious pollution? Are wildlife populations of species which are rare or exist in small numbers or are particularly sensitive at risk? Are there amenity and economic imperatives which supersede ecological considerations, e.g., tourist beaches or vulnerable industries (e.g. fishing or aquaculture)? Is there a pre-existing reliable database of environmental and ecological information, including an assessment of vulnerability? Is it possible to model and to predict the real extent and the scale of impact at different levels of intensity over time? Has this coastline and its associated wildlife been subjected to other pollution incidents, including chronic effects so that some habitats have been degraded by cumulative effects that predate the oil spill in question? Have any species and habitats that are critical to extensive food webs, both locally or at a distance, been affected adversely?

Conclusion: the concept of scale and the general lesson of the *Braer* oil spill

It is important to emphasise the length of coastline which was affected by the *Braer* oil spill was similar to most other major oil spills (Fig. 5). The *Exxon Valdez* oil spill was exceptional in the vast extent of shorelines under threat. In most oil spills, the scale of coastal impact is normally measured in tens or hundreds of kilometres not thousands as in Alaska. Unfortunately, however, the experience of the *Braer* incident indicated that many comparisons were made with *Exxon Valdez* in spite of the knowledge that it was manifestly different in almost every respect. Further, the most frequent type of spill is small and measured in hundreds not thousands of tonnes of oil and it affects lengths of coastlines measured between hundreds of metres and tens of kilometres. This fact reinforces the earlier conclusion that it is impossible to hold a data-bank of relevant *detailed* environmental and ecological information for extensive lengths of coastlines in other than nations with comparatively short coastlines such as Belgium, the Netherlands, Singapore or in particular areas where the risk of pollution is (relatively) higher. There is a threshold of length where the resources that need to be deployed for scientific surveys cannot be provided. If a nation state has a coastal length which is longer, then national or international scientific resources must be applied to areas of greatest vulnerability and, possibly, to selected areas of special fragility for ecological (e.g. international biological sites) or economic (e.g. major tourist beaches) reasons.

These conclusions are sufficiently self-evident as to pose the question as to whether or not they are worth stating. In response, however, it is relevant to note that, unfortunately, some national states do not have oil spill contingency plans with clear environmental components and the corollary of these conclusions which are drawn from experiences elsewhere is to recommend that the first stage of preparation should be a hazard analysis, i.e., to identify those sectors of the coastline that are at greatest risk from oil pollution. At the same time, conduct a rapid environmental overview to determine areas

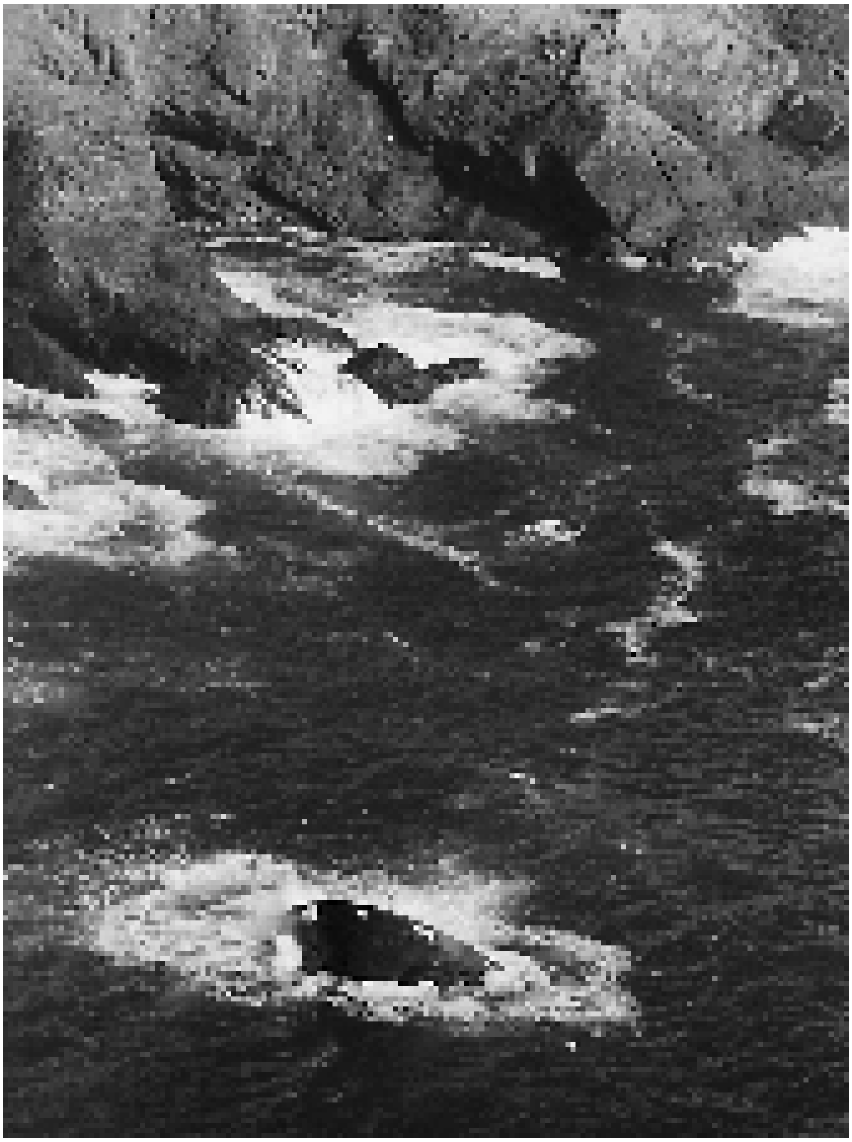


Fig. 6. All that remained of the *Braer* in summer 1993.

of greatest environmental importance (and economic or cultural significance). The correlation of these two variables determines the priority for the application of both scientific and technical resources. This is almost precisely the conclusion reached quite independently by the Donaldson Inquiry in its recommendation for MEHRAS (Table 4). On the other hand, it must be acknowledged that a major oil spill could occur in an area that has not been identified for intensive contingency arrangements. The experience of the *Braer*, however, suggests that it is reasonable to believe that for a coastline without detailed pre-spill environmental data and lying in an area which is not in the high risk category, the two key questions posed by any major oil spill, i.e.: 1. What is the extent and nature of the damage both onshore and offshore?   2. How should surveying and monitoring programmes be conducted in order to assess the rate of recovery and thereby provide assurances to a range of interested bodies? can be addressed as follows: the solutions can be found if a team of appropriate experts, including those with local knowledge, can be deployed relatively quickly and, most important, be allowed to operate with sufficient logistical support in an appropriate authoritative managerial situation. An equally important and relevant conclusion is to recognise that the initial impression of 'disaster' is rarely if ever the correct appellation. Thus, although the environmental co-ordinator and the expert team must give some cognisance to public perception and be prepared to listen to the claims for priority to be given to particular species or habitats, there is an accumulating body of evidence which gives reassurances that most coastal ecosystems are resilient unless specific threshold conditions are exceeded. In the end, the effects of oil spills and the determination of the priorities for ecological monitoring are closely akin to best practice in Environmental Impact Analysis which acknowledges the limitations of models, formula and quantitative indices and admits to the over-riding importance of informed, experience-based human judgement. Nevertheless, the speed and confidence by which this expert advice can be given is related directly to the range and to the quality of the pre-existing sets of coastal zone information. When this data set is meagre then the balance of advice is inherently more judgmental and dependent on the experience of the expert team. Decisions are more secure and defensible when the level of pre-existing environmental and ecological information is extensive, current and easily extracted from a comprehensive data base.

References

Anon. 1977. *Impacts of oil on the marine environment.* UN group of experts on scientific aspects of marine pollution FAO, Rome.

Anon. 1981. *Oil Pollution of the Sea.* 8th Report, Royal Commission On Environmental Pollution. HMSO, London.

Anon. 1985. *Oil in the Sea: Inputs, Fates and Effects.* National Research Council (USA) National Academy Press, Washington, DC.

Anon. 1990. *Coping with an Oiled Sea.* Office of Technology Assessment. US Congress, Washington, DC.

Anon. 1994a. *Canadian Coastal Environments, Shoreline Processes and Oil Spill Clean-up.* Report Environmental Protection Agency (Canada) EPS 3/SP/5, Ottawa.

Anon. 1994b. *Safer Ships, Cleaner Seas.* Report of the Inquiry by Lord Donaldson. Secretary of State for Transport. HMSO, London.

Archer, J.N. & White, I.C. 1989. *Organisation to Combat Oil Spills: The case for co-ordination of Government practice.* ITOPF publication, London.

Bowman, R.S. 1978. Dounreay Oil Spill. *Mar. Pollut. Bull.* 9: 269-273.

Harris, C. 1995. *The Braer Incident: Shetland Islands, January 1994.* Proc. International Oil Spill Conference, Long Beach, California, pp. 812-822.

Owen, E.H. & Teal, A.R. 1990. Shoreline clean-up following the "*Exxon Valdez*" oil spill - field data collection within the SCAT program. *Proc. 13th Arctic and Marine Oil Spill Programme. Tech-Seminar. Environment Canada,* pp. 411-421.

Ritchie, W. 1993. The short-term impact of the *Braer* oil spill in Shetland and the significance of coastal geomorphology. *Scott. Geogr. Mag.* 109: 50-56.

Ritchie, W. & O'Sullivan, M. 1994. *The Environmental Impact of the Wreck of the Braer*. ESGOSS, HMSO, Edinburgh.

Sell, D., Baker, J.M., Dunnet, G.M., Mcintyre, A.D. & Clark, R.B. 1995. Scientific Criteria to Optimize Oil Spill Clean Up. *Proc. International Oil Spill Conference, Long Beach, California*, pp. 595-610.

Received 28 December 1994;
Revision received 18 June 1995;
Accepted 27 July 1995.