



MASTER

Environmental Impact Assessment in the Pipeline Industry

Experiences with the UK North Western Ethylene Pipeline

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1 INTRODUCTION

The North Western Ethylene Pipeline (NWEPI) is the final link between Shell's oil and gas fields in the North Sea and its petrochemical complexes in Cheshire. Ethylene is one of the main feedstocks for the petrochemical industry and is used in the production of a wide range of goods, from plastics to antifreeze. It also plays an important part in many other industrial processes.

The natural gas from which ethylene is obtained comes from the Brent and Central fields in the North Sea. The gas is brought ashore by pipeline to St Fergus, where natural gas liquids are separated from the methane. From there the natural gas liquids, which are used in ethylene production, are moved by existing pipeline to Mossburn. They are then fractionated into their constituents, one of which is ethane. At the adjacent Fife Ethylene Plant the ethane is converted to ethylene. The ethylene is transported by pipeline to Grangemouth and, until the NWEPI was built, from Grangemouth to Stanlow and Carrington by BP and ICI pipelines.

In recent years there has been an increase in the demand for ethylene in the UK petrochemical industry. For the Shell site at Stanlow a secure and plentiful supply of ethylene was needed. The existing supplies, delivered by pipeline and by road tanker, were not enough to keep Stanlow and Carrington in production. It was, therefore, decided to construct a new pipeline that could supply Stanlow with all the ethylene it needed.

The construction of the pipeline was a massive project. It is the longest pipeline built in the UK by a private company, being 411 kilometres (255 miles) in length. The pipe, 10 inches in diameter and made from 17,100 tons of steel, is buried a minimum of 0.9 metres below ground. At the height of construction over 2,500 men and women were employed on the project. The pipe was laid in 1991, with associated reinstatement work taking place in 1992.

2 REGULATORY AND LEGAL ASPECTS

Approval for the construction of cross-country pipelines in the UK must be sought from the government. At the time the NWEPI was being planned approval was from the Department of Energy, now the approving body is the Department of Trade and Industry. In order for such approval to be obtained it is necessary to comply with relevant UK legislation. A brief summary of this legislation is given below.

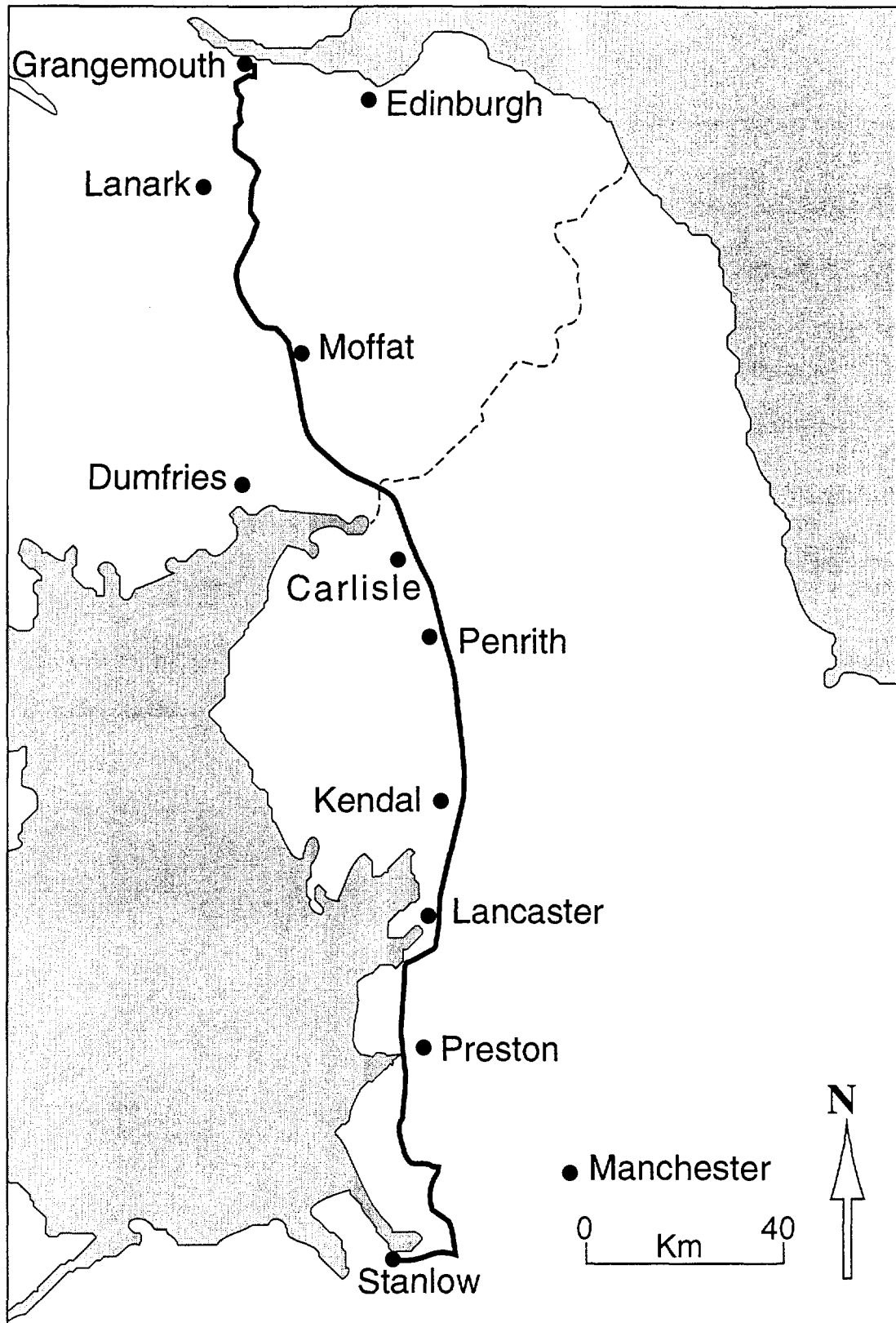
2.1 Pipe-lines Act 1962

In the UK the planning and construction of cross-country pipelines such as the NWEPI is regulated by the Department of Trade and Industry under the powers of the Pipe-lines Act 1962. The purpose of the Act is to ensure the orderly and safe development of pipelines in such a way as to meet the requirements of pipeline users, whilst at the same time minimising disturbance to farmers and landowners. Amongst the provisions of the Act are requirements to ensure the protection of the environment; thus since the early 1960s there has been statutory provision to enable the protection of the environment from pipeline construction.

2.2 Electricity and Pipe-line Works (Assessment of Environmental Effects) Regulations 1990

In June 1985, the European Communities adopted Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment. The requirements of the Directive as they apply to oil and gas pipelines in the UK were first set out in The Electricity and Pipe-line Works (Assessment of Environmental Effects) Regulations 1989 which took effect on 9th February 1989. Subsequently these were amended and new regulations came into force in March 1990.

Figure 1 Map showing the North Western Ethylene Pipeline



The Regulations specify the procedure that will be adopted when considering the need for an environmental assessment to accompany an application for Pipeline Construction Authorisation. The Secretary of State for Trade and Industry will decide whether a particular project is likely to have a significant effect on the environment. If he decides it is likely he will then require that an environmental assessment should be carried out and an environmental statement produced.

2.3 Environmental legislation affecting pipeline planning, construction and operation

There is a vast array of environmental legislation which impacts on the planning and construction of major infrastructure projects such as cross-country pipelines. Of particular importance are the:

- o Town and Country Planning Acts - which will affect the planning, design and construction of above-ground installations.
- o Environmental Protection Act 1990 - which amongst other things has introduced a Duty of Care in respect of waste.
- o Water Resources Act 1991 - which enables polluters of water courses to be prosecuted.

Many of the acts also have a bearing on pipeline operation, especially those relating to pollution avoidance and waste management. A pipeline failure that leads to a pollution incident is likely to result in an action being taken by the Environment Agency against the operating company. An example of this is the failure of a pipeline supplying Stanlow refinery on 19 August 1989. The pipeline failure led to the pollution of the river Mersey and its banks with Venezuelan heavy crude oil. The Environment Agency (then National Rivers Authority) prosecuted Shell UK under the powers of the Water Act 1989. In the Crown Court, Liverpool on 23 February 1990 Mr Justice Mars-Jones fined Shell one million pounds plus costs. In addition, Shell had substantial clean up costs to pay, estimated to be in the region of £1.4 million.

At present there is no statutory obligation to prepare emergency plans for pipelines which deal with the environmental consequences of failure. In this way pipelines are different from many other installations handling large quantities of hazardous materials, which fall under the Control of Industrial Major Accident Hazards Regulations (CIMAH). These regulations require that companies which operate certain hazardous activities produce emergency plans. In addition, county councils are required to produce off-site emergency plans for the same sites. Although at present pipelines are excluded from the provisions of the CIMAH Regulations, new regulations are being produced which embrace pipelines carrying hazardous materials.

3 ENVIRONMENTAL ASSESSMENT DURING THE PLANNING AND DESIGN OF THE NWEF

3.1 The Shell approach to environmental assessment

In its formative years, environmental assessment in the USA was required to be comprehensive and to follow prescribed routes and resulted in voluminous documents. Such a rigid framework delayed decision making and hindered the acceptance of environmental assessment as a regulatory requirement in Europe. Today it is recognised that "Environmental assessment is not only a study or a statement, it is a process which includes the provision of information, consultation with authorities and the public concerned, and the making of a decision. Environmental assessment provides an orderly process for gathering and evaluating information and opinions about the likely environmental consequences of proposed projects, to assist in decision-making" (Fairclough 1986).

Throughout the planning, design, construction and operation of the pipeline Shell adopted this approach in order to achieve a number of aims detailed below.

To assist the authorities

Regulating authorities increasingly require, among other things, information on environmental effects in order to "determine" applications, assess whether the need or associated benefit outweigh the environmental cost, decide whether an application for a development should be approved and to identify appropriate conditions and constraints. An environmental assessment can present information required in a structured way, thus helping the decision-making process.

As a forward planning tool

Environmental assessment, when applied at the conceptual design stage with other factors such as technical and economic constraints, can play a key role in assessing the feasibility and viability of a proposal and in selecting an environmentally and commercially acceptable concept.

As a design tool

The most important application of environmental assessment within Shell is its use as an interactive design tool. It enables a systematic look to be taken at the potential environment problems associated with a proposed development and to identify the key areas which require special consideration for environmental controls. When adopted early in a project, the environmental assessment helps to incorporate these controls in the most efficient way and avoids last minute design changes or even more expensive remedial measures once the development is completed.

To inform third parties

In addition to the authorities and other statutory consultees, there is increasing interest, from the general public and other groups, in the environmental impacts and risks and the potential benefits posed by new developments. An important feature of the environmental assessment is the provision of information to those potentially affected by the development. Objections may be overcome if potential impacts and measures to alleviate adverse effects are presented objectively. Likewise, fears of accidents leading to injury, damage or pollution may be allayed if the probabilities of such events are quantified and preventative measures described.

To inform and assist company management

Environmental assessment is a structured approach for informing management of their present and future position with regard to potential impact and associated risks of development. The assessment is used for establishing long-term environmental management objectives and targets to reduce financial risks caused by adverse environmental impact and to improve the company image.

Environmental assessment also serves to reassure management that all reasonable measures to minimise environmental impact have been considered and that company environmental policy requirements have been satisfied.

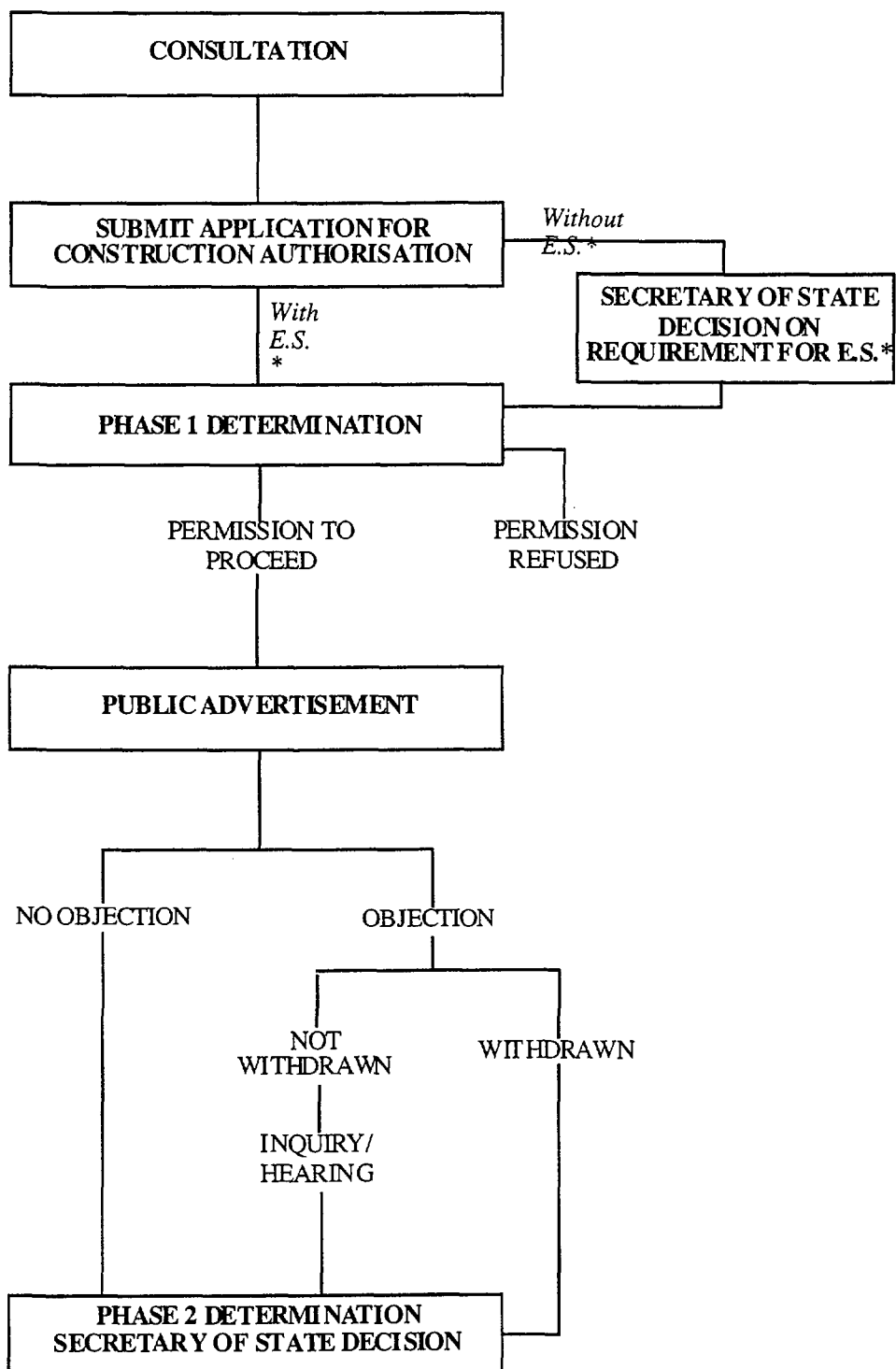
3.3 The project

Conceptual feasibility studies for the NWEF project were undertaken in 1987 and 1988. In March 1989 application was made to the Secretary of State for Energy for Pipeline Construction Authorisation (applications are now made to the Secretary of State for Trade and Industry). A public inquiry was held in June 1990 and in March 1991 the Secretary of State granted Shell Pipeline Construction Authorisation. Construction was completed in 1991 and associated restoration work was finished in 1992.

3.4 Planning considerations

The pipeline passes through four Regional, three County and twenty District local authority areas. Many different types of terrain are encountered, ranging from high moorland in the Southern Uplands of Scotland to designed parklands in Cheshire. The pipeline crosses 32 major rivers.

Figure 2 Procedure for obtaining construction authorisation



*Environmental Statement

The approach to pipeline environmental assessment had to be viewed in the context of the UK planning system. Pipelines and other linear developments which cross planning authority boundaries are controlled by central government. When pipelines are greater than 16 kilometres in length, it is necessary for the developer to apply to the Secretary of State for a Pipeline Construction Authorisation. The procedure for this consideration of a construction application involves three stages (see figure 2). The Department of Trade and Industry considers the application and may refuse it outright or allow it to proceed to the stage of public advertisement. The application is then advertised in local newspapers along the routes. If, after public advertisement, no objections are received, the Secretary of State for Trade and Industry may determine the application. If, however, objections are received, some form of inquiry or mechanism of representation to the Secretary of State is required prior to determination of the application. If an objection is made by a Local Authority, or other statutory consultee, a public inquiry must be held.

The time taken to determine a pipeline construction authorisation is likely to be in the order of 18-20 months. It was against this exhaustive planning process that Shell tailored their environmental assessment approach.

3.5 Environmental assessment method

In planning the pipeline Shell undertook an environmental assessment to identify the potential environmental effects of construction, commissioning and operation, assessed their significance and designed measures to minimise adverse consequences and maximise benefits.

There is no prescribed method for undertaking an environmental assessment of a pipeline and in many ways Shell were innovative in their approach and their methodology appears to have been adopted elsewhere. During the design of this project the assessment included the following components:

- o An examination of existing environment.
- o Impact appraisal and prediction.
- o Identification of mitigation measures.
- o Proposals for future monitoring and further studies.
- o Dissemination of information and preparation of an environmental statement.

These tasks were not seen as distinct stages of the assessment. Many overlapped and there was necessary feedback from one stage to another arising from consultation with statutory and non-statutory groups. The whole process was dynamic, operating alongside other project planning considerations, allowing the route to be modified at an early stage as technical, safety, environmental or commercial constraints became apparent. A route change to accommodate or ameliorate one impact sometimes created other effects which required assessment. The interactive, multi-functional nature of the routing process demanded close collaboration with other members of the project team and outside agencies. A small multi-disciplinary project team was established to allow the degree of effective collaboration necessary.

3.6 Stages in environmental assessment

Within the NWEF project, the application of environmental assessment occurred at the earliest stage in project development and continued through the stages of feasibility, conceptual and detailed design, construction, commissioning, operation and ultimately decommissioning. The strategy was based on an evolving process, a process that built a database of environmental information, increasing the degree of detail at each stage in the process as the route and design of the pipeline is refined.

Feasibility Study

The project's environmental feasibility was reviewed by an environmental specialist at the project's pre-conceptual stage. The study considered various alternative modes of transport and addressed environmental considerations of fundamental importance to the feasibility of the project, including the environmental legislative controls that are imposed on such developments. The pipeline option was selected as the most attractive.

Conceptual Study

The only viable transport option from a safety, environmental and economic point of view was a pipeline, for which two alternative routing options were examined: one wholly onshore, one partly onshore and partly offshore. Of these, only the wholly onshore proved viable.

The environmental study was therefore able to focus-in on an onshore route. A 2 kilometre-wide corridor, avoiding centres of population, and focusing on natural north/south corridors was established and was screened for features that would have a direct bearing on route considerations. At this stage, environmental assessment had a dual purpose: the identification of environments on which the pipeline would have a significant impact and also the identification of environments which would have a significant impact on the pipeline. The opportunity was also taken at this stage in the project to identify other linear developments, including pipelines, as there were obvious advantages in parallel and adjacent routing. In particular it minimised the cumulative effect on land use and offered definite advantages in woodland areas which already had an easement cut through them.

The issues addressed at the route concept stage are outlined below.

- o Existing linear developments and established corridors including:
 - Motorways
 - Trunk Roads
 - Railways
 - Canals
 - Overhead electricity cables
 - Pipelines
- o Historic buildings
- o Scheduled Ancient Monuments
- o Areas subject to subsidence
- o Geographical features
- o Estuaries and rivers
- o Geology and mineral resources
- o Aquifers and water resources
- o Conservation areas and landscape
- o Areas of woodland

With correct design, construction, materials and restoration techniques, there are few onshore environments through which it is not possible to lay a pipeline. However, each of the aforementioned features presented varying degrees of construction difficulty or necessitated greater expenditure on construction materials and/or restoration.

The objective at this stage in the routing operation was to achieve the most cost-effective route by attempting to minimise the length, while ensuring a minimal risk to the public and no significant adverse environmental impact. The assessment was conducted as a desk-top exercise, complemented by an aerial video of the whole route. This video film allowed a rapid means for updating Ordnance Survey maps and provided a ready visual reference for the project team. By screening a two kilometre-wide corridor for fundamental features it allowed the routing engineers a degree of flexibility, in that there was no need to undertake a reassessment so long as the route remained within the appraised corridor.

Detailed Design Stage

Once the principal features affecting the pipeline route had been identified, the role of the environmental assessment was to identify in detail the possible impacts of the proposal. The corridor principle still applied. However, its width was reduced to 500 metres. Within this zone, significant environmental features were identified. This work was carried out by specialist environmental consultants who provided detailed reports.

3.7 Consultation

Following the decision to progress the project to the conceptual design stage, representatives from Shell visited all relevant statutory authorities along the proposed route to discuss the possible implications. After these preliminary discussions, numerous meetings were held to focus on a range of regional and local issues associated with pipeline construction. The authorities were extremely helpful in providing

detailed information about their districts. Shell also consulted with many other statutory and non-statutory bodies responsible for nature conservation, archaeology, landscape and recreation. This consultation was maintained through out the project.

3.8 Examination of the existing environment

For many of the environmental issues associated with the pipeline development, a vital part of the assessment was the acquisition of good baseline data. A description, both qualitative and quantitative, of all aspects of the environment was required to provide a basis for design and assessment and a record of the existing situation. The following phased studies were conducted on the ethylene pipeline.

- o Nature and distribution of land cover.
- o Nature and distribution of land forms.
- o A geological investigation of the pipeline route.
- o A landscape assessment in two phases.
- o An ecological assessment in three phases.
- o Archaeological assessment in five phases.
- o An agricultural assessment.
- o The distribution of soils in two phases.
- o A study of the hydrological implications in two phases.

The different phases of work reflected an increasing amount of detail and effort. For example, the archaeological assessment was carried out in five phases. Phase 1 involved screening a two kilometre-wide corridor for scheduled ancient monuments. Phase 2 involved screening a 500 metre-wide corridor for all other monuments and sites. Phase 3 involved carrying out detailed survey work along a 40 metre-wide corridor. Phase 4 involved the excavation of sites prior to construction, and Phase 5 a watching brief throughout construction and the subsequent publication of results.

3.9 Impact appraisal and prediction

The environmental data generated by the baseline survey work, when considered in conjunction with detailed project studies, was used to identify the probable environmental implications of the development.

The following detailed project studies were undertaken for the NWEP Project.

- o Atmospheric emissions during construction and operation.
- o Noise implication of construction and operation.
- o Blasting and vibration.
- o Agricultural implications of construction.
- o Socio-economic implications of pipeline construction.
- o Strategic-economic appraisal of the project.
- o Safety.

The techniques used for impact prediction are established and well documented. Some aspects were relatively easily modelled, giving quantitative outputs to reasonable degrees of accuracy, such as the propagation of noise and dispersal of contaminants in the atmosphere. Others required a more qualitative approach and relied more on the judgement of experts than on comparison with accepted criteria.

Some issues have fairly well defined criteria, established by standards against which to assess impacts. These, again, were associated with the physical, chemical and hydrological impacts connected with construction and operation. The impacts associated with land-take and ecology did not have easily definable criteria against which to assess impact. The predictions of impact in these situations tended to be presented as qualitative descriptions and the demonstrations that impacts had been minimised by design and other mitigative measures.

Criteria for assessing environmental risk are not well established, although presentation of risk helps to put certain impacts into perspective. The overall perception of environmental risk is influenced

by the concept of risk acceptability, which has been applied when considering the effects of major accidents on the people living adjacent to the route.

3.10 Identification of mitigative measures

With a large project such as the NWEF, there were inevitably some adverse environmental impacts as a result of disturbance of the land surface. These effects were minimised by considering details of routing, construction techniques and site-specific reinstatement and aftercare programmes. For example, when crossing most moorland sites, Shell was able to reduce the normal working width of 20 metres to 12 metres and topsoil stripping operations were restricted to the width of the pipe track only. Instead of stripping topsoil across the whole width, a sand, bog mat or subsoil road was constructed directly onto the flailed vegetation. Turves were lifted from the pipe trench area stored to one side and put back. The road was then lifted and the working area scavenged for debris.

3.11 Proposals for future monitoring and further studies

The environmental statement broadly identified the potential environmental impacts of the development. Monitoring programmes were established to:

- o Obtain, where appropriate, baseline data for the environment prior to the construction, commissioning and operation of the pipeline.
- o Monitor any significant alteration to the biological, chemical and physical characteristics of the local environment.
- o Monitor emissions and discharges at all stages of the development to ensure they met the national, local and company management standards.
- o Monitor any alteration to the inter-relationships of different aspects of the environment.
- o Determine whether any environmental changes which occurred were a result of the development or whether they resulted from natural variation.

The intention was to determine, where appropriate, both the natural fluctuations of environmental parameters and the extent of other anthropogenic induced changes before, during and after construction of the pipeline and throughout its operational life.

3.12 Preparation of environmental statement

The product of the environmental assessment process was a series of technical reports which were summarised, in a user-friendly form, in an environmental statement written by the Shell environmental specialist. The report was submitted to the statutory authorities in draft form. Then, after further consultation, the final document was made available to the public and other interested parties as a supporting document to the application for Pipeline Construction Authorisation. The range and depth of the environmental issues covered demonstrated Shell's commitment to environmentally sensitive development. Where impacts were identified, actions intended to mitigate the impacts were described. However, the report could not be considered comprehensive or technically detailed. The supporting technical reports on specific environmental subjects were, therefore, distributed to the appropriate authorities, whose expertise enabled them to critically assess the detail.

3.13 Publicity and public involvement

Public involvement was not invited before the application for Pipeline Construction Authorisation was submitted. This was principally due to the dynamic, ever changing nature of the project. Confidential discussions with the local authorities indicated issues of local concern. These were addressed throughout the design stage and a commitment to carry out certain works to comply with statutory requirements was inevitably a cornerstone of the environmental statement. Shell tended to utilise a team approach to consultation with an 'action plan' developed at an early stage identifying the targeted groups for consultation.

3.14 Contract documentation

The key to effective environmental management was to turn the products of the environmental assessment, i.e. the series of technical reports and the environmental statement, into action. This was achieved by building the results into the technical specifications and, where necessary, into contract documents including alignment sheets.

There was no one way to achieve this and, as with all contractual matters, a balance had to be sought between providing the contractor with too much and too little information. It has been argued that if too much environmental information is given to potential contractors they will react adversely and charge a premium on the basis that perceived environmental sensitivity presents a risk. Conversely if inadequate information is provided then there is a risk of claims.

There was also debate about whether design engineers should specify to the contractor how a pipeline should be built or whether they should simply specify what should be achieved in an environmentally sensitive area. The solution adopted by Shell was to instruct the contractor to provide 'method statements' for the areas concerned. These were then issued to interested third parties whose agreement was required to enable construction to proceed.

4 ENVIRONMENTAL CONTROL DURING CONSTRUCTION

4.1 General

During the planning and design phase of the pipeline considerable effort was expended on the identification of potential environmental impacts, the identification of suitable mitigation measures, the inclusion of mitigation measures into the design, and where appropriate their stipulation in contract documentation. For those mitigation measures to be effective they had to be:

- o Known to all relevant personnel.
- o Understood by all relevant personnel.
- o Implemented.

In practice these three basic requirements, the cornerstone of effective environmental management, were perhaps the most difficult to meet.

4.2 Raising awareness

Raising awareness was the first step in achieving satisfactory environmental performance. Management had to appreciate the significance of environmental issues and be committed to achieving a high standard of environmental performance. This commitment in the management of a pipeline project was strongly influenced by the level of importance given to environmental issues by the senior management of the company.

In order for the project's workforce to become familiar with relevant environmental issues Shell did a number of things.

- o A full-time environmental scientist was appointed to the management team from the outset of the project. He had the responsibility of briefing the project, construction and engineering managers on environmental issues.
- o Monthly health, safety and environment meetings were held allowing issues of concern to be discussed by the management team.
- o Informal workshops took place, for example an archaeological dig took place along the pipeline prior to construction and many members of the Shell project team took part under the supervision of trained archaeologists. In the evenings there were presentations about archaeology and what had been found along the pipeline route during the pre-construction surveys and what was likely to be found during construction.
- o Health, safety and environment workshops were held lasting two days once construction contractors had been selected. Members of the Shell team and the construction contractors

- participated to ensure that all senior management on the project appreciated the importance of environmental issues on that project and understood the mitigating measures which had been designed and incorporated into the contract documents.
- o All personnel went through a programme of induction training before they were allowed to work on-site. This took the form of a talk from the site safety and/or environmental officer. At these talks a handbook covering safety and environmental issues was handed out to those on the training course.
 - o Tool-box talks were held on an as-required basis with different construction crews. Typically these were held on a weekly basis, or before entering a special section. The talks were given by the supervisor or foreman although if a special environmental crossing was about to be encountered an environmental officer would explain what was important about a site and how to protect it.
 - o Signs were erected along the spread indicating the beginning and end points of areas where special precautions had to be taken.

4.3 Site supervision

The number of inspection staff required on a construction project is always contentious. Financial constraints mean there is pressure to reduce the number of inspection staff. Quality assurance philosophy maintains that well written procedures and the use of appropriately trained staff will help reduce the number of inspection staff required. Experience suggests that the higher the level of supervision the better the end product. Of course the question must be what level of supervision is necessary.

It is essential that environment, like safety, is perceived as a line responsibility and not the sole responsibility of the environmental officer. All supervisors and inspectors can help ensure that environmental requirements are implemented. However, the effectiveness of this is dependent upon the supervisor appreciating and implementing a project's environmental controls.

In sensitive areas a greater input will be needed from an environmental officer. They will probably have been involved in designing mitigation measures and will therefore know how flexible those measures are. When problems arise the environmental officer, with a knowledge of the site, can advise on how to overcome the problem.

In the case of the Shell NWEF the environmental supervision comprised a senior environmental scientist who was part of the project management team and who was assisted by an archaeologist. Each Shell construction team, who were managing a particular spread, employed an environmental scientist and an archaeologist. In addition, environmental officers worked on an 'as required' basis at particular sites, for example when the construction teams passed through Crosby Ravensworth Fell and Lazonby Fell in Cumbria an environmental officer was present at all times.

4.4 Reporting and organisation

As with most construction projects the NWEF was managed by a project team headed by a project manager. Reporting to that manager were various management disciplines such as construction, engineering, and health, safety and environment (HSE). It was important to maintain a link between the project's HSE group and the corporate HSE group. This provided a mechanism whereby the project manager could be circumvented if necessary.

4.5 Contractor plans

Contractors were required to prepare their own environmental management plans. These plans allowed the contractor to implement procedures tailored to their organisation and way of working. On the NWEF the construction contractors were asked to produce plans which covered:

- o Archaeology - what to do in the event of an archaeological find.
- o Waste management - including waste minimisation, re-use, recycling, disposal.
- o Pollution prevention - including avoidance, containment, clean-up, reporting arrangements.

4.6 Monitoring

On the NWEF most environmental monitoring took the form of checks to ensure that the contractor was complying with contractual requirements; for example, waste management and use of designated disposal sites. Some particular forms of environmental monitoring were required at particular locations for example at river crossings it was necessary to monitor dissolved oxygen and suspended solids. When working in close proximity to residential areas it was important to monitor noise levels.

4.7 Audits

The management system was subject to audits to allow shortcomings to be identified and importantly, to allow improvements to be made. Corporate HSE could audit the project's HSE group; the project's HSE group could audit the construction contractor or specialist environmental contractors.

5 ENVIRONMENTAL MANAGEMENT DURING OPERATION

5.1 General

Pipelines are viewed as the safest means of transporting large quantities of hazardous fluids and gases over long distances. From an environmental view point pipelines are also the preferred mode of transport: there is the reduced likelihood of accidents and spillage of products, also the environmental impact of operating pipelines is less than rail or road.

To ensure that pipelines have a minimal impact during operation there are two areas that require action:

- o Avoiding spills/pipeline failure and ensuring that adequate plans have been put in place to deal with such a problem.
- o Ensuring adequate restoration.

To achieve these aims, a number of actions are required, many of which are simple components of a good management system - for example, training, monitoring, audits and reviews, appropriate allocation of responsibility and so forth. These issues are addressed in this section.

5.2 Restoration monitoring

It was important that the success of reinstatement was measured and areas which were unsatisfactory, improved. In agricultural land this was often a question of repairing damage to soil structure and/or drainage. Environmentally sensitive areas included moorland, heathland, unimproved grasslands, species-rich wetlands and deciduous woodlands. Hedgerows were also given special attention. Far too often hawthorn or other species are planted in hedgerows at the end of construction and then not maintained. Many die and are not replaced. Unfortunately, it is the hedgerow that is most often seen by the public.

The type of monitoring required depended on the nature of the site and the purpose of the monitoring. In some cases a simple 'look see' and brief report sufficed. In other cases a detailed ecological survey was needed, perhaps using quadrats across a permanent transect.

5.3 Other monitoring

The only other monitoring that is was required was noise monitoring in the vicinity of pumps/compressors. This was especially important if the pump house or compression station was located near to a residential area.

5.4 Environmental information

Good records about the state of the environment on the NWEF were essential. Data was kept on the location of archaeological sites, recreational areas, water resources including aquifer protection zones, areas of conservation importance including Sites of Special Scientific Interest, landfill sites, landscape features and so forth. Information on the location of these sites and the reason for their sensitivity can prove useful when planning maintenance work or responding to emergencies.

Shell have adopted a Geographical Information System to manage the enormous array of data that it holds on the NWEF.

5.5 Geographical Information Systems

The GIS allows the pipeline manager to look at a VDU screen and see a map of the pipeline route. The manager can then simply point the cursor to a location on the pipeline route and ask for information. That information can include:

- o Name, address and telephone number of the landowner.
- o Engineering data e.g. depth of burial, pipe wall thickness.
- o Crop compensation data since pipe installation.
- o Aerial photographs, video images or other photographs of the site.
- o Environmental data e.g. location of Scheduled Ancient Monuments, SSSIs, Nature Reserves.

The data retrieval option described above is the least demanding of the capabilities offered by the system. The GIS can also be used to give the answers to "what if" questions. For example, if the pipeline were to leak at a particular location, the GIS could tell a manager:

- o The best access route to that section of pipeline.
- o Who to contact, with name and telephone number.
- o Which settlements fall within the area affected by the release.

Furthermore, the GIS can interface with simulation models, and present the results of a simulation run in an easily understood form; for example, in the case of a gas cloud, how big it is and where it will travel under certain weather conditions.

5.6 Record keeping

It was vital that records were kept, especially on the subject of waste management. The "Duty of Care" requires that the originators of waste keep records of what was disposed of, who transported it, and what was the final destination of the waste. The exact requirements are specified in the Duty of Care published by the Department of Environment.

5.7 Audits and reviews

Audits should be undertaken to assess compliance with the company's environmental policy or legislative requirements. Some pipeline operators have been doing this such as British Pipelines Agency and Shell Chemicals UK Limited. British Pipelines Agency have been undertaking audits to help them set priorities for remedial maintenance work. (Barr, 1993)

In some cases, a more general review may be appropriate. A review will not be testing procedures, it will be collecting information. An audit will be verifying actual practice against a yardstick such as a company's environmental policy.

6 ENVIRONMENTAL CONTROLS AT SENSITIVE SITES ON THE NWP: SOME EXAMPLES

6.1 General

Because the NWP is such a long pipeline, and because it had to follow a line which was already littered with other pipelines, railways and roads, it was impossible to establish a route which did not affect any important areas. In particular it had to cross two Roman walls: the Antonine Wall and Hadrian's Wall, both of which are Scheduled Ancient Monuments and are protected by law. It also had to cross four SSSIs, which are also protected by law, and two proposed SSSIs. Only with careful negotiation, and after a public inquiry, were Shell allowed to cross these features.

Throughout the length of the pipeline Shell took care to ensure that construction was undertaken in an environmentally sound manner. For example, trees near the working width had their roots protected from vehicles by fencing, fuel was stored in tanks which were bunded, static plant such as pumps which might leak were stood within drip trays to avoid spillage onto the ground, and sediment in water had to be allowed to settle out before it could be discharge into streams or rivers. Four environmentalists and four archaeologists monitored the day to day construction. Special construction methods were agreed for all the sensitive environmental and archaeological sites.

6.2 Carstairs Kames

The Carstairs Kames are among the most striking and important groups of glacial landforms in Britain. Over a distance of some seven kilometres there is a series of braided sand and gravel ridges and mounds with intervening peat-filled hollows. These features, which reach a height of 25 metres above the surrounding topography, are the product of sediment-laden water flowing from the front of melting ice sheets some 15,000 years ago. They are designated as a SSSI. In recognition of their immense scientific value, Shell has funded a three-year research project on the kames.

The pipeline was routed across the kames in a manner that would minimise disturbance. A low point was chosen for the crossing and, where the pipeline had to run parallel to the edge of the kames, the width of the working area was reduced to as little as four metres. Reinstatement of the area was very important and care was taken to ensure that the working area was returned to its former profile. In addition, every effort was made to ensure that the vegetation was quickly and effectively re-established. As a result reinstatement was very rapid and successful.

6.3 Harnhead raised bog

Whilst every attempt was made to route the pipeline away from raised bogs, one had to be crossed at Harnhead, near Avonbridge in Scotland. The area was recognised by Shell as an interesting environmental feature, although it did not enjoy any formal recognition. The bog, about 300 metres in width where the pipeline crossed, is dominated by mosses, heather (*Calluna vulgaris*) and harestail cotton-grass (*Eriophorum vaginatum*). Thus, today it is no longer in its original and natural state and is unlikely to be 'growing'; indeed, if it was it would have been very unwise to attempt the crossing because of the problems that would result.

In order to limit damage, the working width was reduced from the normal 20 metres to only 12 metres. The road along the pipe trench was built of wood, and the machines were confined to it. The vegetation was lifted off the line only where the trench was to be dug; this was important because the surface layer of a bog provides stability and, if removed, the underlying water-table would be at the surface, making work very difficult.

The surface vegetation at Harnhead was removed by machine in large, one metre square clods, which were stored on permeable matting and wrapped to prevent drying. The pipe was welded and laid by a small specialist crew; this helped to keep vehicle movements to a minimum. Once the pipe was laid and the trench backfilled, the turves were replaced, correct way up, over the trench. The road was then lifted and the area cleaned up. All the work in the area was completed within four weeks.

Annual inspections since reinstatement have shown that the replaced turves are growing well and five years on there is hardly a trace of the pipeline. The key to success in this case was the short time

that the turves were out of the ground and the minimisation of traffic movements through the area. The use of a small dedicated team was also very important in getting good results.

6.4 Lazonby Fell dry heath

Lazonby Fell, which lies just to the north of Penrith, is an area of predominantly dry heathland with some wetter patches, bracken and grassland. Because of its ecological value, and the fact that such areas are under threat from agriculture it has recently been designated an SSSI. This will help ensure the continued management of the area, which includes burning and grazing.

As a result of consultation with English Nature the most ecologically sensitive areas of the fell were avoided. A large part of the pipeline route used an existing track running along side a coniferous plantation; this reduced the need to cross stands of heather by about half.

Before work started, much thought went into choosing the most appropriate construction methods for the site. Then, in late spring, preparatory work began and the heather on the route of the pipeline was cut with a tractor-mounted mower in order to promote new and rigorous growth in the following year.

The construction of the pipeline on Lazonby Fell was to take only three weeks, and a special construction team was assigned to the area. A strip 12 metres wide was fenced off and all activity confined to that area. The existing track was used for vehicles where possible; elsewhere a temporary road of sand laid on permeable matting was constructed. Turves were removed from a 1.5 metre-wide strip along the pipe trench and were stored to one side. Because of the very dry conditions, the turf heaps had to be watered to prevent them drying out.

Once the trench had been dug, the pipeline laid, and the trench backfilled, the turves were replaced over the trench line. They were placed right side up, compacted into the ground with the flat of the excavator bucket, and then watered. Heather cuttings containing seeds collected from nearby on the fell were spread over the area to encourage growth of new plants. The area was fenced to prevent overgrazing by sheep.

An inspection of the area six months after the work was carried out showed that the turves had started to grow back well and that the adjacent heather was relatively undamaged. Five years on the growth of heather is abundant and there is no doubt that the reinstatement has been a success.

6.5 Crosby Ravensworth Fell upland grassland

Crosby Ravensworth Fell is an extensive area of common land near Shap in Cumbria. It supports a variety of upland semi-natural plant communities typical of acidic grassland and heather moorland. There are also areas of geological interest, with limestone outcrops and 'shake holes' caused by the solution of the limestone. The area is designated an SSSI.

The pipeline route crossed a variety of environments on the fell. At the south end, a well-preserved Roman Road was uncovered and studied by Shell's archaeologists. In some of the drier areas there were stretches of heather, the remnants of a once much more widespread vegetation community. However, the main areas of the fell were covered by acidic grassland much invaded by bracken.

'Snow cat' vehicles fitted with wide tracks were used to transport fencing materials to the site, thus minimising damage to the ground and vegetation. In the dry, species-rich parts of the Fell the topsoil was stripped and stored in two layers. The top layer, only a few inches thick, was stripped separately because it contained a viable seedbank that could form the basis of new growth over the pipeline and give rise to a new vegetation cover as similar as possible to that previously present. One wet, species-rich area was turved and the turves stored until they could be replaced. Other species-poor areas were stripped in a single layer as is more normal during construction.

After the pipeline was laid, the subsoil and the topsoil were carefully replaced in the correct order. To stop sheep on the fell from grazing and trampling the re-establishing grasses, the pipeline fences were retained and kept sheep-proof for a minimum of five years.

Because of the fragile nature of the plant communities and the harsh climatic regime on the Fell reinstatement has been slow. This was not unexpected, but after meetings with the landowner and English Nature representatives it was decided to apply additional grass and heather seed to the site to aid recovery and to prevent soil erosion. Now, five years on the site is in good condition but full reinstatement has still to be achieved.

6.6 Goyt Hey Wood

Goyt Hey Wood, near St Helens, had to be crossed; there were so many other constraints in this area, such as a reservoir, coal measures, and towns and villages, that there was no choice. The wood is probably one of the oldest in the area and is the remnant of woodland that must once have been much larger. It lies on the steep slopes of a small stream and comprises oak (*Quercus* species) trees with some willow (*Salix* species) and sycamore (*Acer pseudoplatanus*). There is a rich ground flora of wood anemone (*Anemone nemorosa*), ramsons (*Allium ursinum*), lesser celandine (*Ranunculus ficaria*), bluebells (*Hyacinthoides non-scriptus*) and wild garlic (*Allium carinatum*). The site is listed by English Nature as 'Ancient Woodland' and is designated by St Helens Borough Council as a Category 1 Wildlife Site.

Shell undertook to build the pipeline through the wood without cutting down any mature trees. In addition, work was to begin after 31 August when the woodland flowers, especially the bluebell, had died back. The working width was confined to only 4.5 metres, and a crossing point was chosen which would minimise both the limbing of mature trees and the removal of saplings. The topsoil containing the bulbs and seeds of the important ground flora was carefully removed and stored in an adjacent area ready for replacement. The trench was dug by small excavators and the spoil was also taken out of the area. No through-movement of vehicles was allowed. The pipe that was to be laid was welded outside the wooded area, and then it was pulled through and lowered into the trench. A stream had been dammed off and the water was pumped around to allow the pipe to be laid. After backfilling the pipe trench, the topsoil from the woodland was replaced and the banks of the stream rebuilt. All the work at the site took little more than three weeks.

The following spring the success of the reinstatement was evident; in particular many bluebells were already flowering on the former working area. Today there is little evidence of the pipeline in the wood.

6.7 River Lune

The pipeline runs close to the River Lune during its journey through the Lune Gorge near Tebay and, because of the confined nature of the gorge and the presence of roads and railways, it had to cross the river several times.

The river was crossed using the open-cut method - a trench was dug across the river and the pipe laid whilst the water was still flowing. Although large amounts of suspended solids could be released, their effect was greatly reduced by stopping work for short periods to allow pulses of clear water to flush through the system. The benefit of this technique was its speed.

The River Lune, along with many other rivers crossed, was studied prior to construction by hydrologists from the Institute of Freshwater Ecology. They found a wide diversity of invertebrate species, including mayflies, stone flies, caddis flies, beetles and snails, indicating that the water was of good quality. In August 1992, when the survey was repeated, hydrologists found that the species had returned and thus there had been no long-term effects on the fauna of the river.

6.8 River Mersey

The Mersey Estuary is an important site for wildfowl, which feed on the rich invertebrate fauna on the sand and mud flats when overwintering and migrating. Of particular significance are the populations of pintail, teal, shelduck, pigeon, curlew, redshank and golden plover. The importance of the estuary is widely acknowledged; it is an SSSI and is internationally recognised.

To totally avoid disturbance to the estuary and its fauna, it was decided to drill beneath it. The drill covered a distance of 780 metres and also included the St Helens Canal. The only impacts associated with the drilling operations were either side of the estuary, away from the sensitive areas. Had the open-cut method been used construction would have taken eight weeks; instead, the whole operation took less than a week.

6.9 Antonine Wall

Archaeological sites require a different approach to wildlife sites. Some require excavation before construction begins. For example, at the Antonine Roman Wall near Grangemouth, where archaeologists knew the exact location of the wall a full excavation was carried out. As it was thought that there was a fort there the archaeologists were keen to take the opportunity to excavate it.

The pipeline crossed the Antonine Wall south of Grangemouth in Scotland towards the eastern end of the frontier. Prior to the construction of the pipeline, excavation was required to fulfil the terms of the Scheduled Monument Consent. An area almost 100 metres long and two metres wide was investigated by a team of archaeologists across the sensitive area. The pipe was then laid in this trench by machinery operating from a temporary road laid on the undisturbed topsoil. The road was designed to spread the weight of the heavy construction equipment so that buried archaeological features would not be damaged.

The excavation of the trench proved to be very rewarding. All the elements of the Antonine Wall were preserved, and the presence of the fort was confirmed. The preservation of the archaeological features was relatively good because soil had been dragged over the area from an adjacent hillside by ploughing, thus burying the remains deeper beneath the ground. The Wall was found to have been 4.4 metres wide and to have survived up to 0.7 metres high. It comprised a stone base surmounted by a clay-faced earthen superstructure. Around nine metres to the north of the Wall lay the ditch, which was eight metres wide and over two metres deep. Its adjacent upcast mound was some 13 metres wide. Around 15 metres to the south of the Wall lay the Military Way, a road which ran along the entire frontier and allowed rapid communication between neighbouring forts. A fort was attached to the rear of the Wall, and was probably built around 15 years after the Antonine Wall itself.

Some of the most interesting finds came from road surfaces and demolition spreads within the fort. One such find was a fragmented sandstone slab. When reconstructed this turned out to be a very unusual gaming board. On one side is a roughly incised chequerboard pattern, a design common to Roman gaming boards. The other side had seven compass-drawn circles inscribed on its surface. Parallels for this are still being sought, and it is not yet certain that the circles formed the basis for a game. Also on the road surface and close to the gaming board was a cluster of hobnails which outlined the sole of a boot or shoe. A Samian dish was found beneath the earlier building in the southern half of the fort. Samian wares are good quality tablewares which are often lavishly decorated (though this example was undecorated). The dish, although in two pieces, was nearly complete.

6.10 Low Borrowbridge Roman cemetery

Others archaeological sites could not be excavated beforehand because no one knew they were there. This was the case at Low Borrowbridge, in the Lune Gorge, where construction work had to stop whilst a Roman cemetery was uncovered.

With a Roman fort nearby and evidence to suggest a civilian settlement very close to the pipeline, trial excavations were carried out prior to pipeline construction. Some Roman items were found but there was nothing to suggest a settlement. However, during pipeline construction the following year, the archaeological inspector monitoring topsoil stripping noted five discrete burnt patches, each about 0.7 metres in diameter, with pottery sherds, charcoal, and iron nails visible at the surface. Construction in the immediate area was halted, and the archaeological response team began to evaluate the site. It soon became clear that the burnt areas were cremation burials, and that a Roman cemetery lay within the pipeline corridor. The site was then fully excavated and recorded.

Three types of feature were identified within the cemetery. The earliest were large oblong pits, which may represent graves. In one pit a complete Roman ceramic vessel was found, and, in another, parts of a beautiful necklace made from gold-in-glass, coloured glass and shale beads. The gold-in-glass beads were probably imported from Egypt. No bones were recovered from the pits, although this was not surprising given the acidity of the soil, which caused all but burnt bone to decay. Some of the pits were not large enough to have contained an adult body lying on its back, and it is possible that these were the graves either of children, or of adults buried in a crouched position.

At least 15 small ditched enclosures, measuring between three and five metres in diameter, were discovered within the cemetery. They were roughly circular or rectangular in shape, some with a clearly defined entrance. The enclosures were probably intended to define a family or military burial-plot, the ditches perhaps containing small ornamental hedges or flower beds. They are unique in North West

England, and are not usually found in Roman cemeteries elsewhere, although similar features are known to be associated with Iron Age burial sites.

Post-dating the enclosures, although often respecting their position, were the cremation burial pits, 64 of which were found, many of them cut into the enclosure ditches. They contained tiny fragments of cremated bone, charcoal and carbonised material. Nearly all the burials contained Roman pottery sherds, and 18 almost complete vessels were recovered. A fine tombstone dedicated by one Aurelius Verulus to his wife Aelia Sentica was also found. The tombstone has been dated to the third century AD, as has the majority of the pottery recovered from the site, suggesting that the cemetery was in use during the third century.

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