

ENVIRONMENTAL ASPECTS OF OIL AND GAS
PIPELINE LANDFALLS IN NORTHEAST SCOTLAND

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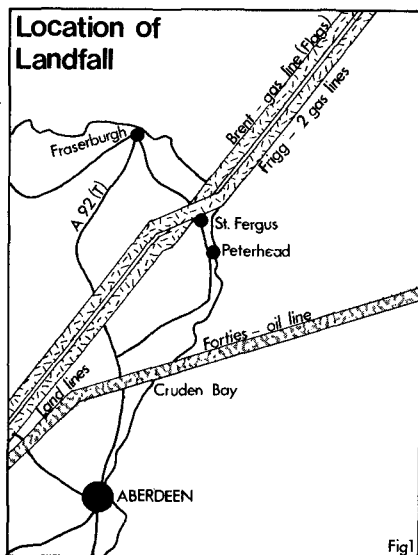
Abstract

Oil and gas pipelines from the North Sea have reached the northeast coast of Scotland from offshore production platforms. The pipelines date from 1973 to 1976. The environmental effects of these pipelines are compared as are the relationships between engineering work, environmental impact assessment and planning procedures. There is also a discussion of methods used to protect and restore these three landfall areas.

Introduction and Setting

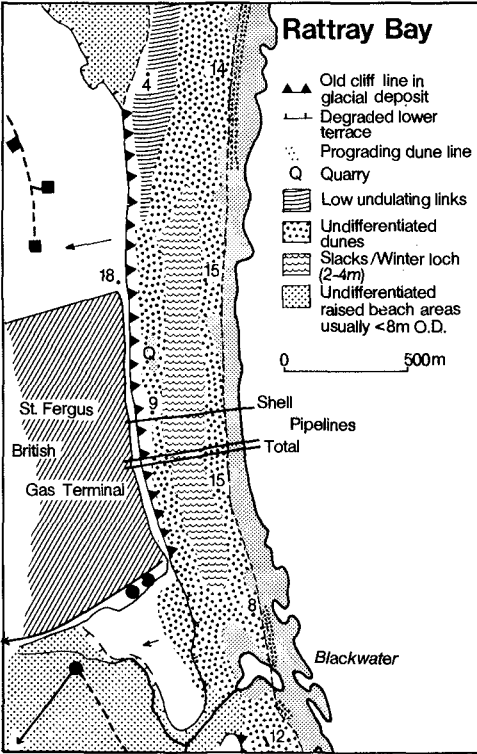
Three oil and gas pipelines make their landfall on the northeast coast of Scotland (Figure 1.). The first pipeline, from the Forties Field, was pulled ashore at Cruden Bay in 1973. Later, pipelines bringing natural gas from the Frigg Field reached the coastline further north at St. Fergus in 1975, to be followed in 1976 by a pipeline (known as the Flags pipeline) from the Brent Field. All three pipelines have very long offshore sections, running up to several hundred kilometres from the production fields. On land, the Forties pipeline goes to a nearby pumping station from which the crude oil is pushed

southwards to the refinery at Grangemouth. In contrast, the gas pipelines at St. Fergus lead a short distance across an area of dunes and links to the St. Fergus Gas Terminal, operated by British Gas (Figure 2). This massive terminal consists of two elements; the larger operational British Gas/Total Oil Marine (U.K.) Ltd.



complex from which the gas is fed via land pipelines into the national gas grid, and a northern extension, which is not yet complete, being developed by Shell to receive and process gas from the Brent Field.

Although separated by 20 km, the landfalls at Cruden Bay and St. Fergus share the common characteristics of the North Sea coastal environment. In particular, the three elements that are



significant relate to tides, waves and near shore sediment movements. The tidal range is approximately 3.0 m but more significant, exceptional tides can elevate the water surface in excess of 4 or 5 metres. These elevations are related to North Sea surges and occur with various periodicities. The maximum increase in height might occur once every hundred or even thousand years but smaller surges of less than a metre have been detected within any given year (Stove, 1978).

Accordingly, the design of coastline structures must be related to these somewhat unpredictable factors.

Fig 2 Sketch Block Diagram Near Pipeline Landfalls

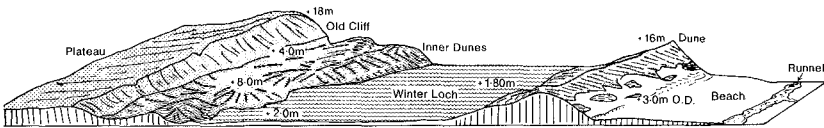




Photo 1. Pipeline Pulling of the Flags Gasline at St. Fergus.



Photo 2. A general view of the St. Fergus terminal and adjacent coastline at an early stage of site work.

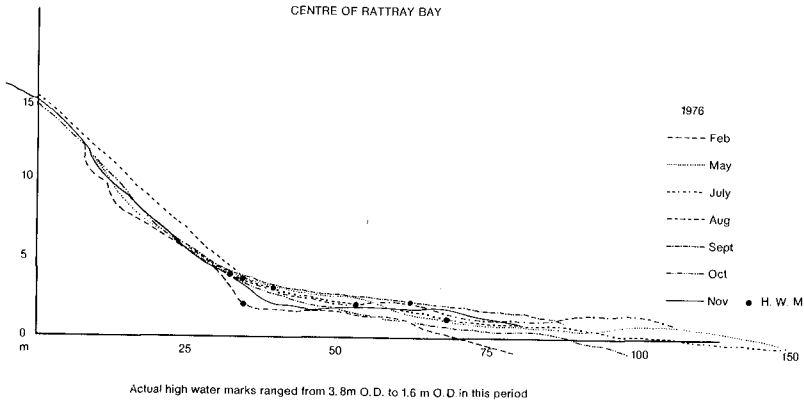
Wave conditions tend to consist of relatively low, short period waves typical of the North Sea basin. Elevations greater than 2 metres are unusual, and the period is normally of the order of 6 to 7 seconds (Buchan 1976, Weatherill 1980). Again, exceptionally high waves can occur when fetch and storm directions coincide, especially from the northeast and easterly directions. Inspection of available meteorological statistics for and local experiences of the North Sea Coast indicate the need to consider the possibility of single highly destructive periods of wave attack. Nearshore sedimentary cover and movement is another variable which is difficult to predict. On the whole, most of the inshore ground is covered by sand or other loose deposits.

Fig 3

1976 SELECTED BEACH PROFILES

(upper and mid- beach)

CENTRE OF RATTRAY BAY



Cruden Bay, for example, being a bayhead structure, appears to have abundant nearshore sediment but offshore surveys show that bedrock is never far from the surface and, in places, outcrops as reefs and shoal areas. Boulder clay on top of rock is particularly common in the St. Fergus area where sand deposits have a patchy distribution and normally occupy the lower areas in the rock platform. The wide sandy beaches are thus somewhat deceptive and although there are migrating sand bars at

and just below low water mark, bedrock outcrops normally lie only a few scores of metres to seaward. The sand bars also appear to be rhythmic and rip cells are common. In fact, the approach of the St. Fergus pipelines to the coast uses an exceptional area of unconsolidated sediments that runs across the rock platform and provides a tract for pipeline burial. In so far as the prediction of sand movements is concerned it is probably correct to state that little is known about nearshore dynamics in both Cruden Bay and St. Fergus. Sediment movements have to be deduced from morphological evidence. Beach profiling revealed that the beach at St. Fergus varied considerably in thickness (Figure 3.). On the basis of these profiles the lowest profile was defined and used as the level below which the pipeline had to be buried under 2m of sand.

Engineering Techniques for Pipe-pulling

For the three landfall areas the engineering technique of pulling strings of large diameter (c. 1m.) coated pipes ashore was essentially the same. Broadly, a trench was cut through the dunes and adjacent surfaces, and maintained by sheet piling. A pulling wire, attached to a powerful winch to the landward, was fixed to the welded pipe strings which were pulled into the sea off a laybarge. (Photograph 1. shows the pipepulling operation for the Flags pipeline at St. Fergus.) This vessel was anchored a few hundred metres offshore and once the landfall was made, the barge gradually worked seawards, laying the pipeline, towards the production platform. After pipe testing and other related work, the onshore end of the sea pipeline was connected to a land pipeline going either a short distance into the Terminal at St. Fergus or for a further 190 kilometres southwards to Grangemouth from the Cruden Bay landfall. Although the same engineering technique was used in both areas the nature of the terrain caused several minor changes to be adopted. Firstly, at Cruden Bay the presence of a high former coastline about a hundred metres inland made the location of the pulling block a difficult one, in so far as the winch was placed on top of this 30m high boulder clay cliff. The actual landfall was made through a beach and dune environment. The dunes at Cruden Bay were only 3m high and relatively protected. The beach was not particularly dynamic and the coastal edge was rarely subjected to wave attack. In short, this was a relatively sheltered landfall and the low sand dune relief provided a relatively simple site for excavation and restoration (Ritchie, 1975). In contrast, the St. Fergus area was much more dynamic and exposed. The dune face was subjected to more frequent wave and tidal contact. The beach was demonstrably more variable in plan and profile (Figure 3). In addition, the dune ridge was up to 14 metres high and retreating in the form of an undercut sand cliff at an estimated rate of up to

half a metre a year. Equally important, there was a long, flat, low, easily flooded strip of land termed the Winter Loch in the lee of the maturely vegetated dune backslope (Photograph 2 and Figure 2). This surface lay beneath the level of high water mark and flooded to a depth of over 30 centimetres from October to April every year. In addition it was recorded as being environmentally sensitive. There is, for example an area of relatively rare vegetation to the north of the landfall and the entire Winter Loch is an important roosting and feeding area for migrant birds. Landwards of this low surface there is a low degraded cliffline cut into glacial deposits. This inner slope leads to a plateau upon which the Gas Terminal was built. For both landfalls at St. Fergus the engineering technique was again that of cutting of a trench down through the dunes and Winter Loch surface to enable wires to run from the lay-barge to the pulling winch on top of the landward plateau some 500m from the beach (Photograph 1). The cutting and sheet piling operations were much more massive than at Cruden Bay. There was also the problem of waterlogging, and the surfaces being crossed were very soft and liable to be damaged easily by the passage of even the lightest vehicle. Moreover, the trench levels at the coast were substantially lower than the beach and the seaward end of the trench required protection from the possibility of flooding and wave damage. As at Cruden Bay there was no question of digging the trench through the inter-tidal beach until a short time before the actual pipe pulling operation.

The first pipe pulling operation, for Total Oil Marine (U.K.) Ltd., required two pipes to be pulled and the trench had to be cut and sheet piled completely across the Winter Loch. Storing sand for back-filling was necessary as it was impossible to take sand from the beach for restoration of the dune ridge. A storage area was therefore required, so that sand excavated during trenching could be used later to replace and restore the dune and adjacent surfaces. The area damaged by the storing operation was equal to that affected by the actual cut. No attempt was made to preserve the turf layer as Marram grass (*Ammophila Arenaria*) tussocks cannot be handled in this way. Later, the Shell pipeline (the Flags Gasline) used a slightly different technique in that the cutting and sheet piling only extended to the limit of the backslope of the coastal dune (Photograph 1). Nevertheless this was also a massive excavation. After excavation however the sand from the cut through the dune was dumped to form an inclined ramp leading, at a gentle gradient, up to the landward plateau where the pulling winch was sited. This ramp provided an access ridge to the cut in the dune. This sand ramp was covered by a nylon sheet upon which was placed crushed rock to form a road bed. The nylon sheet and superimposed road bed were rolled-back after the pipe was pulled and the sand used to backfill the trench and dune breach. As will be demonstrated below, the

the evolution in techniques which were developed successively for the three pipelines was partly the result of experience gained from the earlier operation and partly modified by the nature of the terrain.

Planning Framework

The timing of the three landfalls, 1973, 1975 and 1976 offers an opportunity to compare the evolution of planning processes in relation to industrial developments and related engineering work. Planning approval is normally required for engineering and similar work everywhere in Scotland. Application for permission is made at the District level and major applications are normally also referred to the Regional Authority*. If there are sufficient objections, then the procedure of public inquiry can be instituted. The proposal to develop must satisfy various national and local government acts and statutes. It is not mandatory for an environmental impact statement to be submitted. Unlike current practice in U.S.A. there is no formal procedure for such a submission (for a fuller discussion of issues related to environmental assessment see Chapman, 1981). Nevertheless, over the last few years it has become exceptional for a major developer not to submit some form of environmental impact assessment and/or statement. One of the effects of this flexible situation is that it encourages considerable pre-application discussion. It promotes contact between the developer, the planning authority personnel and interested parties and may lead to a useful interchange of information. In relation to the pipeline landfalls it is probably correct to state that planning for the Cruden Bay landfall took place before the practice of submitting any form of environmental assessment was established. That was not to say that the developer or the contracting engineer did not consider environmental issues, in fact, B.P. Ltd. prepared a massive in-house environmental assessment. In addition, at an early stage, an established environmental scientist was approached to act as consultant with the responsibility for environmental management during site work and to produce proposals for restoration.

For the two developments at St. Fergus environmental

*In Scotland there are three tiers of government, Districts which combine to form a Region. There is also a national dimension in the form of the Secretary of State who is a Cabinet Minister and has the power to call-in any planning application if it is deemed to be in the national interest to do so. The three island regions, Western Isles, Orkneys and Shetland are single tier all-purpose authorities.

assessment procedures and documentation were followed. Nevertheless there was an appreciable difference in the level of assessment, in that the second proposal required fuller statements particularly with regard to ancillary developments. The three pipeline landfalls thus embrace a period of time when planning was evolving to a stage where environmental impact procedures were becoming more widely accepted. Coincidentally it was also the time of local government reform. There was also some changes in the operation of planning functions developed from the Local Government Act of 1972 and Local Government (Scotland) Act of 1973. By 1976 developers and local government agencies had gained experience in these new procedures and a guidance manual was available from the Department of the Environment (Clark, et al., 1976). Although the transitional period is over the stage of rigid statutory procedures has not been reached.

A crucial figure in the linkages between the developer and planning authorities is the environmental scientist. It is difficult to express succinctly how he operates but he is essentially involved in a series of discussions which begin with preliminary proposals that gradually harden into specifications for engineering work. At the same time operational conditions remain of great importance with the need for future restoration being kept continually in mind. It is also useful for the same individual to be involved in monitoring conditions after restoration. That is not to say that he would necessarily produce the full environmental impact statement but would confine himself to those issues that are essentially concerned with the physical environment calling, if need be, on the assistance of other scientists and specialists.

In Scotland, applications for development are submitted to the planning authority which circulates them to three groups; statutory, advisory and informal parties who are invited to comment on the proposal. Since these parties are known there is no objection to prior consultation taking place before the document is submitted. In the long run this saves time and, assuming a constructive approach is taken, leads to a much better environmental statement as well as better planning constraints and conditions. In general there has been little complaint at St. Fergus with the operation of the planning procedures in relation to the pipeline landfalls. In the opinion of the writer much of the success is due to the inherent flexibility of the present planning system.

Inevitably the discussion revolves around different issues for a specific site. At an early stage the construction of an environmental impact matrix allows both developer and planning authority to identify those issues that require further

analysis and information. For example, at Cruden Bay there was little scientific or wildlife interest and even the agricultural interest in the area was minimal. There was some informal beach recreation nearby but the main factor was the presence of a championship golf course only a few metres to the north of the site. At St. Fergus, in addition to the difficult geomorphological situation, particularly that relating to the interface between beach and dune, there was the sensitive and ecologically important environment of the Winter Loch area with important botanical and ornithological interests. At St. Fergus there was little recreational use and the area was not considered as being scenically attractive. This contrasts with Cruden Bay which is undoubtedly a scenic area. There was, therefore, greater interest shown by such bodies as the Scottish Wildlife Trust, The Royal Society for the Protection of Birds, the Nature Conservancy Council and other bodies and individuals in the St. Fergus area. Moreover the scale of development, particularly as the pipeline landfall was only part of the total terminal complex, inevitably produced more local and even national interest. It therefore followed that the exercise of assessing the environmental conditions and the consequence of the operations at St. Fergus became a much larger and more comprehensive exercise.

Nature of Environmental Assessments for Cruden Bay and St. Fergus

The Cruden Bay development did not require an environmental impact statement although as stated previously a comprehensive assessment was prepared internally by B.P. Ltd. During the course of site work written comments were prepared for the developer and the site engineer, relating site work to such environmental issues as prevention of erosion and sand deposition. Implicit in many of these guidance notes were arrangements that looked ahead to the stage of reinstatement. After the pipe was pulled and tested the ground was restored to specifications drawn up by the environmental consultant with the approval of the local planning authority.

At St. Fergus environmental impact assessments were prepared. Essentially the approach consisted of balancing three sets of information. Firstly, it was necessary to understand the construction and operational techniques that would be employed by the developer and his agents. Secondly, the attitude of the planning agencies had to be ascertained. Normally this consists of determining the types of questions that the planning authority and possible objectors would ask of the developer (see Clark et al, 1976). The third factor to be considered was the specific attributes of the landfall area. The environmental impact assessment took the form of a matrix which divided the different parts of the landscape into separate elements, as for

example, drainage, vegetation, surface stability and so on. The remainder of the table consisted of the three phases of work; that is, the construction phase (to cut the pipeline trench), the operational phase and the restoration phase. The matrix approach proved to be an acceptable method of presentation and analysis particularly as each impact was assessed on a simple scale of low, moderate, high, and in the case of a "high" assessment, the issue was discussed at length in a complementary text. The whole document was prefaced by a description of such general factors as weather conditions and physiographic setting.

Having completed this exercise for the three landfall sites it is possible to indicate some of the problems that arise in such work. On the one hand there is the need to collate existing information on the area. This may vary greatly in quality and quantity. There are gaps in basic environmental information. Accordingly, if time is available, it is necessary to obtain information by conducting surveys or commissioning particular studies. For some environmental variables this is not possible and it is necessary to make assessments that are based on theoretical knowledge and/or from indirect evidence. Experience also shows that should objections arise they often revolve around what can only be described as vague issues and terminology. One may contrast, for example, an environmental impact such as produced by sound or heat radiation, (these impacts are calculable and can be compared against statutory limits and regulations), with issues that derive from the opinion of an observer. The word environment itself is vague. Similarly, how does one assess a criticism that cites "disturbance to wildlife" or, how does one evaluate the effect on the scenic appearance of an area? There is no easy way to resolve these arguments other than by discussion with the parties involved so that some consensus of opinion can be obtained. In the end these issues have to be considered against relative rather than absolute standards. Another issue which is worth stressing is the need for all parties to recognise that there will always be gaps in the environmental knowledge for any given area, and that these gaps cannot be filled in the time available, if at all. For example at St. Fergus an important issue is the movement of sediment in the nearshore area. Anyone with a basic knowledge of coastal geomorphology will recognise that this fundamental question is incredibly difficult to answer and would require considerable instrumentation and time to establish a measure of the amount and direction of potential sediment movement. Environmental restoration is also a difficult problem. At St. Fergus, and to a lesser extent at Cruden Bay, it was also made clear from the outset that full environmental restoration was impossible. This was particularly true at St. Fergus where the eroding coastal dune and the maturity of the vegetation on the backslope and Winter Loch area created insurmountable difficulties for full and complete

restoration programmes. The argument was presented that restoration should aim to produce a surface that was compatible and similar to adjacent areas. It was thought that in the fullness of time natural forces would probably achieve an ecological situation that was increasingly similar to adjacent areas. It would be wrong for the writer of an environmental impact statement and the developer who contracts such a survey to claim that an exact replacement of a complex habitat and environment such as that pertaining to a changeable open beach and eroding, mature sand dunes would be attainable. Equally it is unreasonable for a planning authority to expect such replication. In dealing with an environmental impact statement for a natural landscape area such as a dynamic coastline a truly scientific and comprehensive evaluation of the physical and biological environment is not possible. One should look for a more general statement, backed up as far as possible by all available scientific evidence, to which one should add knowledge gained from comparative experience augmented by whatever site and local surveys are feasible. It is important that the developer and the planning authorities accept the limitations of such an approach. Nevertheless, the environmental assessment and statement are major advances in the functional relationship between planning and industrial development. They provide an invaluable common basis for worthwhile discussion which should lead to sound engineering practice and good environmental management. The experience of the North Sea pipelines would show that this approach is successful but one would not recommend that the environmental impact assessment process should become more structurally defined and rigid. The success of the projects at Cruden Bay and St. Fergus can, at least partially, be related to the use of environmental assessment statements and similar documents but just as important has been the flexibility and exchange of information that has been involved in producing, interpreting and discussing these documents.

Environmental Restoration - Case Studies

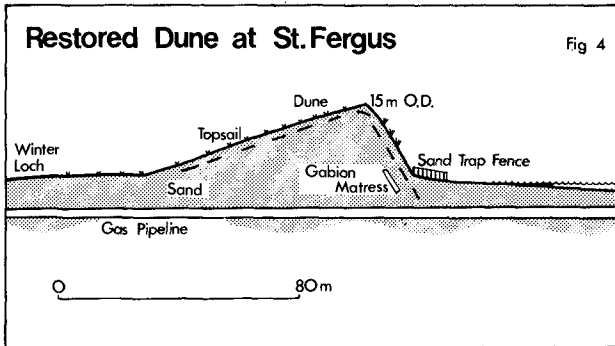
The Cruden Bay site was developed by B.P. Ltd. and they had selected what is arguably the best landfall site on the coast (Figure 1). It is a low energy, protected environment with little ecological or recreational interests. The only problem was the championship golf course nearby. The methods used to restore the surface were straightforward and largely adapted from the experience gained by workers in Holland on similar dune restoration problems. (For a useful summary see Brooks, 1979 or Quinn, 1977.) One of the important methods was the use of brushwood cuttings from local coniferous plantations. These branches were used to construct sand trapping fences and, later, they were used to clad the seaward face of the reconstructed dune. It should be stressed that the area involved in restoration was very small. The dune frontage was about 40 metres and the pipeline

trench and associated areas was of the order of 120 metres long. It is of interest that approximately the same area was affected by the need to store sand for back filling. The surface was restored in two stages since the landward end of the pipe had to remain open for several months for pipe testing procedures. Accordingly the access road was the last feature to be restored. Essentially the original profile was restored, but the dune face was set back and lowered slightly. The surface was then covered by a thin layer of top soil and seeded using a mixture determined by a local grassland expert. The alternative of leaving a bare surface and allowing natural recolonisation by plants was eschewed since sand might have blown onto the adjacent golf course. The crest was protected by a fence, designed to trap sand, but having an equally important function in preventing pedestrian access. The dune face was covered in brushwood and held down by netting. Dune grasses, Marram and Sea Lyme, were hand planted through this cover. Excess sand was deposited on the beach nearby. The remaining material that was used with great success was a water based bitumen compound called Crelawn, which not only held the surface stable but also promoted early and vigorous plant growth (Ritchie, 1975).

The success of this operation was obvious from the outset. Vegetation growth was rapid and the signs of engineering work disappeared within a year. At this stage it was possible to remove fences and other small structures. The beach surface was restored naturally by wave action within a few days. The situation now about seven years later is that the site is indistinguishable from adjacent areas. A botanical survey has shown that some of the early exotic species have been replaced by more local vegetation types. The dune face has built up, aided by the transfer of the excess sand from the beach. There is little sign of any brushwood or other devices used to promote restoration. Although one is tempted to suggest that this restoration was a product of good techniques, it is also important to stress that this was a particularly favourable location.

In contrast the sites at St. Fergus were recognised from the outset as being much more difficult. The scale of operation was larger and the coastline more open and changeable. Early discussions with the first developer, Total Oil Marine (U.K.) Ltd., emphasized that it would probably be impossible to provide complete restoration. The aim was to produce a surface that was similar to adjacent areas and to produce a series of landforms that effectively produced the same degree of stability and protection to the important Winter Loch zone to the landwards. At the St. Fergus site the same working procedures were involved as had been used at Cruden Bay but the area was much greater. There were also substantial delays in the timetable of sitework and pipe pulling,

related largely to the difficult progress of the offshore programme. Accordingly the period of storage of sand for backfilling was very long. There was also a protracted period of vehicle movements in all seasons across the various surfaces. The main access track required a surface bed of broken granite. The delay, a long storage period and considerable vehicle traffic across an artificial road bed combined to add to the problems of final restoration. The sequence of restoration consisted of replacing the sand in such a way as to restore the original profile. After considerable discussion it was agreed that a useful "insurance" should be pro-



vided by inserting a toe protection of gabions, buried at the base of the dune on the seaward face (Figure 4). The arguments of such emplacement concerned the need to protect the dune face in the interim period between restoration and the achievement of natural stability. The fear was that in this critical period the dune might be attacked by an exceptionally high water level with destructive waves. In the event, this did not happen and the gabion wall remains as a fail-safe device beneath about 1.5 metres of surface sand. The same device, for the same reasons, was used on the Shell pipeline landfall a hundred metres to the north. Once the profile was restored it was held in place by stretching old fishing nets from the toe of the dune over the crest and down the back-slope. A further 30 centimetres of sand was added, and the crest and back-slope were covered by a layer of topsoil. (Unfortunately in this particular area the topsoil proved to be of very low quality, with a high clay content, and this has led to some minor problems which had to be rectified at a later date.) The seaward face, crest and

backslope were then replanted. The backslope was planted by standard agricultural techniques using a carefully selected mixture of agricultural grasses. A small proportion of "wild" flower and grass species were also used; the species being selected from the list of plants that was compiled before site work commenced. A similar procedure was used for the Winter Loch surface. An open pattern of Marram grass was replanted by hand on the backslope although it was realised that it would have little chance of vigorous growth, as there was little sand accretion in the lee of the dune crest. The seaward face was hand planted exclusively with Marram grass.

Since the work was completed in 1976 it has been possible to assess the success of the various procedures. The best feature, and the feature that satisfies the prime need of protection, is that of the seaward face. There has been vigorous growth and ample sand accretion. This was certainly aided by constructing sand trapping fences at intervals along the toe of the dune. The backslope has been the least successful area for although growth was initially good this seems to have been aided more by the application of fertilizer than by any natural factors. It should be added that immediately after planting the weather for the next two years was exceptionally bad. There being periods of heavy rain followed by a summer of near-drought conditions. The situation was further exacerbated by the clay content of the top soil which is relatively impervious and caused surface runoff problems. The problem of compaction and the difficulty of removing all the crushed stone from the Winter Loch area also proved to be a problem and it is fortunate that the developer agreed to a second phase of restoration work so that this problem could be solved by a second period of surface clearing and reseeded. There were also minor drainage problems to the landward which were quite unforeseen and related to wider drainage changes brought about by the construction of the main terminal site. These highly localised problems were also solved but they emphasize the need for some form of monitoring programme for up to five years after site work is finished. Further north the same landform zones were breached by the trench for the Shell pipeline and with the experience of the B.P. Landfall at Cruden Bay and the Total Oil Marine (U.K.) Ltd. site a hundred metres or so to the south it was possible to anticipate some of the problems and refine environmental and restoration advice accordingly. It is possible to highlight these although one must stress that the techniques used were, in the main, the same as had proved successful on the two previous sites. One of the advantages was the greater lead-time which made it possible to complete a more thorough survey of the area before site work, this included a careful topographic survey. It was also possible to confine the working area by fencing before any vehicle reached the site area. Corridors

were established beyond which the areas were regarded as inaccessible. Since the storage of sand had proved to damage rather large areas, excavated sand was used to produce a ridge which descended at a low gradient to the dunes and became the bed for the access track and pulling wires (Photograph 1). This greatly reduced the area of surface damage. The sand ridge also had engineering advantages and these have already been described. After pipe pulling the sand ridge was used to fill the gap in the dunes, and the Winter Loch and adjacent surfaces were then carefully lowered to their previous elevation and slope. Exactly the same procedures were used for the dune face, the back-slope and Winter Loch surfaces as had been used previously with the significant difference that good quality top soil was imported to cover the backslope and Winter Loch surfaces. Another minor difference was that the seed mixture was cross-drilled rather than surface spread. This gave better establishment. In all other respects the methods and the progress has been similar to that of the other pipelines.

It is too early to judge the success of both St. Fergus operations but it is possible to state that the initial objectives have been satisfied in that environmental damage and disturbance was minimal and there were few if any side effects on adjacent areas and surfaces. The dune ridge is undoubtedly stable and providing a barrier which is equal if not superior to the original dune ridge. The hydrology of the Winter Loch surface has been restored and there are already signs that the vegetation is changing to that of its previous condition and the ecology, particularly the use of the area by birds, is little different from what it was before the onset of engineering work. It would be untrue to claim that the area is now indistinguishable from adjacent areas. Unlike Cruden Bay it was never felt that this was possible. The areas which give rise to least satisfaction are the backslope zones. It is doubtful if they will ever have their former Marram dominated, mature, tussocky appearance. Their pre-existing state was a sensitive combination of soil and micro-climatic conditions sustained by a precise input of blown sand escaping from the eroding front of the dune. By stabilizing the dune face and promoting vigorous vegetation growth the escape of sand to the backslope has been prevented. Since Marram grass requires an input of fresh sand for growth the situation is obviously one where a definite decision had to be taken. To achieve vigorous Marram growth one would have to have left large areas of dune face and back-slope bare of vegetation to enable sand to move freely across the dune crest. To do this would obviously have raised the possibility of severe sand erosion which could have disrupted the entire restoration programme; not only by creating blow-outs on the dune ridge but by transferring excessive amounts of sand to the fragile Winter Loch environment inland. Since priority was

given to physical stability it was obviously unacceptable to leave any areas bare of vegetation for any length of time.

Summary

Restoration and environmental work at Cruden Bay and St. Fergus has demonstrated the reciprocal advantages of environmental assessment and impact statements to the developer, the engineer and planner. It has also shown the value of early and informative discussions between the developer, site engineer, planning agencies and environmental consultants. It has also suggested the need for careful specific site selection in that some areas are manifestly easier to manage and restore than others. In this respect it is possible to recommend that an environmental consultant should be used before the precise site is chosen. No new techniques have been developed as a result of these three operational situations, although the policy of pre-determining access and working areas has been a useful innovation. Otherwise, the actual programme consisted of using techniques and methods developed elsewhere; they have simply been modified to suit particular local conditions. It has also been demonstrated that after restoration there is a need for a continuing monitoring programme to last at least 5 years. It has also shown that the developer needs to accept a commitment to review the progress of restoration work particularly in such dynamic and potentially fragile environments as the coastal zone. Management does not end when the pipelines come ashore. The input of capital and personnel for such monitoring is not great, amounting to little more than a few visits each year but this small provision will provide considerable benefits. It will also serve to improve or consolidate the relationships between the local community, the planning authority and the developing agent. At St. Fergus this has gone one stage further and the area including the restored ground has now assumed that status of Local Nature Reserve, with a Management Committee consisting of representatives of conservational interests and the pipeline and terminal operators.

Acknowledgements

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