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Marine Pollution Monitoring Management Group

Seventh Report of the Group Co-ordinating Sea Disposal Monitoring

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**Marine Pollution Monitoring
Management Group**

Seventh Report of the Group Co-ordinating Sea Disposal Monitoring

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FOREWORD

The Group Co-ordinating Sea Disposal Monitoring (GCSDM) was established by the Marine Pollution Monitoring Management Group (MPMMG) in 1987 following a review of monitoring practices at sewage-sludge disposal sites. That review had clearly demonstrated the need for a more uniform and coordinated approach and the GCSDM sought to encourage this by defining environmental quality objectives for the disposal sites and standards by which compliance could be judged. Initially the standards were expressed largely in descriptive terms but progressively it has been possible to refine these and express them in numerical terms.

This, the seventh report produced by the GCSDM, summarises the work of the Group and its Task Teams in the last 3 years. As with previous reports this report includes a review of monitoring conducted at sewage-sludge disposal sites and compares the approaches and results with the procedures and standards proposed by the GCSDM. It is concluded that monitoring was carried out to a broadly similar pattern and the results were largely comparable and continue to suggest that no changes are occurring in the sewage-sludge disposal areas. The report also includes a brief summary of the monitoring undertaken in 1995. The results of this monitoring and any conducted in 1996 will be reviewed and summarised in the next GCSDM report. Sewage sludge disposal at sea is due to end in 1998 and the report suggests that it would be prudent to continue some monitoring at four major disposal sites to demonstrate that the past disposal operations have not had hitherto undetected undesirable effects.

Also included in this report are brief summaries of the activities of the various Task Teams established by the GCSDM and in operation during the period 1993-1996. Both the Metals and Organics Task Teams completed their tasks in 1994 and their reports are being published as a single edition in the same series as this report. The Sediment Bioassay Task Team completed its work early in 1996 and concluded that it is now possible to apply bioassays both in a predictive and monitoring context. Its report is also being published as a separate report in this series. The recommendations apply to both dredged material and sewage-sludge disposal sites and it is suggested the procedures proposed be operated in parallel with the more traditional monitoring of chemical quality of sediments and comparison with the EQS values proposed by the Organics and Metals Task Teams.

The Comprehensive Studies Task Team conducted a major review of its earlier report on monitoring to demonstrate whether or not an area qualifies as less sensitive under the terms of the Urban Waste Water Treatment Directive (DIR 91/927/EEC). A brief summary of the main clarifications made - the report is basically unchanged, is included in Section 3.4 of this report.

Sections 3.5 to 3.7 contain brief summaries of the progress by Task Teams on dredged material disposal monitoring, sewage effluent monitoring and marine litter. The Dredged Material Disposal Monitoring Task Team is expected to complete its work in 1997 and will advise on the currently available best procedures for monitoring dredged material disposal impact. The other two task teams are reviewing current practices with a view to recommending a more co-ordinated and uniform approach to monitoring either the effects of sewage effluents or the scale and effect of marine litter respectively. Summaries of their findings will be included in the next report of GCSDM which will be published in 1998 or early 1999.

J. E. Portmann

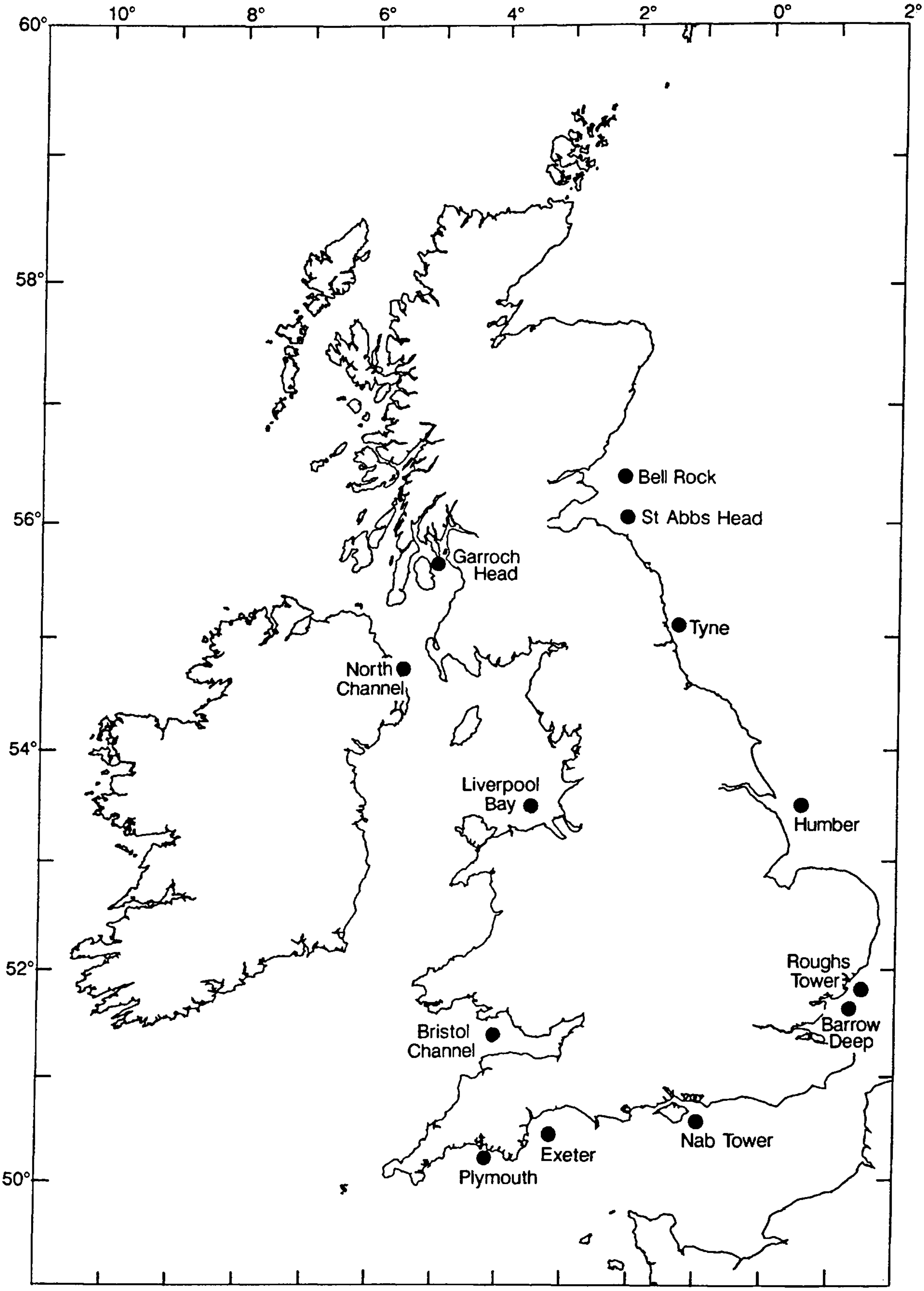

Figure 1. Locations of UK sewage-sludge disposal sites

1. INTRODUCTION

The Group Co-ordinating Sea Disposal Monitoring (GCSDM), is a sub-group of the Marine Pollution Monitoring Management Group (MPMMG). It was set up in 1987, in order to co-ordinate the monitoring work carried out at sewage-sludge disposal sites. The main aim of the Group was to establish common objectives and procedures for monitoring. By the end of 1991, with the help of specialist Task Teams established by the Group, a set of common environmental quality objectives was defined and standards developed by which the meeting of those objectives could be verified. Detailed guidelines on the methods to be used for monitoring compliance with the standards were also successfully developed. The Group has produced annual reports giving details about its work and the extent to which its advice and recommendations were followed. (MAFF, 1989, 1991(a), 1991(b), 1992, 1993(a) and 1994(a)).

Dredged material disposal has a number of similarities with sewage sludge disposal and, because of its success in the latter area, the Group's remit was extended in 1992 to cover dredged material and other disposal operations. During 1993, environmental quality objectives and environmental quality standards for dredged material sites were proposed based on those defined for sewage sludge disposal. These were presented in the Group's sixth report, produced in 1994.

The disposal of sewage sludge to sea is due to be phased out by the end of 1998 and has already ceased at a number of sites. As a result of the accompanying reduction in the requirements for site monitoring and the changing priorities of the Group, it was decided not to produce an annual report in 1995.

In the two years since its last report, the GCSDM has furthered the work on dredged material disposal and extended its work into a number of new areas. Most of the original Task Teams have now been disbanded but new Task Teams have been established as the need has arisen. This, the seventh report of the GCSDM contains details of the Group's activities and the progress of the Task Teams during the years 1994 and 1995. It reviews the monitoring carried out at sewage-sludge disposal sites during 1993 and 1994 and also outlines the surveys carried out in 1995.

A list of members of the GCSDM and its Task Teams during 1994 and 1995 is given in Annex 1.

In some instances their organisations or addresses have since changed, but for consistency, the name and/or address that applied for the major part of the period is used in this Annex.

2. TASKS UNDERTAKEN BY THE GCSDM IN 1993

2.1 Mode of operation

As a sub-group of MPMMG, the role of the GCSDM is to provide advice to the parent group on particular monitoring requirements and to demonstrate through its reports the extent to which its advice is implemented, both by the licensees and by the regulatory agencies (for England and Wales, Ministry of Agriculture Fisheries and Food (MAFF); for Scotland, Scottish Office Agriculture, Environment and Fisheries Department; and for Northern Ireland, Department of the Environment (Northern Ireland) (DoE(NI)). The GCSDM itself, has a restricted membership and meets only two or three times a year. The detailed work that underpins its advice is carried out by the Group's specialist Task Teams, the members of which come for a wide range of organisations with the relevant expertise. During 1994 and 1995, the following Task Teams were active: a Metals Task Team (Sub-section 3.1); an Organics Task Team (Sub-section 3.2); a Sediment Bioassay Task Team (Sub-section 3.3); a Comprehensive Studies Task Team (Sub-section 3.4); a Dredged Material Disposal Monitoring Task Team (Sub-section 3.5); a Sewage Effluent Task Team (Sub-section 3.6); and a Marine Litter Task Team (Sub-section 3.7).

2.2 GCSDM activities

At the end of 1993, the GCSDM resolved to review its activities in the light of current and future changes in the UK water quality policy and regulatory regime. At the Group's first meeting in 1994, the following recommendations were made and subsequently agreed by the MPMMG:

(i) to continue the development of methodology for sewage-sludge disposal site monitoring.

(ii) to continue with the development of standards and methods for dredged material disposal site monitoring.

Environmental quality objectives and standards for dredged material disposal monitoring were proposed by the GCSDM in its sixth report and both the Metals and the Biology Task Teams made some progress in considering appropriate monitoring strategies for assessing compliance with the proposed standards. However, it was felt by the Group that the work could be taken further by a specialist Task Team. The Dredged Material Disposal Monitoring Task Team was duly established and met for the first time in October 1994 with the following terms of reference:

- Review the potential impacts of dredged material disposal against the objectives set by the GCSDM for the quality of areas used for dredged material disposal.

- Propose guidelines for the methods to be used for monitoring such areas.

- Propose standards by which the meeting of objectives can be assessed, taking due account of the nature of the receiving area and the different types of dredged material likely to be involved.

- Advise on situations where monitoring may or may not be required and as appropriate, suggest minimum frequencies of monitoring for the assessment of compliance with the defined objectives and standards.

(iii) In 1993, a report was produced for the Department of the Environment (DoE) recommending comprehensive studies required for the 'less sensitive areas' identified under the Urban Waste Water Treatment Directive (DIR 91/271/EEC) (European Communities, 1991), the recommendations of which were adopted by DoE and followed up by the Water Industry. The report recognised that not all of the techniques proposed were fully validated and that the methodology would need to be continuously reviewed. It was agreed that preparations should be made for the Group to review the report, through the Comprehensive Studies Task Team.

(iv) Under the Group's new remit, consideration was given to the adoption of a wider role in respect of sewage discharges. In considering 'comprehensive studies', the GCSDM had found that many studies of sewage discharges had been carried out. However, the focus had been on meeting bacterial standards rather than integrated studies of inputs/water movement, nutrient enrichment, benthos and plankton response. It was also the case that studies varied greatly in methodology and degree of rigour. It was considered that there was a current and future requirement to establish guidelines for monitoring sewage discharges and their effects. As a first step, it was proposed that current practices should be reviewed. To this end, a Sewage Effluent Monitoring Task Team was established in 1994 with the following terms of reference:

- To consider sewage disposal (excluding combined sewage outfalls and intermittent discharges) into estuaries and coastal waters and its effects

- To propose monitoring and assessment techniques designed to measure these effects and establish causal relationships.

- To propose statistical and other standards for the conduct of monitoring.

- To gather information on the scope, extent and conduct of current studies and to report on these in the light of points one to three above

The original aim was to report on current monitoring by June 1995, and to produce a final report by the end of 1995.

(v) A further area of work considered for inclusion in the Group's terms of reference was Marine Litter. Litter is not explicitly included within the Oslo and Paris Commissions definition of pollution, although its implicit inclusion has been the subject of considerable debate. A Marine Litter Task Team was established at the end of 1995, to review the status of litter in the marine environment and to make recommendations for further appropriate actions.

The objectives of the Task Team were:

- To evaluate the extent of litter in the marine environment;

- To quantify, where possible in economic terms, the impact of litter on UK interests;

- To seek to identify options for controlling litter, where possible recommending a national agency which should take the lead on key issues; and

- To raise awareness about the problem of litter.

It was since agreed that the Task Team would report directly to the MPMMG, but should keep the GCSDM informed of its progress as appropriate.

During 1994 and 1995, the GCSDM met on six occasions to review the progress of its Task Teams.

3. PROGRESS BY THE TASK TEAMS

A list of the various Task Teams (and their membership) operating during 1994 and 1995 is given in Annex 2.

3.1 The Metals Task Team

The Metals Task Team was first established in 1988 and was in operation until 1994. The original remit of the Task Team was to review the monitoring of metal contamination at sewage-sludge disposal sites and to make recommendations to the GCSDM accordingly. The Task Team initially undertook a review of the methods used for the collection of sediments at sewage-sludge disposal sites and carried out a 4-phase intercomparison exercise for the analysis of metals in sediments. Its work was then extended to include the definition of sediment standards at disposal sites and later, sampling and analytical methods to be used at dredged material disposal sites.

A final report on the work of the Task Team was produced during 1995. The report will be published together with the final report of the organics Task Team, as a stand alone document, but the following is a summary of the main recommendations:

(i) Sediment samples for monitoring purposes at sewage-sludge disposal sites should be collected using a stainless steel grab and on return to the laboratory should be freeze-dried and sieved through a 63 µm sieve to extract the fine fraction. This fraction should then be digested using *Aqua regia* and the metals extracted, measured using the analyst's preferred method; generally atomic absorption spectrophotometry or inductively coupled plasma/mass spectrometry (ICP/MS).

(ii) To provide the necessary Quality Assurance (QA) data, it is recommended that internal reference material is analysed at the same time as the unknown samples.

(iii) Based on the results of the intercomparison exercises carried out by the Task Team, it is apparent that the laboratories concerned are all capable of producing analytical data on samples from disposal sites that would be of broadly comparable quality and therefore of a suitable standard to allow comparison across and between disposal sites. It is equally apparent that any new contractor would not necessarily achieve the same standard.

(iv) A set of 'Action Limits' is proposed for sediment quality at disposal sites, based on the equilibrium partitioning approach. Exeedance of these levels would trigger further study to assess their environmental significance rather than automatic management action.

(v) Sediment samples for monitoring purposes at dredged material disposal sites, should be collected using a stainless steel grab and on return to the laboratory should be freeze-dried and sieved through a 2 mm sieve and completely digested using hydrofluoric acid (HF). The metals extracted, should then be measured using the analyst's preferred method; generally atomic absorption spectrophotometry or inductively-coupled plasma/mass spectrometry (ICP/MS). The data should be normalised (aluminium or lithium being the preferred normalisers) using a technique such as a metal normaliser regression model with calculation of residuals about the regression line.

(vi) Disposal operations at dredged material disposal sites vary considerably. The Task Team have therefore recommended criteria to allow the selection of those sites likely to require monitoring for sediment metals. These proposals are for guidance only and not for strict adherence. At disposal rates >15 000 tonnes per annum, monitoring of sediment metals is recommended and at rates <15 000 tonnes per annum with no positive results from a biotest of the waste, no monitoring of sediment metals is required. It should be noted that this guidance would, in many cases, mean that monitoring of the disposal site is not required.

(vii) At dredged material disposal sites where monitoring is required, only site specific 'no change' standards should be used and measurements should be made in relation to a reference site.

Having completed all the tasks within its remit, the Metals Task Team was disbanded in early 1996.

3.2 The Organics Task Team

The Organics Task Team was another of the Task Teams which was established back in 1988 and it too continued to operate through until 1994. The Team's remit was to review procedures used in the monitoring of sewage-sludge disposal sites and to conduct suitable intercomparison exercises for the determination of trace organic compounds in sediments and also to define sediment quality criteria against which the compliance with environmental quality objectives (EQOs) could be assessed. Those compounds which appear on the Red List were given the highest priority, but other important contaminants, for example Polycyclic Aromatic Hydrocarbons (PAHs), were also considered. In 1993, the Team's remit was extended to determine whether the analytical guidelines and standards derived for sewage sludge disposal sites would be equally applicable for dredged material disposal sites and if not to recommend suitable alternatives.

A final report on the work of the Task Team was produced in 1995. The report will be published together with the final report of the Metals Task Team, as a stand alone document, but the following is a summary of the main recommendations:

(i) Field variance was shown to be highly significant (30%) on average and must be taken into account when planning monitoring strategies and interpreting survey data. Unless it can be well characterised it affects the ability to detect changes in the concentration of contaminants in sediments with any degree of confidence. The report provides some guidance on minimising field variance effects but further work is still required.

(ii) Steps should be taken to minimise the risk of sample contamination and/or sample losses during the collection and storage of samples for subsequent organic analysis. The recommended approach is set out in the report.

(iii) The results of several intercomparison exercises carried out by the Task Team, indicated a number of problems common to many laboratories. These included the use of inappropriate chromatographic columns, poor calibration, poor chromatography and inadequate sample clean-up. Protocols for sample preparation and analysis are recommended as an aid to analysts to help avoid the common pitfalls associated with the analysis of organic contaminants in marine sediments. The report also strongly recommends that all laboratories involved in monitoring marine sediments should participate in the National Marine AQC Scheme and that consideration should be given to making this a condition of all disposal licenses which are granted.

(iv) Marine disposal licences should contain a requirement for data to be reported on a congener-specific basis rather than a formulation basis. To maintain continuity both congener and formulation data should be provided initially, the latter being gradually phased out.

(v) The equilibrium partitioning (EP) approach was recommended as the most practicable scientific approach to deriving sediment quality criteria. This approach was used to define 'Sediment Action Levels' for a variety of List I and List II organic compounds. It is acknowledged however, that the approach does have a number of limitations associated with it (details of which are given in the report) and all users of the information should be fully aware of these. 'Sediment Action Levels' are at best interim values and there is an urgent need to carry out proper field evaluations. In addition, the use of 'Sediment Action Levels' alone is insufficient and the development of other approaches is required in order to derive sediment quality criteria for compounds whose behaviour cannot be predicted by the EP approach (e.g. PAHs).

(vi) The Task Team concluded that the sampling and analysis protocols recommended for monitoring sewage-sludge disposal sites would be equally valid for dredged material disposal sites. However, due to the physical disruptions caused at such sites, monitoring should be carried out immediately adjacent to the site. Where there is a risk that dredged materials may be contaminated with potentially toxic components, then such material should be monitored and risk assessments made prior to disposal, especially if the disposal is to a near-shore site. The 'Sediment Action Limits' proposed for sewage-sludge disposal sites should, in principle, also be valid for dredged material disposal sites. However, it has not been possible to verify this because licences do not currently contain any specification for the monitoring of organic compounds and thus little, if any, monitoring has been carried out.

Having completed all the tasks within its remit, the Organics Task Team was disbanded in early 1996.

3.3 The Sediment Bioassay Task Team

The Sediment Bioassay Task Team was established in 1992, to consider and recommend appropriate bioassays for use in evaluating dredged material prior to relocation. One of the main advantages of using bioassays is that they can be applied to samples of unknown, or incompletely known, composition and can provide an integrated assessment in a manner which can be difficult to achieve on a chemical-by-chemical basis. The terms of reference of the Task Team were to review the availability and applicability of current marine sediment bioassay procedures and to recommend an approach and methods which could be applied to pre-dredging assessment of potentially contaminated sediments.

The final report of the Task Team was submitted to the GCSDM in August 1995. It is intended that the report will be published as a stand alone document, but the following is a summary of the main findings and recommendations:

(i) Environmental hazard may arise in two ways as a consequence of the release of dredged material at a disposal site. Firstly, contaminants may be released to the water column, giving transient effects on water quality. Secondly, contaminants which do not desorb may give rise to more persistent biological effects in material which settles on the seabed. In general, contaminants released into the water column are less likely to accumulate at the dredging sites and are therefore less likely to present a hazard at the disposal site. It was therefore considered that the primary objective of a toxicological assessment of dredged material was to estimate the potential hazard to receiving sediments. Three strategies were considered: assessing the toxicity of elutriates using standard acute aqueous-phase bioassays; assessing the toxicity of the whole dredged sediment using acute lethal or sub-lethal solid-phase bioassays; and assessing the toxicity of receiving sediments using acute lethal or sub-lethal solid phase bioassays.

(ii) Elutriate tests can provide useful data on the behaviour of sediment-associated contaminants during the disposal process, but are unlikely to provide information on the potential effects of contaminants retained on the solid phase and deposited on the seabed; they are not therefore, suitable as a primary tool for assessing suitability for disposal. The most suitable approach to testing dredged material, is one which incorporates both elutriate and solid-phase testing. This will provide the most comprehensive information on the behaviour and availability of contaminants (both known and unknown) in the material.

(iii) A number of existing aqueous-phase marine toxicity tests were considered to be suitable for testing elutriates. The most commonly used test species are: *Tisbe battaglia, Acartia tonsa, Crassostrea gigas* embryos and marine algae (e.g. *Skeletonema, Phaeodactylum*). All of these tests are already routinely conducted in a substantial number of laboratories and are defined by well tested and widely-recognised guidelines or protocols. All are tests of short (72 h) duration, with broadly similar sensitivities to a range of toxicants.

(iv) Two solid-phase bioassays were currently considered to meet the Task Teams requirements. These are procedures that use *Corophium* and *Arenicola.* Both techniques are capable of producing results from field sediment assays which are acceptably precise and consistent. Both methods have published guidelines (e.g. PARCOM, ICES) and have been ring-tested in a variety of contexts with acceptable results. Both methods are readily applicable to the direct bioassay of dredged material and the testing of sediment samples from the receiving environment and will thus enable the comparison of pre- and post-disposal effects in the same units of toxicity.

(v) For both methods the end point is mortality; a secondary endpoint in the *Arenicola* assay is a sublethal physiological response based on the rate of production of faecal casts on the sediment surface. A recommendation is to use the *Corophium* and *Arenicola* acute bioassay methods as initial tools for biological assessment of dredged material. In the medium to long-term, consideration should be given to the further development of the *Arenicola* sublethal assay and the development of comparable endpoints with crustaceans and molluscs.

(vi) The report does not recommended reliance on a single test method due to the risk of 'false negative' observations; the use of a 'battery' of tests is recommended.

(vii) Assessment criteria (pass/fail) are, by necessity, largely arbitrary. Elutriate toxicity data should be interpreted in the light of estimates of mixing and dilution of the dredged material following disposal and in terms of the size of the defined mixing zone. For solid-phase dredged material tests, it is suggested that an initial criterion of 40%-50% mortality is adopted, but that this be modified in the light of the results of post-disposal solid-phase tests on the receiving environment.

3.4 The Comprehensive Studies Task Team

The Comprehensive Studies Task Team (CSTT) was established in June 1992 in response to a request by the DoE, for the GCSDM to produce guidelines on the Comprehensive Studies required to demonstrate that an area qualified to be regarded as a 'less sensitive' area under the terms of the Urban Waste Water Treatment Directive 91/271/EEC (European Communities, 1991). The Task Team submitted a final report to DoE in August 1993, the recommendations of which were adopted by DoE and have since been followed up by the Water Industry. It was recognised that not all of the proposed techniques were fully validated and that they may be subject to development, consequently, there was a need to review the report to validate the standards and methods recommended. It was agreed that the first review should take place after 18 months.

During this time several studies were completed and a Comprehensive Studies workshop was organised by the Task Team to enable users of the report to discuss the experience gained and the problems encountered in applying the methodology. It became evident that whilst users had found the report extremely useful, there were a number of issues that were unclear and had caused confusion. In the light of this information the Task Team produced a revised version of its original report in order to clarify those matters which were causing confusion. It was emphasised, however, that the criteria upon which judgements should be based remain unchanged.

On of the main changes to the CSTT report is the way in which the effects on the benthos can be assessed. Since the first version of the report, the empirical relationships between benthos changes and mass emission rates of suspended solids have been tested on some UK sewage discharges. It has been found that the relationships have over predicted the benthic effects. Although this approach could still be used to predict the worst case scenario, a new model recently developed is likely to give more realistic predictions.

A model has been developed which predicts organic carbon deposition on the seabed and associated changes in soft sediment benthic communities. This model is called BenOss (Biological effects and organic solids sedimentation) and has been published by UK Water Industry Research Limited (UKWIR, 1996). BenOss will be reviewed and improved as further data from comprehensive studies become available. The model has been developed to the point where it may be used with some confidence to assess the need for large investments in effluent treatment. As it is one of the few quantitative predictive methods available for benthic communities, its use is recommended as part of comprehensive studies.

The suite of models developed predicts the amount of suspended solids (organic carbon) accumulating in the near vicinity of domestic sewage outfalls in terms of (mass of carbon) (unit area)$^{-1}$ (time)$^{-1}$. A grid generation sub-programme allows the user to generate an area of interest from a master grid of a given site. A Lagranian particle tracking model has been used to simulate settling of the sewage particles and their movement through the water column. For this part of the model site specific information is required, such as sewage effluent information and current velocities in the area. The model then simulates resuspension and carbon degradation once a particle has been deposited on the bed. The effect of the organic carbon on the benthic communities is then predicted by a benthic module.

The model has been developed so that it is not site specific and has a variety of features which can be used depending on the site in question. The long sea outfall of Edinburgh sewage treatment works has been used as a study site during model development. As part of the model validation a fluorescent tracer study was carried out. Even though the Edinburgh sewage outfall has no, or very little, effect on the benthic communities, the tracer study showed incorporation of particles into the sediment. Long term accumulation or cyclical effects may therefore occur and monitoring of the benthos should be carried out.

This predictive tool should be used to complement, rather than replace, other methods used to assess benthic communities. This model will not replace the need for sampling the benthos, but should aid in assessing the likely differences resulting from primary and secondary treated effluent.

The revised edition of the report was published in 1996. The guidance offered may be subject to future reviews in the light of further experience.

3.5 The Dredged Material Disposal Monitoring Task Team

There is at present no statutory requirement in the UK to monitor dredged material disposal sites. As the UK is a signatory to OSPARCOM, current procedures tend to be based on the OSPARCOM guidelines. Long-term monitoring is currently undertaken by MAFF at approximately ten sites and this has provided information and understanding about processes against which applications for licences are judged.

Disposal sites vary in a number of aspects including, the nature volume and rate of dredged material deposited, the characteristics of the receiving water and the interactions between the two. These factors will determine the need, if any, for monitoring at a particular site. The Task Team agreed that there was a need to derive a method of evaluation in order to determine whether or not monitoring was required at a specific site and if so the type and scale of such monitoring. The Task Team agreed that there was a need to derive a method of evaluation in order to determine whether monitoring was required at a specific site and if so the type and scale of such monitoring. It was considered that a matrix approach with scoring and weighting which could take into account the interactions of identified parameters for an individual site offered a good basis for deciding the extent of possible monitoring.

The Team has developed a tabular, flow chart approach which allows cessation of further input at various stages. The tables allow the input of information relating to:

- characteristics of the dredging operation and the dredged material
- characteristics of disposal site
- characteristics of the far-field site
- use of the disposal site and the far-field site
- potential for movement of material
- potential for impact
- likelihood of impact
- perceived interests
- decision guidelines.

The tables can be used to consider whether there is a concern about the operation, e.g. legislative, scientific or public, and if not, no further action will be taken. If there is concern, this will be identified and the impacts of concern, whether at the disposal site or in the far-field, will be reviewed taking account of the method of disposal, the material type, existing sediments, hydrography and movement potential.

The next stage, on which the Task Team is currently working, will be the formation of recommendations relating to the type and methods of monitoring to be used. The methods likely to be selected are expected to be already generally well established and previous work by other task teams will provide a useful basis from which to start.

3.6 The Sewage Effluent Monitoring Task Team

The Task Team held its first meeting in November 1994. It was agreed with GCSDM that combined sewer outfalls would not be included in the initial review, as the enormous variance in the frequency of operation, volume of discharge and impact would make it difficult to assess their effects along with those of continuous discharges.

The first course of action by the Task Team was to carry out an appraisal of current monitoring effort by means of a pro-forma questionnaire. Respondents were asked to provide information on the monitoring carried out on selected, typical discharges in each of 5/6 defined categories in their area.

This information was gathered and collated and formed the basis of the Task Team's first report, together with details on the range of possible effects of discharges of sewage on the environment. The conclusions of this first report were that while a wide range of monitoring techniques were being used, their application was very inhomogenous. Bathing waters microbiology, the National Monitoring Programme and the Urban Waste Water Treatment Directive comprehensive studies provided isolated islands of consistency. This report was forwarded to the GCSDM at the start of 1996, at which time good progress was being made with the draft final report. This final report recognised that the effects of any sewage discharge are critically dependent on the nature of the receiving water and the size of the discharge. A single optimum sampling strategy is therefore unrealistic. A section of the final report therefore comprises a series of examples of what could be regarded as best practice, backed up by more general guidelines to apply in specific circumstances, such as when an effluent contains significant amounts of an EC List I or UK Red-listed substance.

The effects of any sewage discharge will be critically dependant on the nature of the receiving water and the size of the discharge. A single optimum monitoring strategy is therefore unrealistic. A more helpful approach is likely to be a series of examples of what could be regarded as best practice, backed up by more general guidelines to apply in specific circumstances, e.g. when an effluent contains any, or significant amounts of, an EC List I or UK Red-Listed substance.

3.7 The Marine Litter Task Team (MaLiTT)

In fulfilment of its objectives, the efforts of the Task Team have focused on the collation of information and the preparation of a draft report, which will form the basis for a future consultation document. It is proposed that the first consultation round will call for the input of any additional information and further ideas.

In November 1996, various members of MaLiTT are due to attend/chair a Workshop *Litter in the Aquatic Environment* which will serve as a useful forum to debate some of the issues raised by the Task Team's work. It is intended that the first draft of the consultation document will be finalised shortly after this Workshop and will seek the views and consensus of those involved in the issue of litter in the marine environment.

4. REVIEW OF MONITORING AT SEWAGE-SLUDGE DISPOSAL SITES DURING 1993 AND 1994

4.1 Introduction

This section assesses whether the various monitoring programmes meet the goals described in the first report of the GCSDM (MAFF, 1989). It considers examples of monitoring undertaken in 1993 and 1994.

Table 1 lists the sewage-sludge disposal sites surveyed in 1993 and 1994 (see Figure 1 for locations) and the techniques used. Some areas are surveyed only every second or third year therefore no samples were collected during 1993 or 1994. This report aims to show examples of monitoring and therefore not all of the work carried out is described.

4.2 EQO: Protection of the ecosystem to ensure that it is typical for the type of area concerned

In its first report, the GCSDM suggested that suitable indicators of alterations in environmental quality were the extent to which benthic diversity changes and the extent to which contaminant concentrations in sediments and water are maintained within appropriate set standards. The extent to which these criteria were met at the various disposal sites in 1993 and 1994 is reviewed below.

4.2.1 Tyne

A sewage-sludge disposal site located some 10 km north east of the River Tyne (see Figure 2) has been in use for about 15 years, and presently receives about 500 000 wet tonnes per annum of sludge arising from primary treatment of sewage of largely domestic origin from the Newcastle area. Spatial surveys of the environmental effects of the operation are conducted biennially by Northumbrian Water in fulfilment of 'self-monitoring' obligations (see below). As a complement to this work, MAFF has conducted a more limited annual programme of benthos sampling at representative stations (see Figure 2), which has now continued for a sufficiently long period to allow a more detailed evaluation of temporal trends to be made.

Table 1. Summary of techniques used in surveys at sewage-sludge disposal sites in 1993 and 1994

Area/Authority	Sediment			Benthos epibenthos	Fish/shellfish sampling	Litter assessment	Underwater video
	Metals	Pesticides/ PCBs	Microbiology				
Tyne							
MAFF	*			*		*	
Northumbrian Water	*	*		*			
Humber							
MAFF					*		
Yorkshire Water	*	*					
Roughs Tower							
Anglian Water	*	*					
Barrow Deep							
MAFF	*			*		*	
Thames Water	*	*	*	*	*		
Nab Tower							
Southern Water	*	*	*				
Bristol Channel							
MAFF						*	
Exeter							
Welsh/Wessex Water	*	*		*		*	
Liverpool Bay							
MAFF	*					*	
North West Water	*	*		*			
North Channel							
DoE(NI)	*		*	*			*
Garroch Head							
SRC							
SOAEFD					*		
Bell Rock							
FRPB/LRC							
SOAEFD	*		*		*		
St Abbs Head							
FRPB/LRC							
SOAEFD	*		*		*		

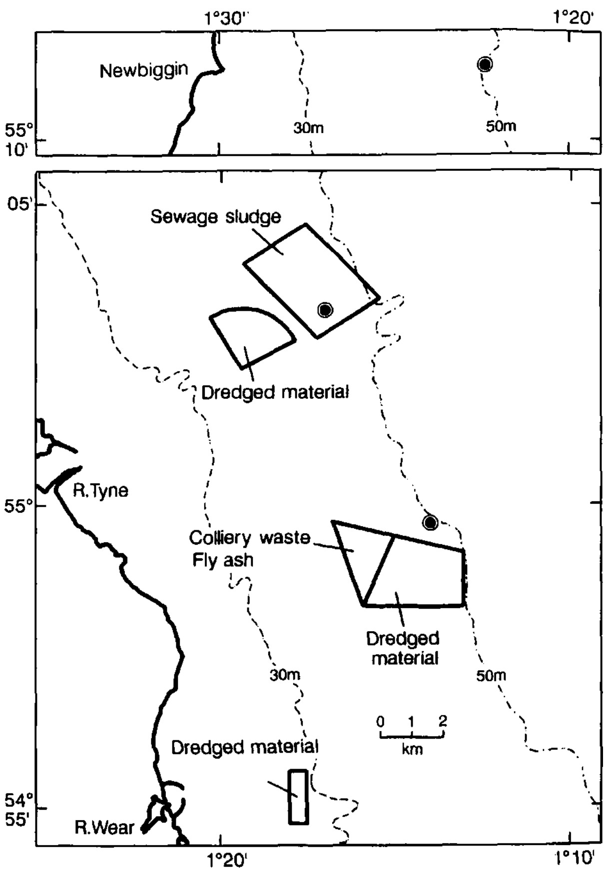

Figure 2. Location of benthic stations off the Tyne estuary

Earlier results from biological monitoring of this area were reported by Rees *et al.* (1985, 1992). Evidence was found of marginal enrichment of benthic populations in the immediate vicinity of disposal, accompanied by elevations in physical indicators of sludge contamination, notably tomato pips. These changes were judged to be within acceptable bounds, when assessed against proposed 'Environmental Quality Standards' at sewage-sludge disposal sites (Rees and Pearson, 1992; MAFF, 1992 and 1993(b)).

Figure 3(a) shows that densities of the macrofauna retained on 0.5 mm mesh sieves were generally significantly higher at the disposal site. Numbers of taxa also tended to be somewhat higher at the disposal site compared with those at the northern site: Figure 3(b), but the differences were not usually significant.

Although not sustained over all years, there is some evidence of synchronicity in changes over time between sites, for example in densities at the disposal site and at the southern reference site between 1986 and 1990 (Figure 3(a)). When the data for each station are summarised in the form of the Shannon-Wiener diversity index (Shannon and Weaver, 1949) and its complementary index of 'evenness' (a measure of the apportioning of individuals among the species), changes are very clearly synchronous with time (Figure 3(c) and (d)). This

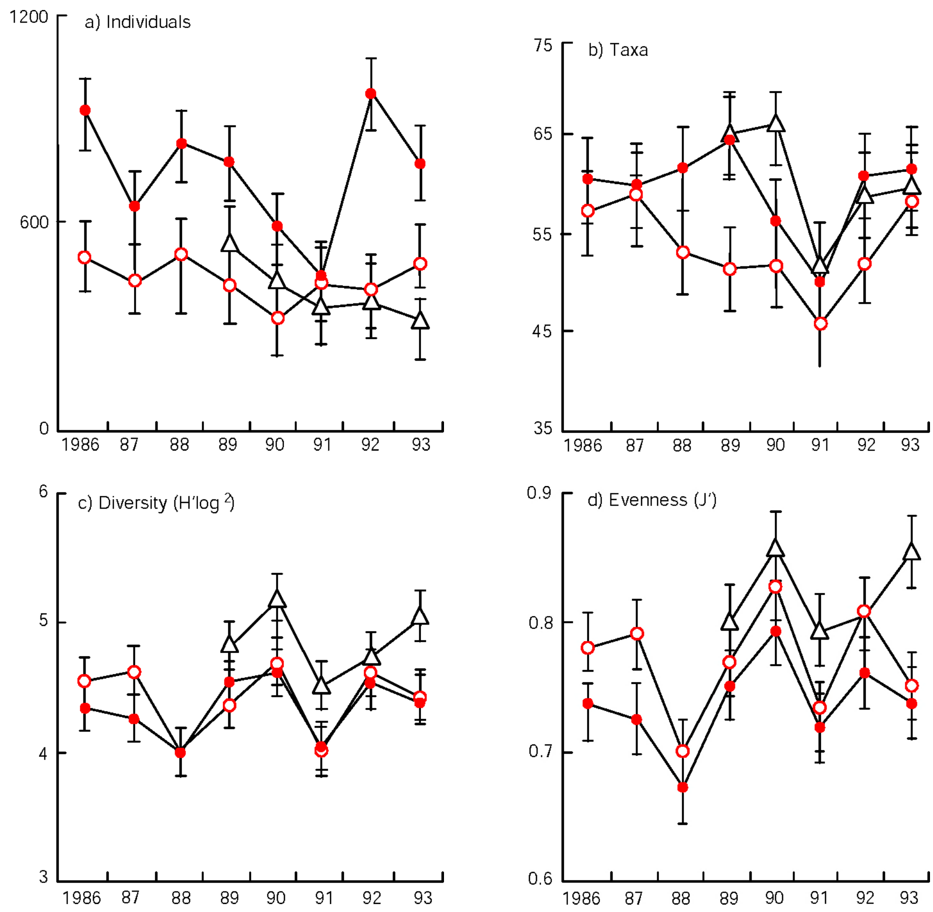

Figure 3(a-d). Trends in univariate measures for the macrofauna off the Tyne estuary. Data are expressed as means per 0.1 m² with 95% Least Significant Intervals. (Closed circles: sewage-sludge disposal site; open circles: southern reference site; triangles: northern reference site)

appears to indicate similarity in the influence of natural environmental factors across all sites, and hence provides support for the validity of between-site comparisons of trends.

Values of diversity and evenness indices are generally highest at the northern reference site. There are no significant differences in diversity at the disposal site and southern reference site; marginally lower values of evenness at the disposal site are consistent with earlier inferences concerning an enhancement in numbers of common species in response to sludge disposal.

Guidelines for assessing the acceptability of benthic changes in response to sewage-sludge disposal have been applied to comparisons between the disposal site and, respectively, the northern and southern reference sites, in Figure 4(a)-(d). As previously reported (Rees and Pearson, 1992), for the comparison between the disposal site and the southern reference site, ratios of abundance significantly in excess of zero remain indicative of marginal enrichment but, as for the ratio of numbers of taxa, remain within acceptable bounds. This is also true for the comparisons between the disposal site and northern reference site over a shorter period.

A 'Quality Standard' for benthos aimed at maintenance of the *status quo* at reference stations (MAFF, 1993(b)) requires the derivation of a 'baseline' value from at least the first three years for which comparative data are available. The scope for application to Tyne data is presently limited, as sampling at the northern reference site only commenced in 1989. Even so, an examination of changes in faunal statistics showed that they presently remain within the set boundaries.

In the case of metals data, the method of ensuring that only acceptable changes occur had not been running for long enough for assessment to be made on the basis of the present data. At the time of the current survey year's data, a baseline with which to compare annual monitoring data had been established, but no annual data had yet been collected.

4.2.2 Thames

Sewage sludge from the London area has been disposed of at two sites in the outer Thames estuary for about a hundred years. Since 1967, a location in the Barrow Deep has been used (Figure 5), and this presently receives about 4 million wet tonnes per annum of sludge arising from secondary treatment of sewage.

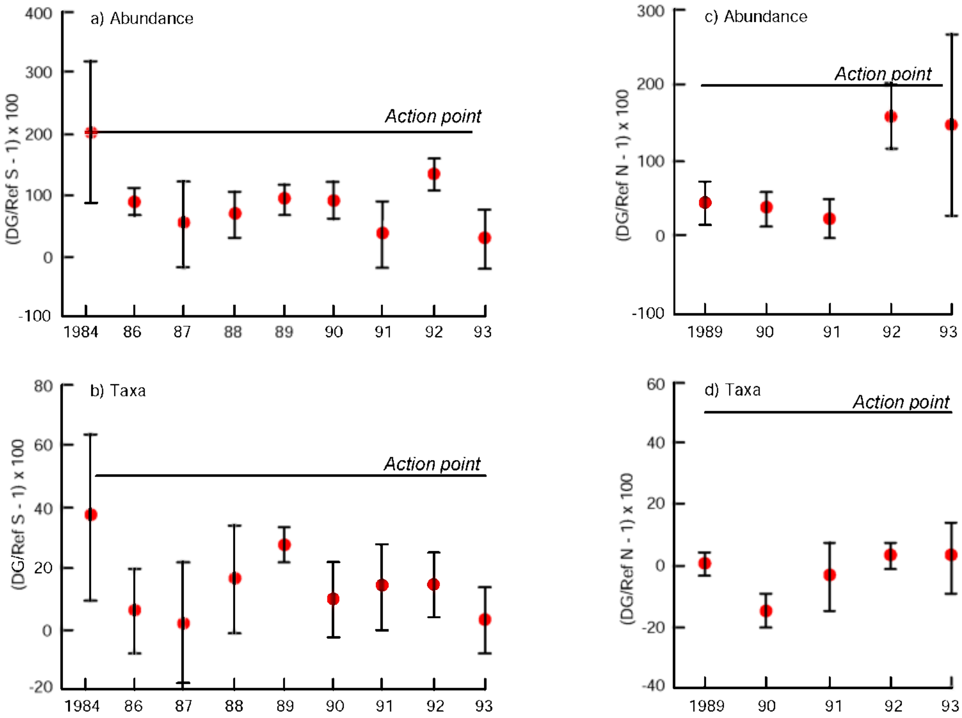

Figure 4(a-d). ***Means with 95% confidence intervals for pairwise comparisons of univariate measures at the Tyne sewage-sludge disposal site; (a-b): disposal site and southern 'reference' station; (c-d): disposal site and northern 'reference' station. (Proposed 'Action Points' for acceptable change are superimposed***

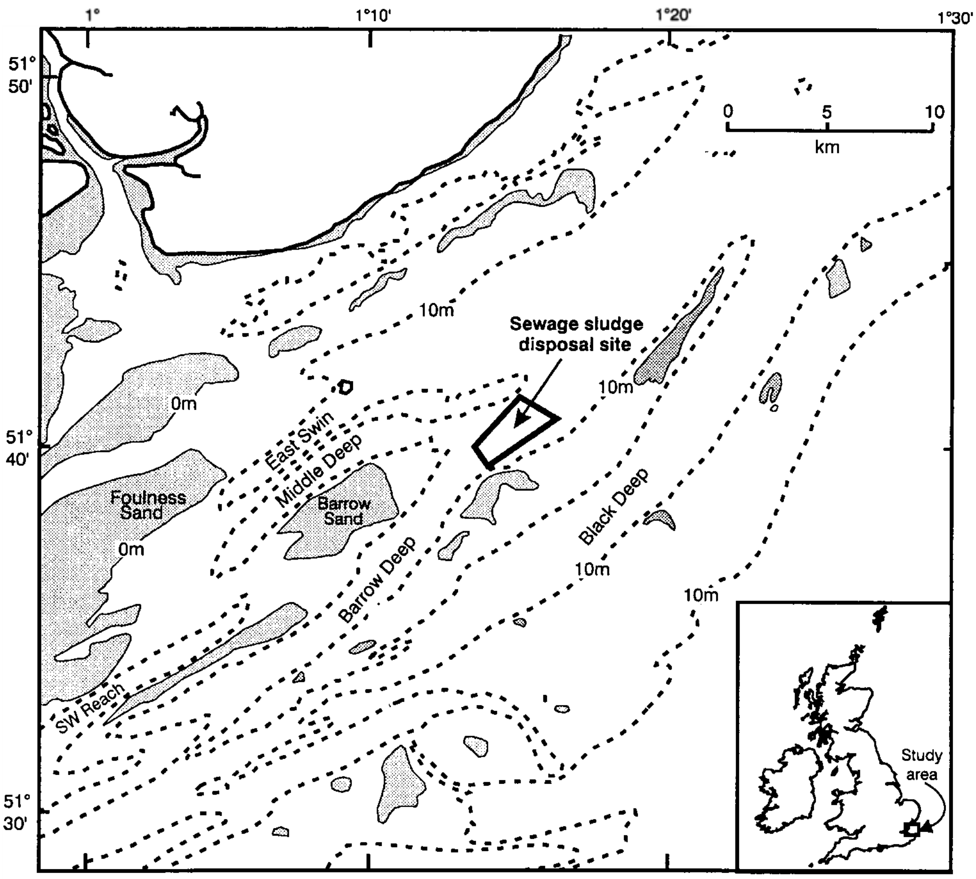

Figure 5. ***Thames Estuary: location of sewage-sludge disposal site***

As part of a 'self-monitoring' programme by the Thames Water Company, more details of which are given below, compliance with proposed 'Action Points' for acceptable change arising from sewage-sludge disposal (MAFF, 1993(b)) was tested by means of comparisons between three clusters of 5 stations located, respectively, within, just outside and at distance from the sphere of waste influence. These 'Action Points' were derived from conditions at quiescent areas in receipt of organically rich wastes and hence there remains some doubt about their applicability to dispersive areas. Furthermore, the limits assume that the primary effect of sewage-sludge disposal will be organic enrichment, and that any such effect will be at an early stage. The latter seems a reasonable assumption, based on previous investigations at the Thames site. The outcome of compliance-testing for the primary variables (total abundance, numbers of taxa and biomass) in 1990 and 1993 showed that these remained within prescribed limits (Figure 6).

4.3 EQO: Maintenance of the receiving environment without distinguishable change

In its first report the GCSDM explained that compliance with this objective would be judged by the extent to which contaminant concentrations and the benthic fauna at and around the disposal site, had remained unchanged.

4.3.1 Tyne

The Tyne disposal site (see Figure 2) currently receives about 500 000 wet tonnes per annum of sewage sludge arising from primary treatment of sewage which is largely domestic in origin. The site has been in use for about 15 years, and is located above muddy sand sediments in waters of about 50 m depth.

A comprehensive 'self-monitoring' survey was conducted on a sampling grid (Figure 7) in 1993 by Northumbrian Water, and included studies of sediment chemistry, physical and bacterial tracers of sludge and the benthic fauna. (Video surveys of the seabed for assessment of the epifauna and litter content were conducted in 1994).

The distribution of faecal bacteria and tomato pips showed higher counts at and immediately to the south of the sewage-sludge disposal site. Beyond this, counts fell off rapidly, although high counts of faecal bacteria were found near to the Tyne mouth, arising from contamination of outflowing estuary waters. These results accord with earlier MAFF findings (Rowlatt *et al*., 1989), and confirm at least a short-term tendency for settling of significant quantities of sewage-derived particulates in the immediate vicinity of the disposal site.

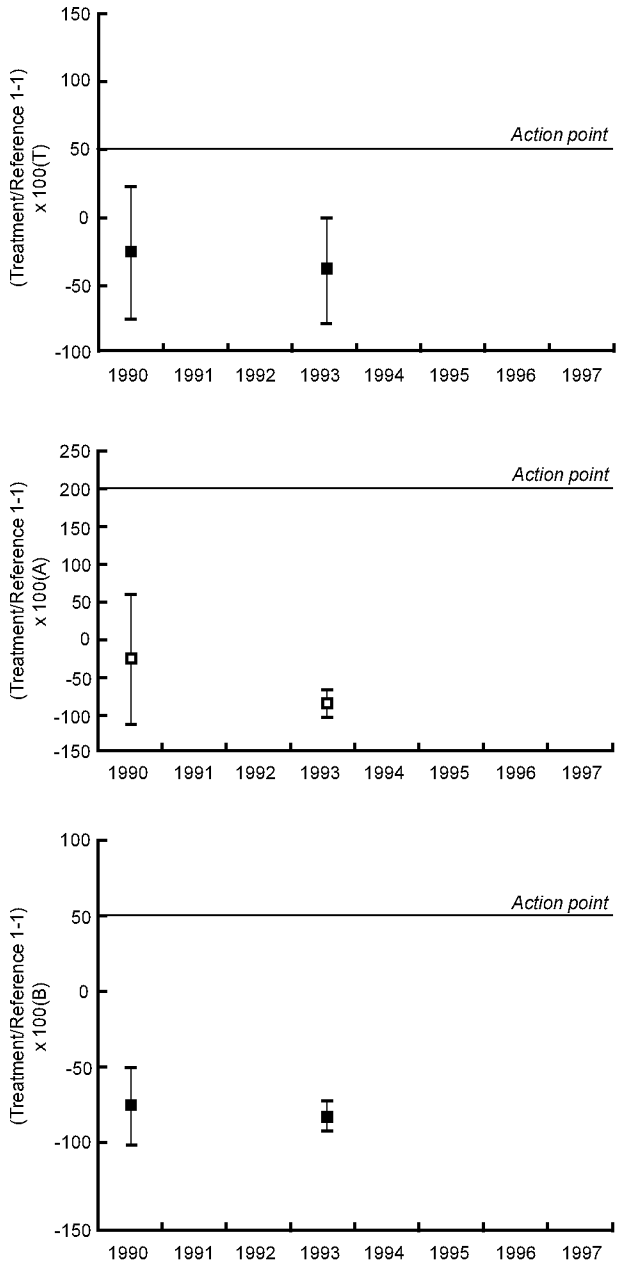

Figure 6. ***Thames sewage-sludge disposal site. Means and 95% confidence intervals for pairwise comparisons of the primary variables. (Proposed 'Action Points' for acceptable change are shown)***

The benthic fauna was relatively diverse, typically with 40-50 taxa retained on a 1 mm mesh sieve. Plots of univariate measures (e.g. total abundance, range of taxa) provided no clear evidence of the effects of sewage-sludge disposal, although higher densities of organisms tended to occur in the immediate vicinity of the disposal site. The outcome of multivariate analysis highlighted the relationship between the distribution of common species and sediment type, but provided little further insight, which might in part be a result of the rather severe criterion for truncating the data matrix prior to analysis, resulting in only 36 (of 218) taxa being included.

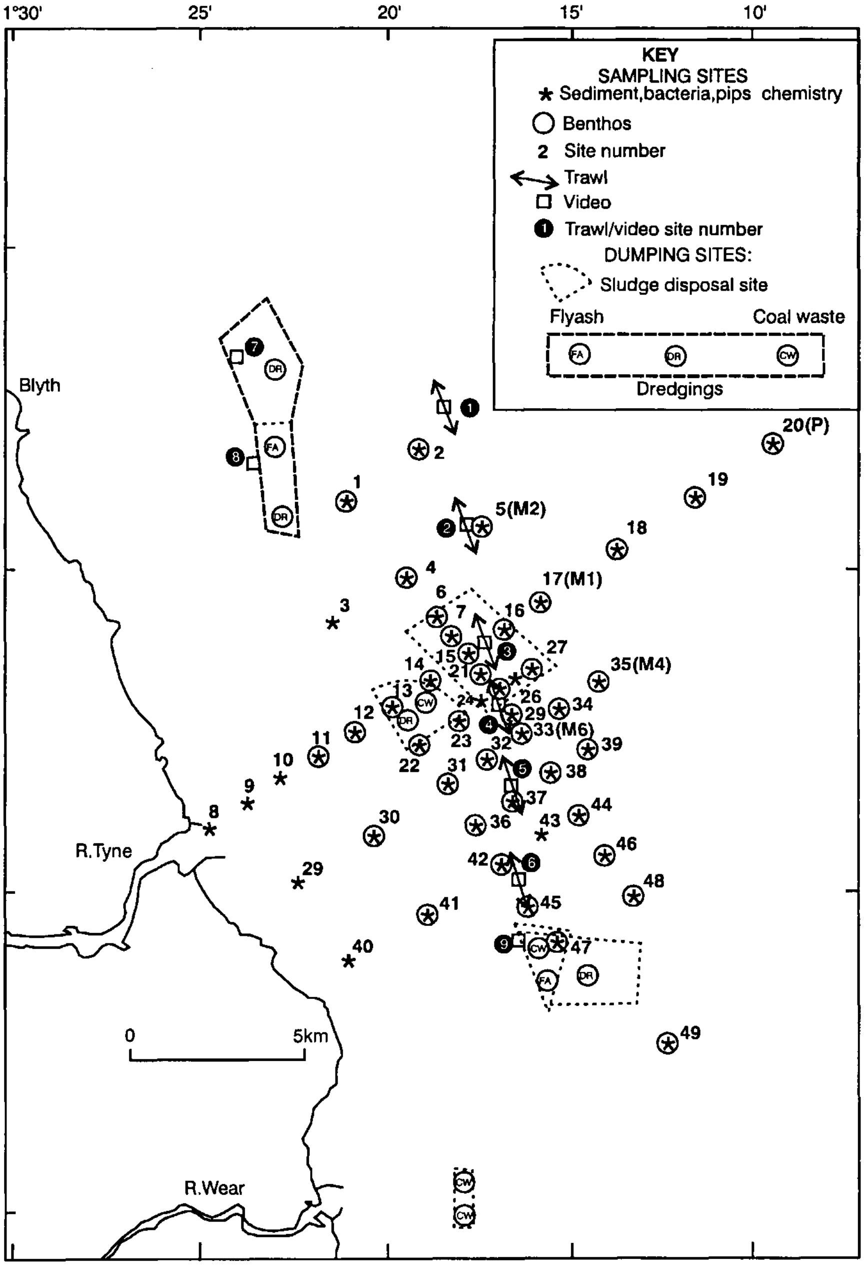

Figure 7. Tyne: location of sampling sites

A comparison of trends in the data over time (1989, 1992 and 1993) was complicated by differences in the month of sampling between years. Despite this, there appeared to be an increase in the densities of some species more characteristic of sandier sediments.

Overall, it was concluded that no gross effects of sludge disposal were apparent, but that subtle changes in the composition of the fauna in the immediate vicinity of the disposal ground might be consistent with the effects of mild organic enrichment. This conclusion accords with studies at 'representative' sites off the Tyne, reported by Rees *et al.* (1992).

When averaged over seasons in 1993 and 1994, both the variety and densities of taxa caught in 2-m beam trawls were elevated in the vicinity of sewage-sludge disposal; this was particularly marked for crustacean densities. An examination of seasonal changes among sites showed that these remained fairly muted.

Volumes of litter retained in the trawl declined significantly after 1990, which appeared to correlate with the installation of screens at the Howdon Sewage Treatment Works (STW) (Newcastle).

Video surveys have been applied to good effect in assessing the frequency of occurrence of larger litter items, and of the conspicuous epifauna. Images were obtained with a towed sledge at several sites in June 1994. Sewage-derived litter was evident at many of these, and highest concentrations occurred in the vicinity of the sewage-sludge disposal site. This gives rise to some concern that the screening installed at Howdon STW is not fully effective in the removal of larger waste items. Other items of rubbish were elevated near to a dredgings disposal site, and are assumed to have arrived *via* the dredging vessel from estuarine sources.

Variability in counts of some conspicuous species (e.g. the sea-pen *Virgularia*) between years suggest a possible influence of commercial trawling activity. The data provide no evidence of any adverse effects arising from sludge disposal, although somewhat elevated counts of hermit crabs in the vicinity of the disposal site might suggest increased food availability, an observation which is supported by beam trawl sampling for the epifauna.

4.3.2 Nab Tower (Isle of Wight)

Located at some 30m depth east of the Isle of Wight (Figure 8), the disposal site is the recipient of both sewage sludge and dredged material. Some 260 000 and 790 000 wet tonnes per annum, respectively, were disposed of to the site in 1994. The location is also notable for extensive aggregate dredging activity in the near vicinity. Monitoring data therefore require careful interpretation, given the potential to confound effects arising from a variety of man-made causes.

The disposal site is aligned in a NE/SW direction (see Figure 8), approximately conforming with the direction of tidal currents in the vicinity.

Substrates in the general area are characteristically coarse in nature, and hence not well suited to traditional grab sampling. For the macrofauna, a Box dredge (i.e. a modified Anchor dredge with a flat plate replacing a bag at the rear) was deployed at 19 stations, generating 'semi-quantitative' data which were nevertheless adequate for identifying the main trends across the sampling area. The data were analysed using a variety of univariate and multivariate techniques.

Overall, the fauna was characterised by a combination of infaunal and epifaunal species, in line with the distribution of particle sizes, which showed distinct modes at the coarser and finer ends of the size spectrum. Three main assemblage types were identified. The first, represented by only 3 stations, was located at and to the north east of the disposal ground, and was characterised by an impoverished fauna : on average, about 21 species per sample were found. The second assemblage consisted of stations aligned along a SW/NE axis, i.e. in the central part of the sampling grid. These were characterised by higher densities and numbers of species (on average, 43 per sample), and dominance by the slipper limpet *Crepidula fornicata.*

The third assemblage type was confined to the east and west of the sampling area, where the concentration of fine material was generally lower than elsewhere. These substrates supported the highest densities and numbers of species (88 per sample, on average).

Patterns in the distribution of benthic assemblages were thus consistent with the effects of disposal activity both

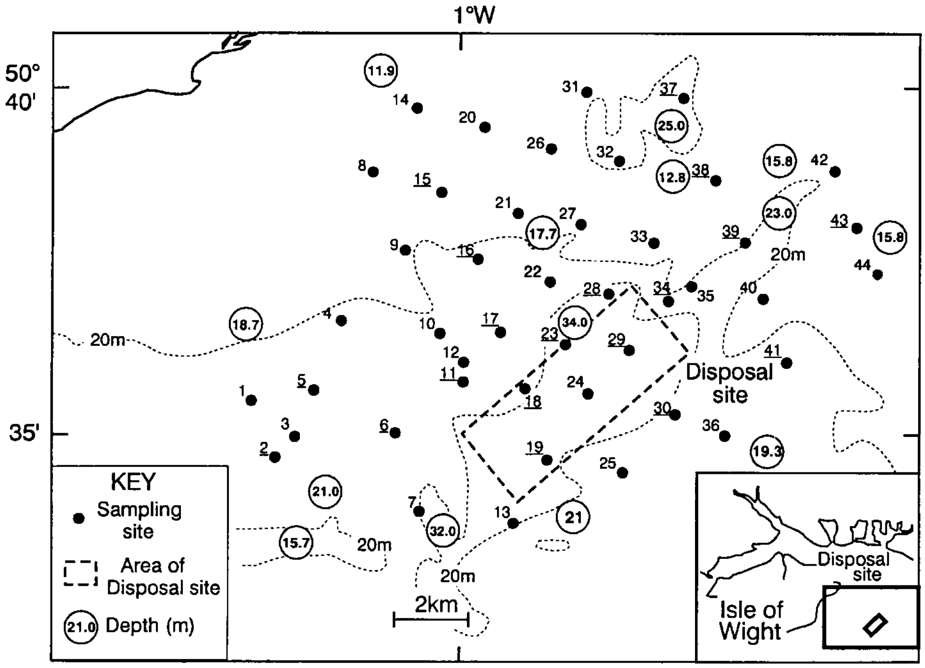

Figure 8. ***Nab Tower disposal site, along with depth contours and station positions. Stations at which benthos samples were collected are underlined***

at the site itself, and peripherally in line with the tidal axis. Observed changes away from the disposal site may arise from the physical consequences of a relatively high near-bed suspended solids load generated by the dispersal of the finer components both of dredgings and, to a lesser extent, sewage-sludge deposited at the site.

Surveys of the sediment quality at the Nab Tower site were carried out in 1993 and 1994. The following discussion gives a broad outline of conclusions from the former but more detail from the latter. It also demonstrates the difficulty in ascribing effects to a particular cause at a site where more than one waste is deposited.

1993

The 1993 Nab Tower survey, revealed consistent patterns of accumulation of certain contaminant groups. Contaminants found at elevated concentrations, were observed at sites on a south-west - north-east axis, running across the disposal site.

Sediments taken from these sites contained elevated concentrations of fine material and some metals (especially mercury). Some metals were at concentrations above the GCSDM action levels. This may indicate contamination as a result of sewage sludge disposal. This was supported by the distribution of bacterial indicators (faecal streptococci and *Clostridium* spp.). However, consideration of the organic content, and in particular the C:N ratios, indicated that the dredged material deposited in the area is dominant. Only one site was found to have C:N ratios indicative of sewage derived material, and this was to the west of the disposal ground. Since the dispersion of sewage sludge across the area must be more extensive than this suggests, it may be possible that the organic content of the dredged material is masking the presence and distribution of the sewage sludge.

The distribution of contaminants seemed to reflect the quantity of material deposited, together with the main water movements, in this area. The exact origin of these contaminants is difficult to ascertain, given the presence of both Solent Harbour dredged material, and sewage sludge. Some indication that these materials settle at different rates, resulting in slightly different accumulation patterns, was evident. The particulate sewage matter is probably settling at slower rates than the Harbour dredged material, resulting in the wider distribution along the southwest to north-east axis, which was particularly noted for sewage variables such as the bacteriological indicators.

Thus, the exact effects of the sewage sludge are difficult to determine as other waste is deposited at this site. As no sludge tracer study has ever been attempted, the exact dispersion of the sludge is unknown.

1994

The concentrations of heavy metals within the Nab Tower sediments in 1994 were generally low across much of the area. However, an area of accumulation was evident in the immediate vicinity of the disposal site (Figure 9). This was the case for all 7 metals considered (Cd, Cr, Cu, Hg, Ni, Pb, Zn) although the proposed action limits set by the GCSDM were exceeded at only a few sites. The exception to this was lead, where the proposed action limits were exceeded at 14 of the sites sampled, extending across much of the area.

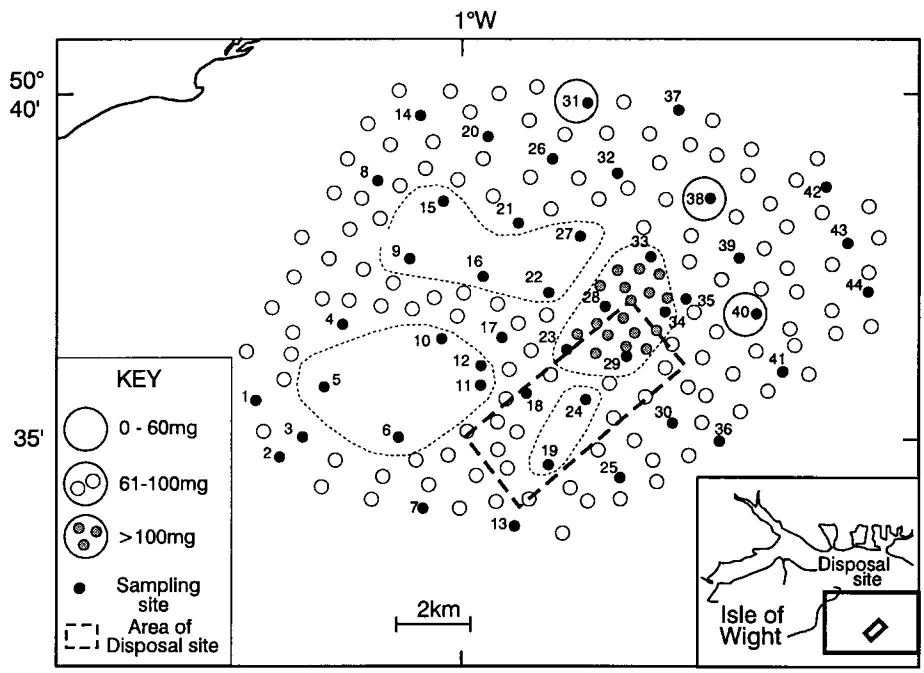

Figure 9. Nab Tower 1994 contour map showing distribution of zinc

Due to the uncertainty concerning the source of the contamination, dredged material or sewage sludge disposal, no action has yet been possible. Sediment monitoring is continuing and action will hopefully then be clarified. This highlights a problem with action levels, namely associating cause and effect. This is of great significance as it may have financial implications for disposal operators.

Evidence for the existence of metals accumulation within sediments outside the immediate vicinity of the disposal ground was slight, although some sites to the north/north east of the disposal ground contained slightly elevated concentrations of certain metals, such as lead and mercury, which may suggest that some far field deposition occurred. However, the slight accumulation noted in this area may represent the influence of the sedimentation of contaminants from the Solent. It should be noted that the concentrations of all metals recorded from the Nab Tower sediments during the 1994 survey were equivalent to or at levels less than those recorded from other sludge disposal sites around the UK coast (MAFF, 1993(b)).

Areas of far field accumulation of organic carbon were evident in the south western and north eastern corners of the survey area, as well as in the immediate vicinity of the disposal site (Figure 10). No discernible patterns of distribution were evident for organic nitrogen.

Consideration of the C:N ratios indicated a clear distribution pattern in the immediate vicinity of the disposal ground and extending north from this point, with values in the range 8:1 to 12:1 (Figure 11). This range is thought to represent the values typical of surface sediments, whilst ratios of <8:1 (present at the majority of sites sampled) may represent values typical of deposited sewage sludge (Norton *et al.*, 1981). However, the combination of sewage sludge, with high nitrogen levels, together with maintenance dredgings, typified by high carbon levels, as is the case at the Nab Tower disposal site, may serve to mask the exact origin of the sediments. It is therefore difficult to make assumptions about the apparent area of accumulation, suggested by the C:N ratios, extending to the north east from the disposal ground. However, it may be that a combination of maintenance dredgings and sewage sludge cause some change in the balance of organic matter within the sediments across much of the Nab Tower survey area.

Many of the organic micropollutants measured in the Nab Tower sediments, particularly PCBs, were at concentrations below the limit of detection. Amounts of the various OCPs were present at all of the 20 sites sampled, but were found at their greatest concentrations at sites in the vicinity of the disposal site. The levels of PCBs recorded at the Nab Tower would indicate that contamination was not detectable within the sediments (MAFF, 1993(a)). The origin of the contaminants identified was difficult to assess since many were present in both maintenance dredged material and sewage sludge.

The bacteriological variables measured indicated the presence of far-field depositional areas both to the north and south extents of the survey area, as well within the immediate vicinity of the disposal site (Figure 12). In particular, the distribution of the long term bacterial indicator, *Clostridium* spp., suggest the presence of depositional areas extending, north from the disposal site for several kilometres (Figure 13).

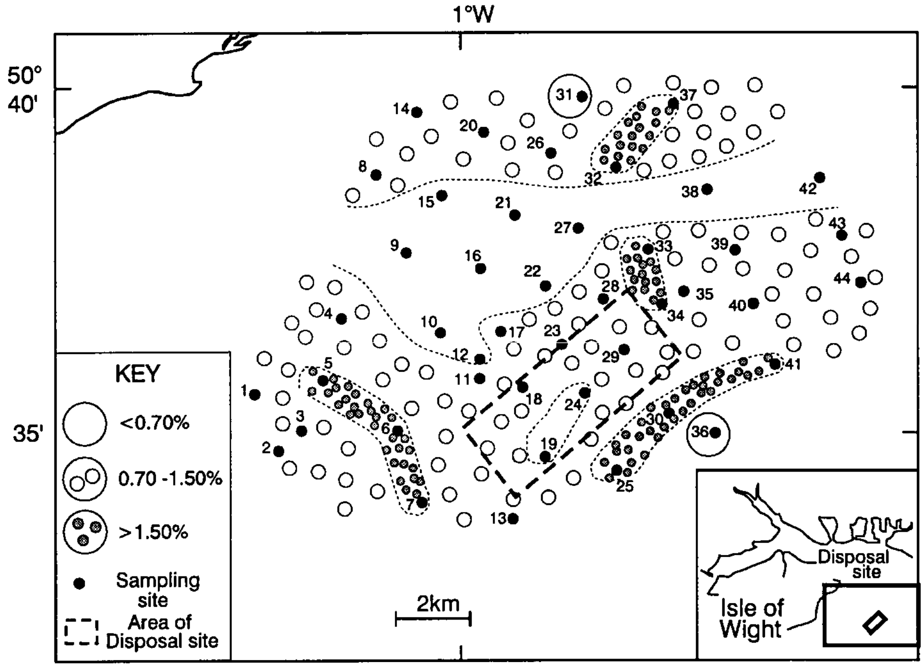

Figure 10. Nab Tower 1994 contour map showing distribution of % organic carbon

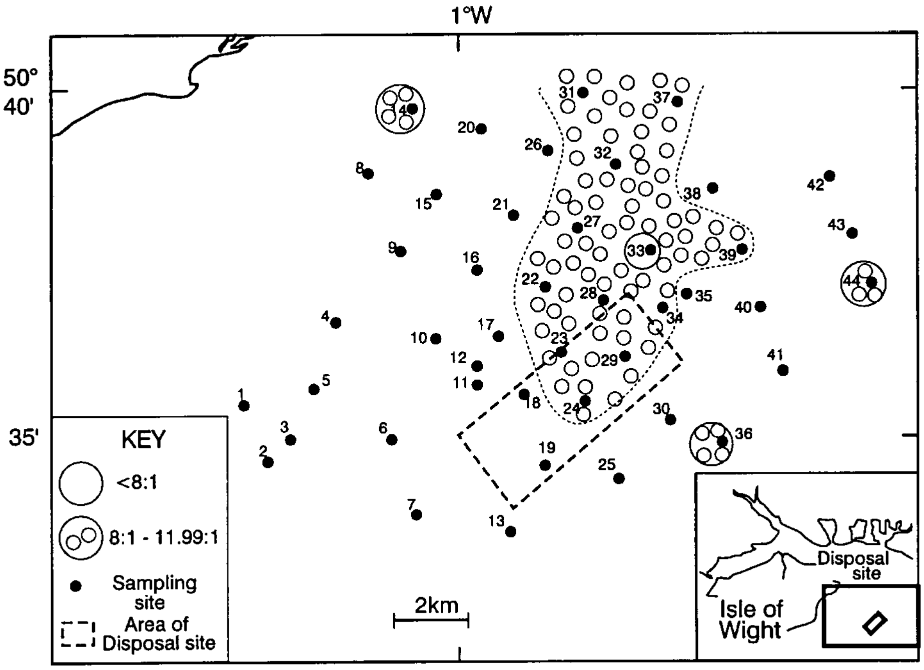

Figure 11. Nab Tower 1994 contour map showing distribution of C:N ratios

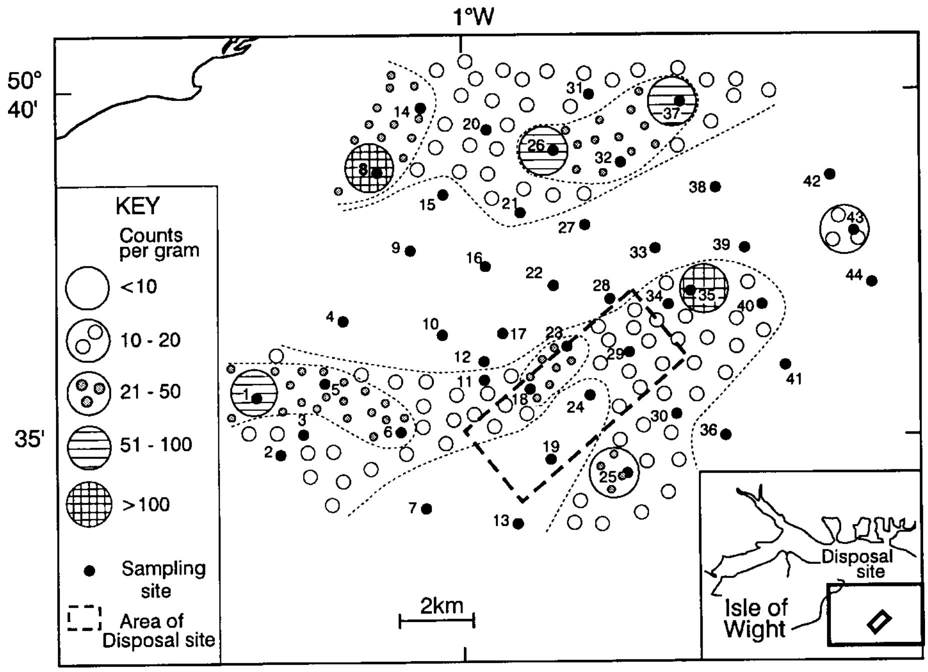

Figure 12. Nab Tower 1994 contour map showing distribution of faecal streptococci

Correlation analysis of the physical variables indicated relationships between all of the metals groups, suggesting a common source, most likely the presence of dredged material and sludge material. The metals also associated strongly with the fine sediment fractions and organic content reflecting the natural association between fine clay minerals, organic matter, and trace metals (MAFF, 1993(a)). More significantly, the organic material also correlated well with the bacteriological variables and this would suggest a common source for the trace metals, bacteria and the organic matter. This is likely to result from the dispersion of maintenance dredgings and sewage sludge across the Nab Tower area.

The data collected during the 1994 Nab Tower survey, revealed consistent patterns of accumulation of certain of the contaminant groups considered. These contaminants, which included several of the trace metals, OCPs, and organic carbon, were particularly concentrated in the immediate vicinity of the disposal site. This was associated with the highest levels of fine material recorded.

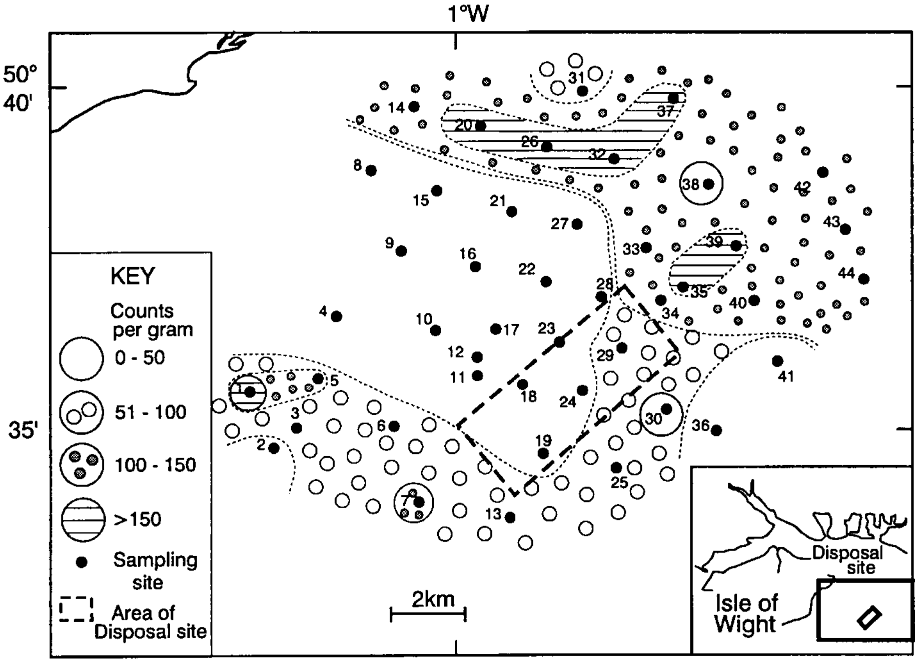

Figure 13. Nab Tower 1994 contour map showing distribution of Clostridium spp.

Additionally far field depositional areas were noted in line with the south west - north east axis of the main current regimes, some distance from the immediate disposal site. The accumulation of certain contaminant groups, including several of the trace metals, organic carbon, and particularly the bacteriological indicators, in the northern and southern extents of the survey area, serves to indicate the extent of the dispersion of both dredged material and sewage sludge across the Nab Tower survey area.

The disposal of both maintenance dredgings and sewage sludge at the Nab Tower disposal site is clearly resulting in the accumulation of certain contaminants in the sediments sampled. It would seem that this is occurring at some distance from the disposal site, as well as at the site itself.

However, as the preceding discussion demonstrates, it is difficult to separate clearly and unambiguously the effects of different wastes deposited at the same site.

4.3.3 Bristol Channel

A site off Swansea Bay (see Figure 14) was used since 1974 for the disposal of sewage-sludge from South Wales and the West of England. Disposal ceased in October 1992. As a result, a 'self-monitoring' survey by Welsh and Wessex Water Companies planned for that year was deferred until 1993, to allow some observations to be made on environmental status about one year after cessation.

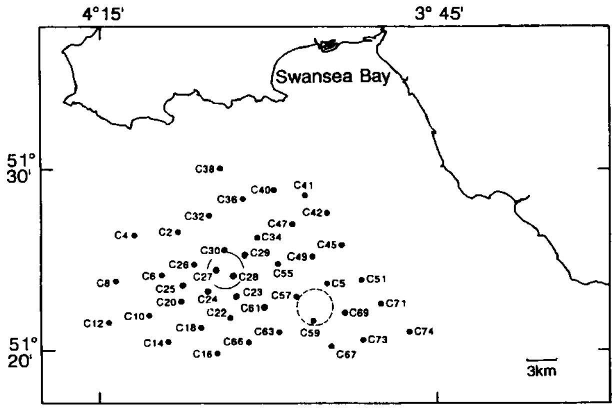

Figure 14. Bristol Channel: location of 'C' grid sampling sites

Previous surveys (in 1988 and 1990) had demonstrated that no significant impact arising from sewage-sludge disposal could be detected. In view of the coarse nature of much of the seabed in this area, an Anchor dredge was deployed for qualitative assessment of the benthos (see Figure 15). The return, in terms of quantity of material retained, was poor at most stations and little can be gained from a more detailed analysis, other than to note that (as would be expected in such a 'high energy' area) there was no evidence for a proliferation of species indicative of organic enrichment, and the range of taxa encountered accurately reflected the mixed nature of the sampled substrates.

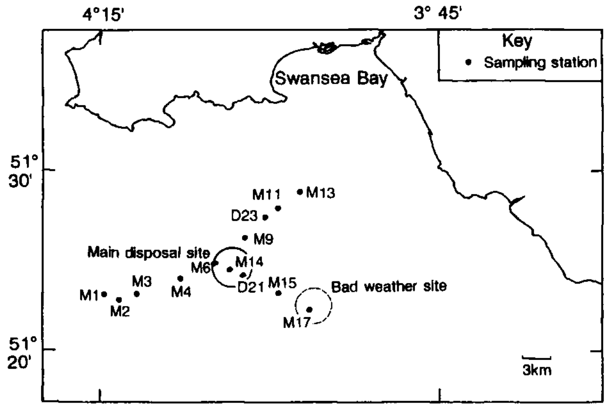

Figure 15. Bristol Channel: location of 'y' grid sampling sites

The sediment metals results show that concentrations were similar to those recorded in 1990. No obvious trends in metal concentrations were observed other than relatively high concentrations of cadmium and lead in the area of Swansea Bay where significant quantities of dredged material are deposited. Insufficient data has been gathered to allow the definition of a baseline against which to measure metal concentrations at the disposal site.

All CB congeners in the survey area were found to be below the detection limit of the method used.

The survey concluded that the disposal of sewage sludge and the following cessation of disposal had not had any measurable impact on the marine environment.

4.3.4 Thames

Since 1967, the Barrow Deep disposal site (outer Thames Estuary) has received about 4 million wet tonnes per annum of sewage sludge from the London area, making it the largest of the UK disposal operations.

A 'self-monitoring' survey was conducted by Thames Water Company in July 1993 on a grid pattern comprising some 53 stations (Figure 16). The relatively exposed and shallow location (typically 10-20 m in the channel systems), coupled with moderate-strong tidal currents, determines that this is a dispersive area, and hence substantial local accumulations of sewage-sludge particulates are not expected to arise. The same grid was sampled in 1990 and hence quantitative comparisons between recent and earlier data could be made.

Relationships between benthic macrofaunal data and a range of environmental variables were examined using univariate and multivariate analytical techniques. Correlations were generally poor or absent, and substrate type was the single most influential factor explaining spatial variability in the benthos, expressed both in terms of abundance and biomass. However, there was a weak relationship between the distribution of biomass in 1993

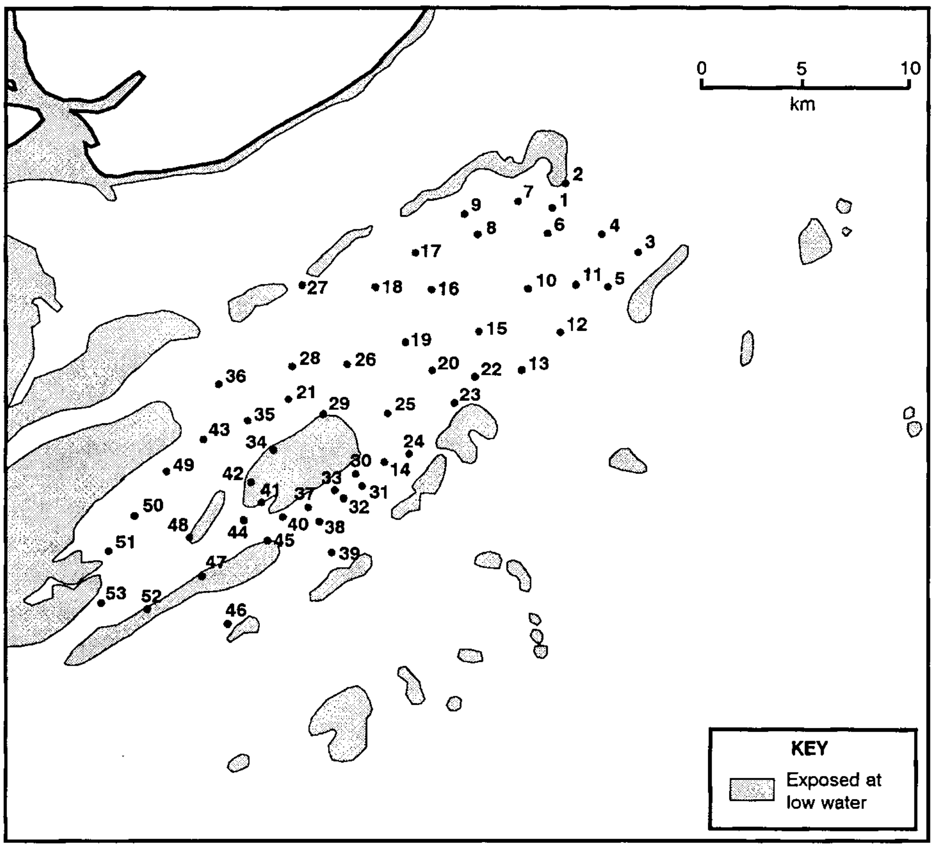

Figure 16. Geographical location of the 1993 sampling sites

and a combination of the concentrations of metals in sediments and median particle size.

In 1992, MAFF collected a series of samples at stations on a wider geographical scale than previous studies, which included transects running along the main channel systems. These channels are a distinctive feature of the outer Thames environment.

The results from analyses of sediment samples for trace metal analysis were reported in MAFF (1994(b)). A number of these stations were also sampled for the benthic macrofauna, the results from which are more fully reported in MAFF, 1997. In summary, the present status of the benthic fauna in the vicinity of the sewage-sludge disposal site is very similar to that encountered some 15 years previously. Spatial differences within the survey area can, at any one time, be largely explained by natural influences, especially substrate type, tidal currents and wave action.

Coarser substrates which coincidentally occur in the immediate vicinity of waste disposal provide a natural explanation for elevated numbers of individuals, taxa and biomass here. However, there is an indication of an additional 'enrichment' effect associated with sewage-sludge disposal but the effect is marginal, since there is no evidence for the elimination of suspension-feeders, or for the proliferation of classical 'indicator' species. These findings point to the continued acceptability of this disposal practise at current levels of input.

4.3.5 Roughs Tower

Situated in water about 15 m deep, the disposal site near Roughs Tower off Harwich (Figure 17) receives both sewage sludge and capital and maintenance dredgings. Approximately 225 000 tonnes of sewage sludge are deposited each year.

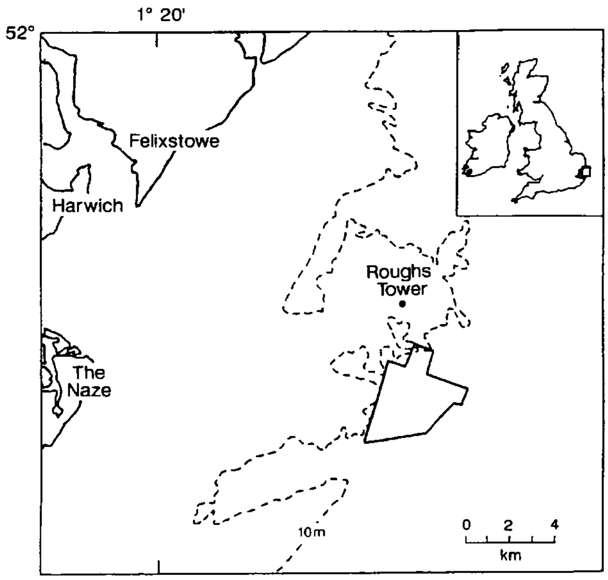

Figure 17. Roughs Tower sewage-sludge disposal site

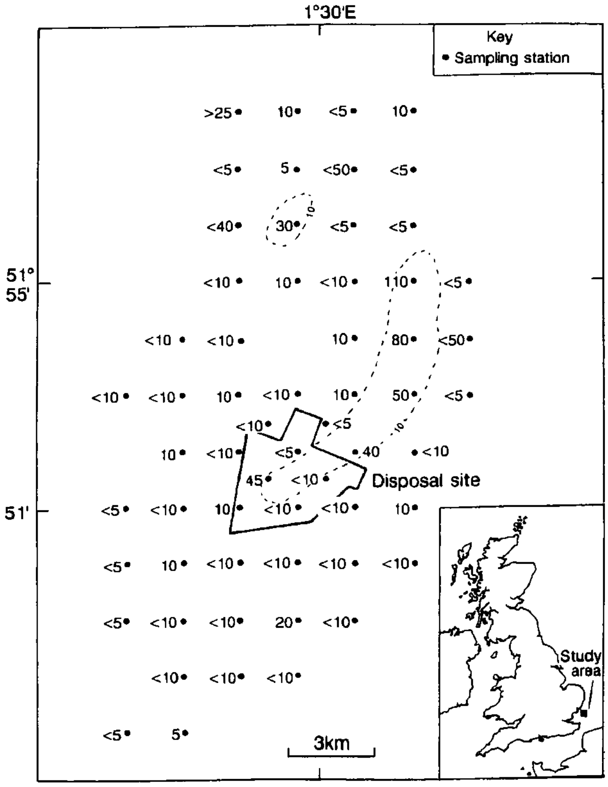

Figure 18. Concentrations of E. coli (numbers per 10 g) in sediments around the Roughs Tower sewage-sludge disposal site

A monitoring survey carried out by Anglian Water Services in 1993 showed elevated counts of sewage bacteria (*E. coli* and faecal streptococci) in sediments around the disposal site and along the tidal axis where initial dispersion occurs (Figure 18). However, analysis of metals (zinc, cadmium, mercury and lead) in these sediments showed no evidence of elevations in metal concentrations along the tidal axis. This suggests that there is no long-term build-up of sludge derived material in this area.

4.3.6 St Abbs Head/Bell Rock

(i) 1993

The two disposal sites, located off the Forth estuary (see Figure 19), are used alternately, i.e. in winter and summer, respectively, for the disposal of sewage-sludge from the Edinburgh area. They were sampled in June and October, 1993, respectively. The benthic infauna retained on 0.5 mm mesh sieves were sampled by means of a Van Veen grab, while the larger epifauna and fish were sampled by Otter trawl.

As at the Tyne sewage-sludge disposal site, significant accumulations of tomato pips (and other fruit seeds) occur in the vicinity of sludge disposal, and can be counted in grab samples. Sediments continue to support a high diversity of species, with some 308 at 11 stations at St Abbs Head, and 352 at 9 stations at Bell Rock. Data from both locations were analysed by a variety of

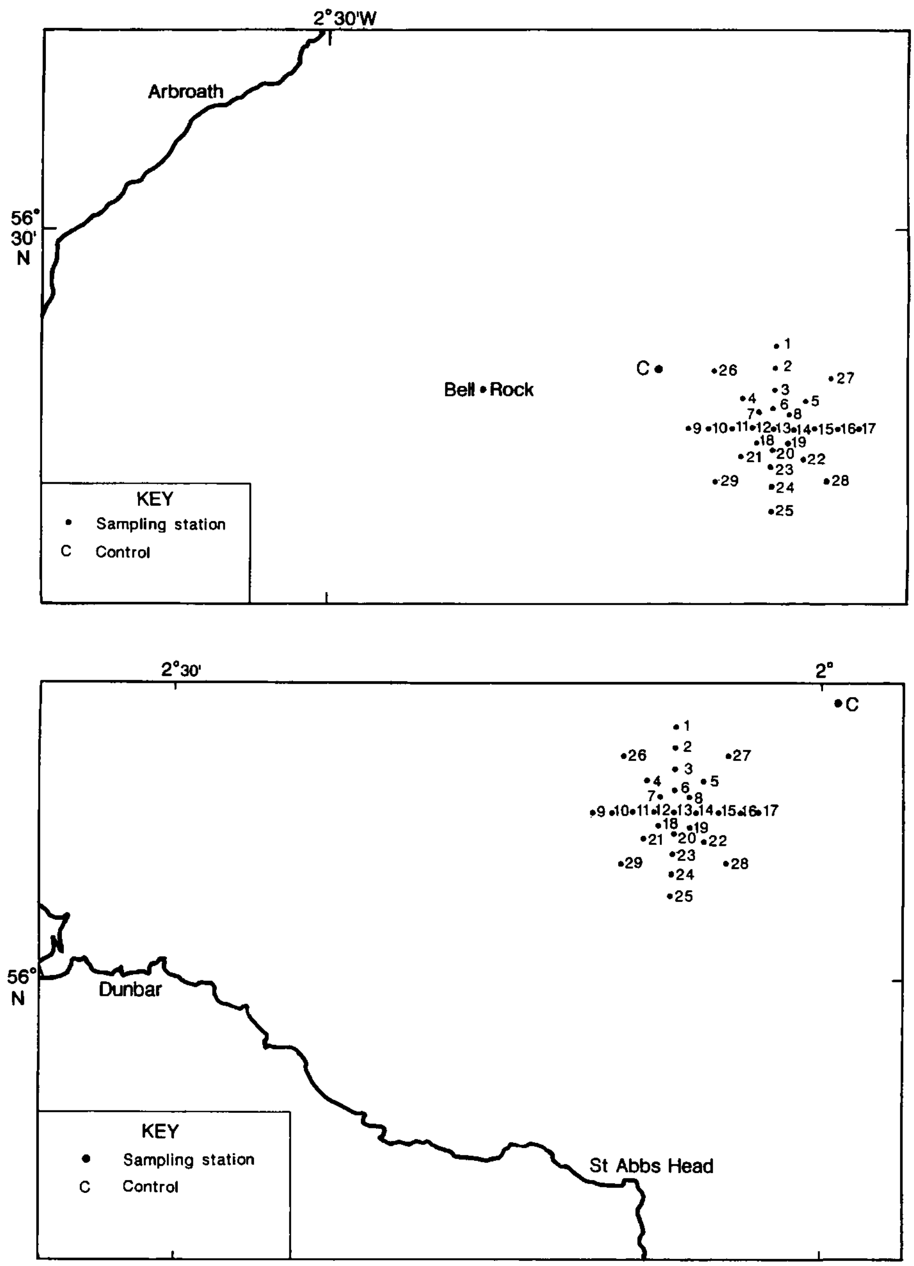

Figure 19. Sampling station positions at Bell Rock and St Abbs Head

statistical techniques. The 'Infaunal Trophic Index' is a measure of the trophic structure of benthic communities which can in turn provide an indication of organic enrichment. It was devised for use in southern California waters for assessment of the effects of sewage discharges, (e.g. Word, 1979) but has recently been adapted for UK use (Codling and Ashley, 1992). Calculations showed that all but one station exceeded a 'threshold' value of 60, representing a borderline between 'unaffected' and 'changed' communities in response to organic inputs.

Stations were divided into 'impacted' and 'non-impacted' groups based on earlier determinations of coprostanol (a biochemical tracer of sewage-sludge) in seabed sediments. At both sites, there were no statistical differences between these groups, when expressed in terms of summary measures of benthic community structure. Despite this, the presence of the polychaete worm *Capitella*, a commonly cited indicator of organic enrichment (see Pearson and Rosenberg, 1978), at central stations at St Abbs Head and, in lower numbers, at Bell Rock suggested a mild effect of sludge disposal, as noted in previous years. However, the densities of these worms, and hence the likely degree of enrichment, was considerably less than those observed at Garroch Head, a more quiescent west coast disposal site (see below).

(ii) 1994

The two sites were sampled in July and October 1994, following established procedures for collection of sediments, epibenthos and fish. There was no evidence of appreciable change in the structure of benthic communities between 1993 and 1994 which might be attributable to sewage-sludge disposal. There is evidence of continued accumulation of tomato pips at both disposal sites, with average numbers of 490 m^{-2}, representing the highest recorded in annual surveys to date. However, these counts are not exceptionally high when compared with other sewage-sludge disposal operations, e.g. off the Tyne (Rees *et al.*, 1992), in Liverpool Bay (Rees, 1993) or, until recently, the New York Bight (Studholme *et al.*, eds, 1991).

4.3.7 Garroch Head

(i) 1993

About 1.5 million wet tonnes per annum of sewage sludge from the Glasgow area are disposed of at this site (see Figure 20) in the Firth of Clyde. This is a deep-water location with low tidal currents which results in significant accumulations of deposited sludge in the immediate vicinity of disposal.

Samples of the benthic macrofauna were collected by Van Veen grab at 9 stations located along transects running through the centre of the disposal site, and at a further reference station some 10 km to the northwest. This continued the practise of annual monitoring surveys at this location. Grab and core samples were also collected for measurement of a range of physico-chemical variables, including the redox potential of sediments. Low (negative) values of the latter were found in areas of appreciable sludge deposition, reflecting a significant oxygen demand within sediments imposed by microbial degradation of carbon deposits. An Otter trawl was deployed for the assessment of the epifauna, fish pathology/microbiology and litter content.

Changes in the benthic fauna in response to sludge disposal, expressed in terms of total abundance (A), biomass (B) and total numbers of species (S), along with ratios of these measures, were comparable with previous years and are summarised in Table 2. Low numbers of species at the centre of the disposal site are accompanied by very high densities, notably of the 'enrichment indicator' *Capitella*. At distance from the disposal site, numbers of species approach 'background' levels, where there is a more equitable distribution of individuals among these species, which tend to be of larger individual body size, and a 'super-abundance' of indicator species does not occur. Trends in the data between these two extremes are usefully summarised by the ratios A/S and B/A which show, respectively, a marked reduction in numerical dominance by one or two species, and an increase in mean weights per individual, with distance from the disposal site centre.

In a comparison with data from previous years, it was concluded that, while the fauna close to the disposal site centre remained similar, there was evidence of slight improvement at intermediate distances (2-3 km). Although the fauna at the reference site showed no evidence of enrichment arising from sludge disposal, its relatively sparse nature and the presence of certain species (e.g. spionid polychaetes) indicative of physical disturbance, suggested that the site may continue to be affected by commercial trawling activity in the area.

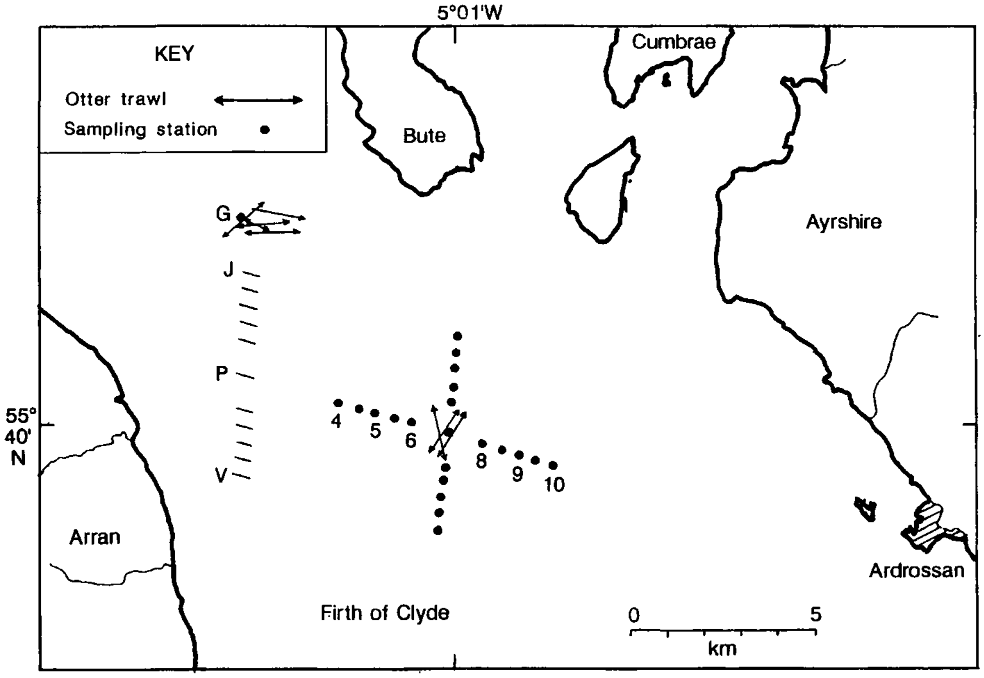

Figure 20. Sampling station positions at Garroch Head sewage-sludge disposal site

Table 2. Values for the abundance ratio (A/S) and biomass ratio (B/A) at each station. (Values for A, the total abundance, and B, the total biomass in mg, are based on the mean of the two samples from each station; the value of S is of the total number of taxa taken in the two samples: B/A is calculated from the number per m^2 to ensure compatability with other surveys)

Station	Distance and Direction from the Centre	S	A	B	A/S	B/A
P7	Centre	4	5186	68220	1297	13
M7	1.2 km N	23	6894	46257	300	7
P8.5	1.5 km E	21	4826	35540	230	7
T7	1.7 km S	20	4172	55740	209	13
P5	2.0 km W	47	483	25465	10	53
V7	2.6 km S	26	216	29715	8	138
J7	2.6 km N	65	299	15670	5	52
P10	3.0 km E	40	196	25435	5	130
P4	3.0 km W	35	173	21310	5	123
G1	10.0 km NW	33	47	4045	1	87

(ii) 1994

The same sampling strategy as in 1993 was followed in June 1994. The outcome was notable for an extension of the zone of low redox values within sediments, indicative of reducing conditions arising from the microbial breakdown of sludge-derived organic carbon. However, a comparable pattern to that observed in 1993 was evident in benthic faunal statistics. For example, lowest species numbers were found at the centre of the disposal site, highest numbers occurred peripheral to the site, while intermediate numbers occurred at the distant reference site, which is representative of 'background' conditions. Such a pattern conforms with the classical 'enrichment' model of Pearson and Rosenberg (1978).

There was an indication of some deterioration in conditions at the centre of the disposal site, characterised by gross enrichment effects, but a slight improvement on the periphery. This pattern has previously been linked to more accurate disposal practises. All such changes were well within the limits previously recorded from annual monitoring programmes. There was an increase in abundance and biomass of the fauna at the distant reference station compared with 1993, which may reflect a reduction in physical disturbance arising from commercial trawling in the vicinity.

4.3.8 Liverpool Bay

Sewage sludge has been deposited in Liverpool Bay (see Figure 21) since the turn of the century, and the site presently receives about 2 million wet tonnes per annum of digested sludge from the Liverpool and Manchester areas. Annual, and more recently biennial, 'self-monitoring' surveys of the benthos have for many years been conducted by the University of Wales, Bangor on behalf of the North West Water Company. These have been supplemented by less frequent spatially extensive surveys by MAFF (e.g. Norton *et al.*, 1984).

The location is dispersive in character and, with a largely inshore drift in bottom waters, the identification of sludge effects is complicated by outflows from the Mersey and Dee estuaries, which are in receipt of urban and industrial waste discharges. Substrates in the inner Bay are characteristically heterogeneous in nature, with gravelly sediments further offshore contrasting with areas of soft mud (often supporting a very high biomass of benthic organisms) off the estuary mouths. Substrates are also patchy on small spatial scales and this has led to a suggestion for collection of 'replicates' on small grids of stations, rather than at single points, in order to better represent the fauna at different localities (Rees *et al.*, 1994).

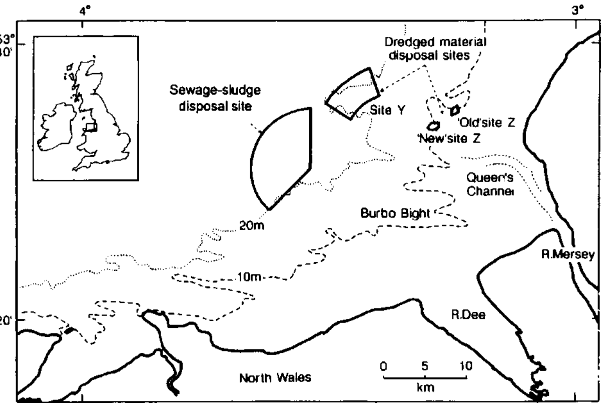

Figure 21. Location of Liverpool Bay sewage-sludge disposal site

Trends in the fauna in space and time have recently been summarised by Rees and Walker (1991) and Rees (1993). The output from multivariate analysis of common species pooled across the entire sampling area suggests a cyclic element to longer-term changes, with a number of species not seen since the early 1970s returning again by the late 1980s (Figure 22). The pattern may reflect a combination of large-scale climatic events and, at least for recent years, downward trends in contaminant inputs (including sewage sludge) to the Bay.

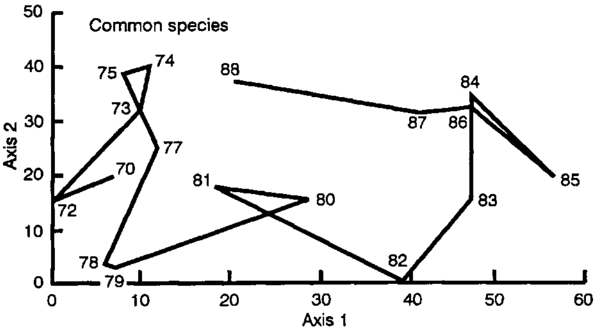

Figure 22. Output from multivariate analysis showing trends in the data from annual surveys of the benthos of Liverpool Bay between 1970 and 1988 (from Rees and Walker, 1991)

While physical evidence of sludge disposal is detectable in grab samples over a wide area inshore from the disposal site (e.g. by reference to counts of tomato pips in grab samples: see Rees, 1993), effects on the benthos are difficult to identify in the area of sludge disposal. Inshore, sludge particulates may, along with estuarine efflux, contribute to the enrichment of muddy deposits in the Burbo Bight area of the Bay.

The recent biennial sampling regime aims to improve the facility for assessments of any sludge effects through statistical comparison between a limited number of stations selected as representative of potentially impacted and reference areas, in accordance with the guidelines of MAFF (1993(b)). However, as 1993 was the first occasion for implementation of the revised sampling approach, insufficient data are presently available from this area for a proper evaluation of its utility. At the same time, limited additional sampling is conducted at a number of 'key' stations which together will ensure continuity with earlier grid surveys, and hence will continue to allow examination of long-term trends in the Bay as a whole.

4.3.9 North Channel (Irish Sea)

The North Channel disposal site has been used for the disposal of sewage sludge from the Greater Belfast area since 1909. At present approximately 300,000 wet tonnes of sewage sludge of domestic origin is disposed in the North Channel. The site is located off Belfast Lough (Figure 23) with more than 50 m depth, and is

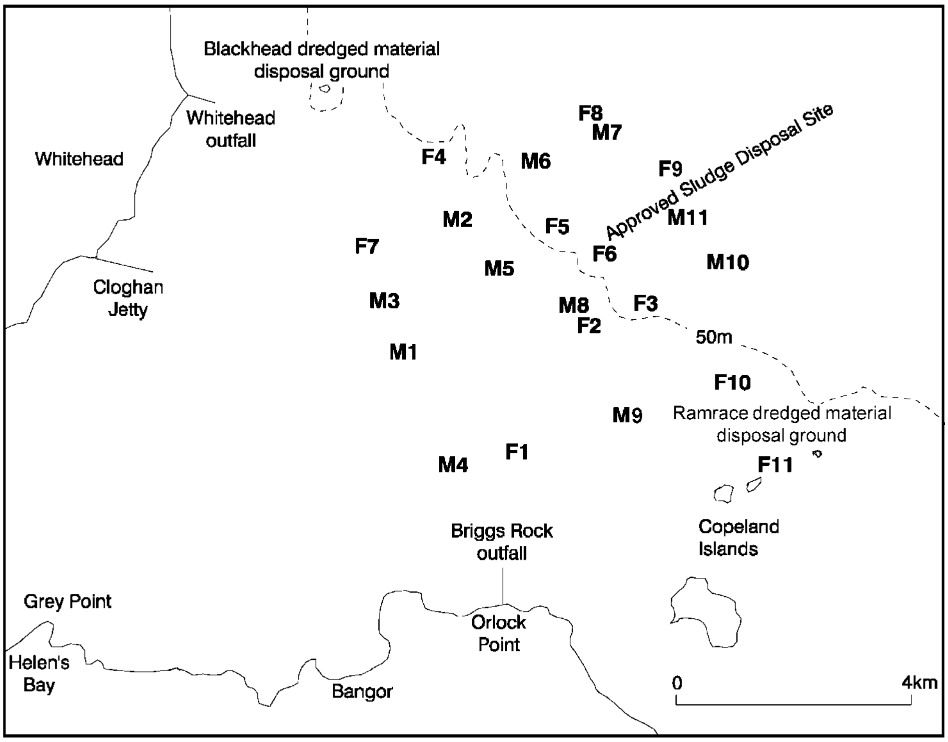

Figure 23. Location of the North Channel licensed sludge disposal ground sampling points

characterised by strong tidal currents of up to 2.5 knots. The predominant flow is NW-SE.

Dredged material disposal sites are located to the NW and SW (Figure 23). Therefore the possibility of effects from these activities and from other discharges in to the area must be considered when evaluating data from the monitoring program.

Annual monitoring is undertaken by the Industrial Research and Technology Unit (IRTU) of the Department of Economic Development on behalf of the Environment and Heritage Service, an agency within the Department of the Environment (Northern Ireland), and this data forms the substance of the present review. The site is assessed both by sediment sampling and by direct observation using a video equipped remotely operated vehicle (ROV).

Sample stations were originally selected to cover most of the sediment types represented within the area (Figure 23), and monitoring has been conducted in roughly the present form since 1989. A 0.1 m^2 Day grab is used to collect samples for determination of particle size distribution, microbiology (*Clostridium perfringens* spores, faecal streptococci, total coliforms and faecal coliforms), trace metals content, trace organic compounds content, CHN and the benthic infauna. A total of 21 stations are regularly sampled: 10 (F1-F10) for all parameters including fauna, and 11 (M1-M11) for microbiology, CHN and trace organic compounds.

Observations made using the ROV have indicated no contamination at the site, either from litter or deposited organic material, that can be attributed to sludge disposal activities. Because of the heterogeneous nature of the monitoring area, the sampling data have been interpreted with emphasis on the identification of any temporal trends evident from annual monitoring, rather than by the inter-comparison of stations.

Microbiology results were highly variable between years, and did not clearly identify a pattern that could be solely attributed to sewage sludge disposal. Indeed, the more inshore sampling stations may have been influenced by coastal sewage discharges.

Similarly, counts of tomato pips were also variable between years, attaining the highest densities (369m^{-2}) at the inshore station F7, west of the disposal site, in 1990. Generally the higher counts were found at stations along the inshore edge of the disposal site over the period 1990-1992. Overall, these densities are low when compared with locations where the effects of dispersion are lesser, such as off the Tyne, where counts in excess of 1000 m^{-2} are regularly encountered in the vicinity of the disposal site.

The sediment profile at each sample station was typically sand or gravel in nature, with a low silt/clay content (<20 %). However, high values (up to 50%) were encountered at stations F1 and F7, which are located inshore at the mouth of Belfast Lough.

Across all faunal (F) stations, the average density and range of taxa from 3 replicate Day grab samples was comparable between the years (only 1 sample was taken in 1989). Values of the Shannon-Wiener diversity index did not vary substantially between years except at station F7, where there was a reduction in 1992. However by 1994 values had returned to their earlier levels.

Multivariate analyses of the data demonstrated that the pattern of variation in community structure between stations was relatively constant between years. Figure 24 shows the outcome of cluster analysis and ordination by multi-dimensional scaling for the results from 1994. The station F10 is consistently found to differ from other stations, however this can be explained as a consequence of the relatively coarse nature of the sediment at this site, with the large influence that this has on the composition of the benthic fauna.

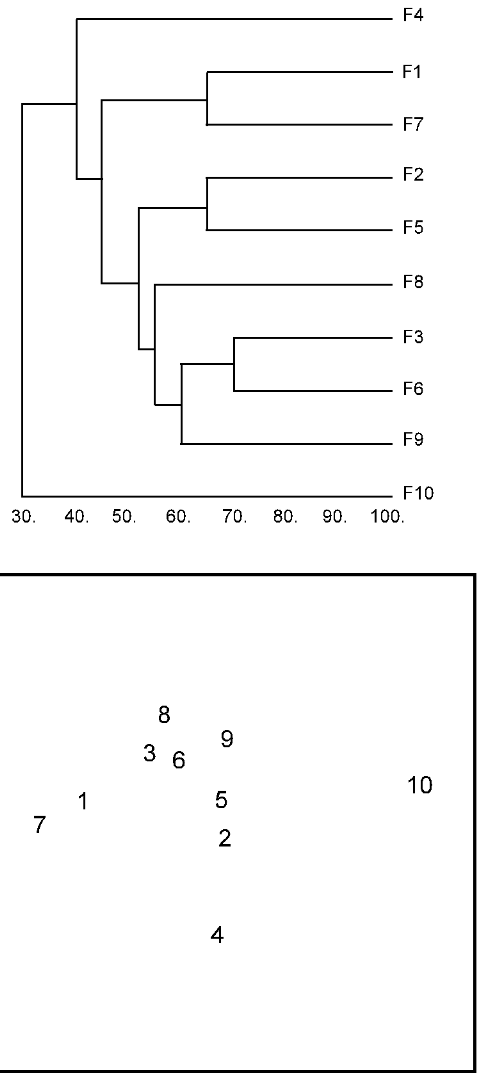

Figure 24. 1994 cluster analysis and ordination by multi-dimensional scaling (MDS)

Stations F1, F4 and F7 which lie to the west (inshore) of the disposal site also generally maintained a distinctive character. Again these differences may be a consequence of natural variation in sediment type and water depth. However, the innermost stations, F1 and F7, were characterised by high percentage silt/clay contents, elevated counts of *Clostridium perfringens* spores (indicative of faecal contamination), and at F7 elevated tomato pip counts with a trend to increased densities of benthic fauna. This may suggest some organic enrichment. However these sites could be influenced by nearby sewage discharges (see Figure 23) as well as by the inshore transport and deposition of disposed sewage particulates. There is no evidence to suggest that sludge disposal activities influence the benthic fauna at any other station, including those immediately adjacent to the disposal site.

4.4 Conclusions

This review of activities in 1993/94 demonstrates that the GCSDM guidelines for the conduct of seabed monitoring programmes (MAFF, 1989) have been widely adopted in soft-sediment areas, ensuring that the findings from different areas are broadly comparable. Quantitative sampling of coarse sediments is a more intractable problem but, fortunately, such problems are only rarely encountered at sludge disposal sites. Disposal at the Bristol Channel site, an area typified by the presence of stony or gravelly substrates (itself a reflection of the 'high energy' conditions that prevail) ceased in 1992.

Criteria for assessing the acceptability of changes in the benthos at sewage-sludge disposal sites were listed in MAFF (1992) and applications to data sets for the Tyne and, on a more limited scale, the Thames, indicate that these have not been breached. There remains scope for wider application of this methodology, especially at Liverpool Bay (where the sampling programme has recently been modified to accommodate this approach) and at the Scottish grounds where long time-series of data are available although not always at an appropriate level of replication. Although there were no measurable effects on the benthos in the immediate vicinity of the North Channel disposal site off Belfast Lough, further work is required inshore in order to establish whether local 'enrichment' of the fauna may be linked with the settling of sludge particulates, or with the effects of nearby coastal sewage discharges.

This review also raises the question whether monitoring should be continued after the end of sludge disposal which by international agreement will occur no later than the end of 1998.

The main objective of such post-cessation monitoring would be to assess whether environmental conditions improve after the cessation of sludge disposal. This would therefore check whether the generally held view that few unacceptable effects have occurred was correct or not. In order to carry out this test it is felt that several exemplar sites should be examined. These sites should include those with a long history of sludge-disposal monitoring to or close to GCSDM standards. It is suggested that the sites at Garroch Head, Tyne, Thames and Liverpool Bay are suitable.

5. MONITORING ACTIVITIES AT SEWAGE-SLUDGE DISPOSAL SITES IN 1995

5.1 Introduction

During 1995, surveys were carried out at the following disposal sites (see Figure 1): Tyne, Humber, Roughs Tower, Barrow Deep, Nab Tower, Exeter, Plymouth, Liverpool Bay, Bell Rock, St Abbs Head, Garroch Head and North Channel.

Short summaries of the surveys are given in the following sub-sections:

5.2 MAFF survey of the Tyne sewage-sludge disposal site, June 1995

(a) Beam trawl samples were taken at the site shown in Figure 25, for the identification and enumeration of litter and benthic infauna.

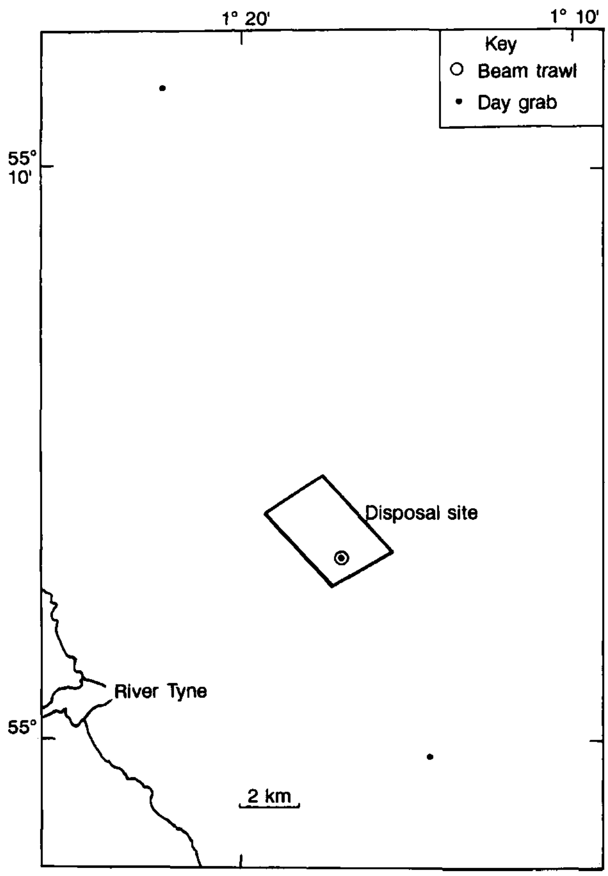

Figure 25. MAFF survey of the Tyne sewage-sludge disposal site, June 1995

(b) Sediment samples were collected (using both a Day grab and a multicorer) from the stations shown in Figure 25. Metals (Cd, Cu, Cr, Hg, Mn, Ni, Pb and Zn) were determined in the <63 µm fraction of the top 0-1 cm of the sediments and benthic infauna were identified and enumerated.

5.3 Northumbrian Water survey of the Tyne sewage-sludge disposal site, June/October 1995

(a) Sediment samples were collected by Day grab from the stations shown in Figure 26.

(b) Metals (Cd, Cu, Cr, Hg, Mn, Ni, Pb and Zn) were determined in the <63 µm fraction of the top 0-1 cm of the sediments.

(c) Benthic infauna were identified and enumerated in samples from the sites shown.

(d) Beam trawl hauls were carried out at the sites shown and epifauna were identified to species level and enumerated.

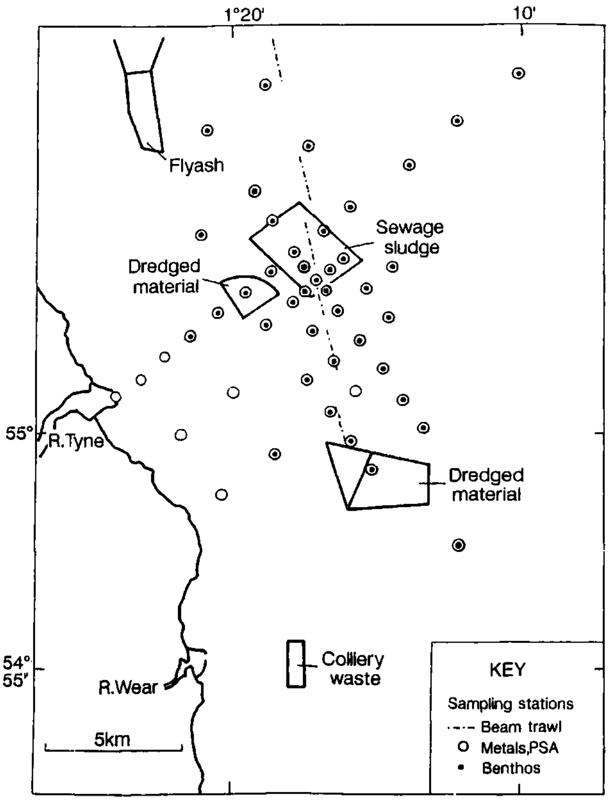

Figure 26. Northumbrian Water survey of the Tyne sewage-sludge disposal site, June/October 1995

5.4 MAFF survey of the Humber sewage-sludge disposal site, June 1995

(a) Samples of horse mussel (*Modiolus modiolus*) were collected from the station shown in Figure 27. These will be analysed for metals as part of a study on temporal trends in chemical quality of the mussel population.

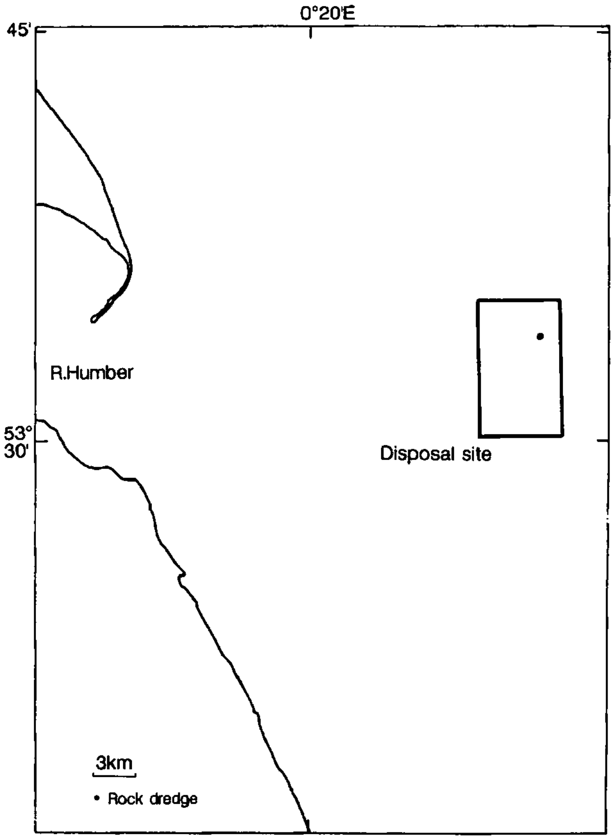

Figure 27. MAFF survey of the Humber sewage-sludge disposal site, June 1995

5.5 Anglian Water survey of the Roughs Tower sewage-sludge disposal site, September 1995

(a) Samples of sediment were collected using a 0.1 m^2 Day grab, from the sites shown in Figure 28.

(b) Faecal bacteria (*E. coli*, and faecal streptoccoci) were enumerated in surface scrapes of the sediment from all of the sites sampled.

(c) Metals (Cd, Hg, Pb and Zn) were determined in <63 µm fraction of the surface 0-1 cm of the sediment from 49 of the 60 sites sampled.

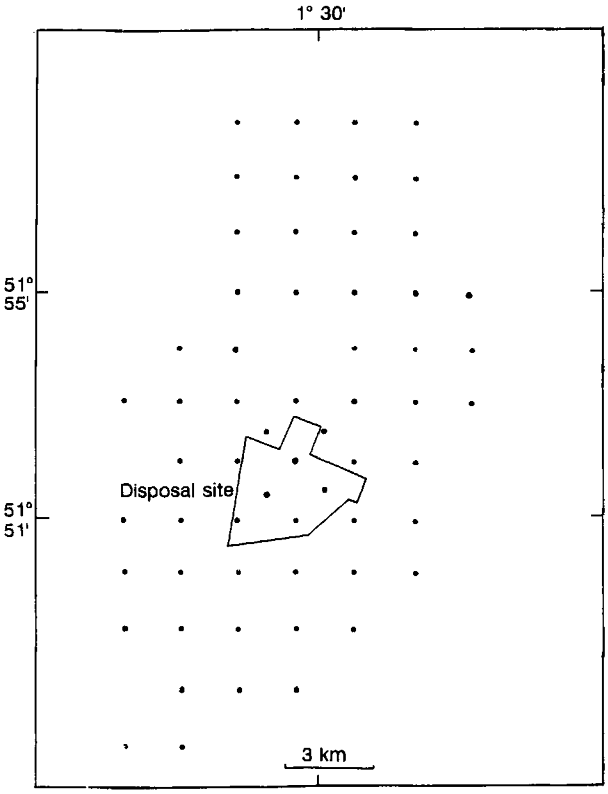

Figure 28. Anglian Water survey of the Roughs Tower sewage-sludge disposal site, September 1995

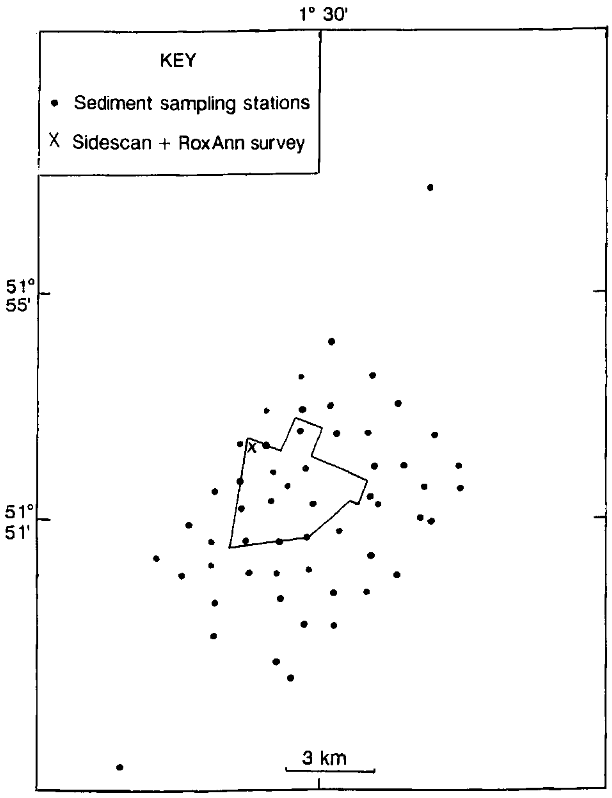

Figure 29. MAFF survey of the Roughs Tower sewage-sludge disposal site, June 1995

5.6 MAFF survey of the Roughs Tower sewage-sludge disposal site, June 1995

(a) Sediment samples were collected from the stations shown in Figure 29.

(b) Metals (Cd, Hg, Pb and Zn) were determined in <63 μm fraction of the surface 0-1 cm of the sediment from 54 sites.

(c) Benthic infauna were identified and enumerated in samples from 9 of the sites shown.

(d) A ten hour sidescan and RoxAnn™ survey was also carried out.

5.7 MAFF survey of the Barrow Deep sewage-sludge disposal site, June 1995

(a) Sediment samples were collected using a Day grab from the sites show in Figure 30 and a number of sites within each of the three sampling boxes.

(b) Metals were determined in the <2 mm fraction of the surface 0-1 cm of the sediments. Carbon and nitrogen were determined in the <63 μm fraction of the samples.

(c) Benthic infauna was identified and enumerated in samples from the sites shown.

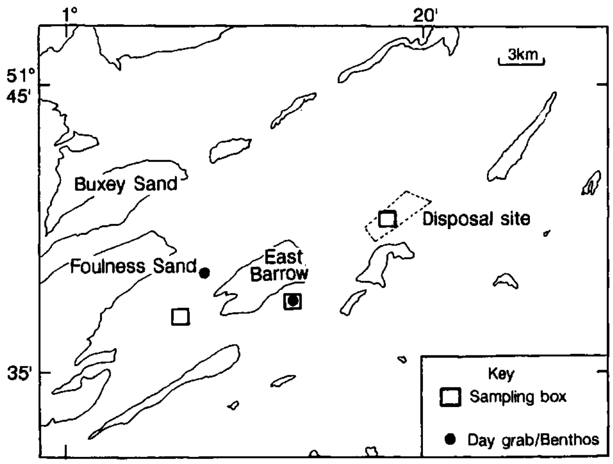

Figure 30. MAFF survey of the Barrow Deep sewage-sludge disposal site, 1995

5.8 Southern Water survey of the Nab Tower sewage-sludge disposal site, June 1995

(a) Sediment samples were collected from the sites shown in Figure 31.

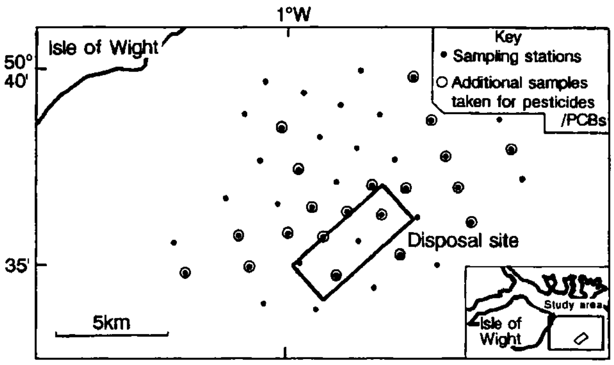

Figure 31. Southern Water survey of the Nab sewage-sludge disposal site, June 1995

(b) Metals, CHN, PSA were determined in samples from all sites.

(c) Faecal bacteria (*E. coli, T. coli* and *Clostridium* sp.) were enumerated in surface scrapes of the sediment from all of sites sampled.

(d) PCBs and OCPs were determined in 19 of the 44 sites sampled.

5.9 MAFF survey of the Nab Tower sewage-sludge disposal site, June 1995

(a) A nine hour sidescan and RoxAnn™ survey was carried out at the station shown in Figure 32.

(b) Sediment samples were collected at the sites shown, for metals and particle size analysis.

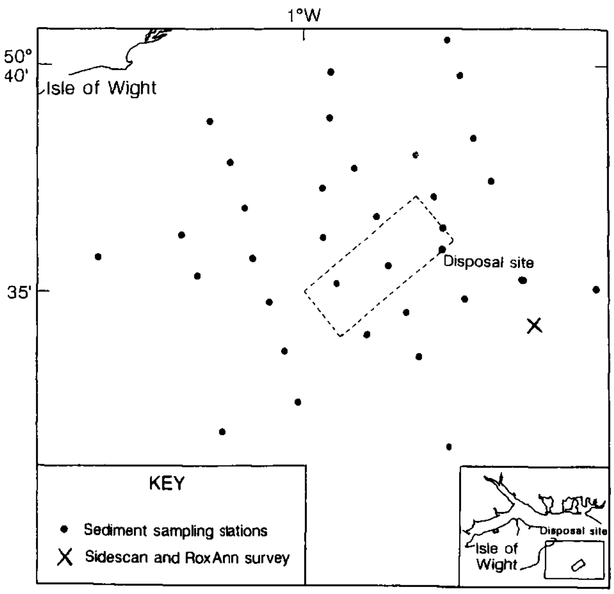

Figure 32. MAFF survey of the Nab Tower sewage-sludge disposal site, June 1995

5.10 South West Water survey of the Exeter sewage-sludge disposal site, September 1995

(a) Sediment samples were collected from the sites shown in Figure 33.

(b) Grain size, metals, organic carbon and nitrogen, and faecal streptococci were determined in all of the samples.

(c) Macrofauna was identified and enumerated at all of the sites.

(d) Additional sediment samples were taken at three of the 22 sites for the analysis of PCBs.

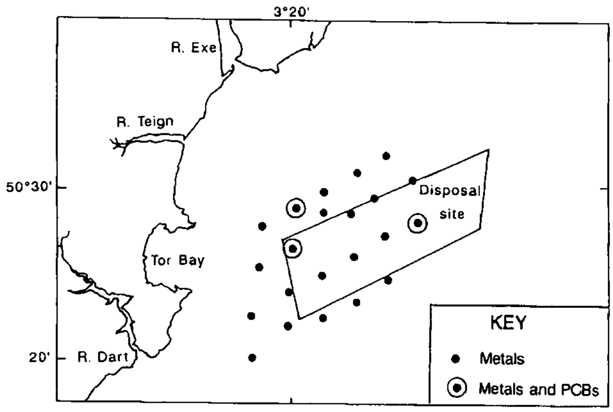

Figure 33. South West Water survey of the Exeter sewage-sludge disposal site, September 1995

5.11 South West Water survey of the Plymouth sewage-sludge disposal site, September 1995

(a) Sediment samples were collected from the sites shown in Figure 34.

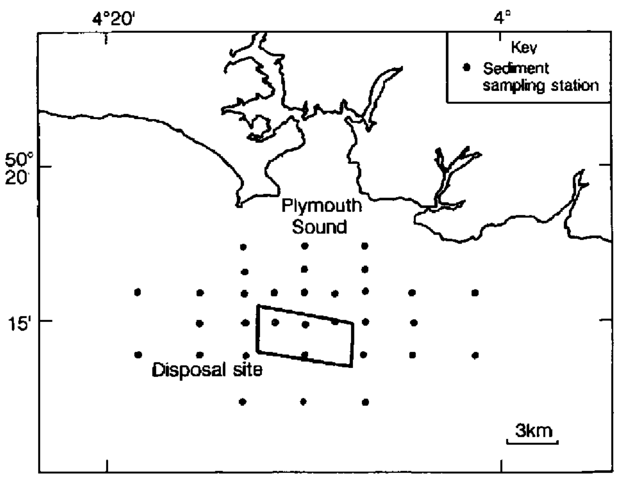

Figure 34. South West Water survey of the Plymouth sewage-sludge disposal site, September 1995

(b) Grain size, metals, organic carbon and nitrogen, and faecal streptococci were determined in all of the samples.

(c) Macrofauna was identified and enumerated at all of the sites.

(d) Additional sediment samples were taken at three of the 32 sites for the analysis of PCBs.

5.12 North West Water survey of Liverpool Bay sewage-sludge disposal site, 1995

(a) Sediment samples were collected from the sites shown in Figure 35.

(b) Metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) were determined in the <90 µm fraction of the surface 0-1 cm of the sediment.

(c) Samples for the identification and enumeration of benthic infauna were collected from 8 of the sites.

5.13 MAFF survey of the Liverpool Bay sewage-sludge disposal site, June 1995

(a) Sediment samples were collected by Day grab from the stations shown in Figure 36.

(b) Metals were determined in the <90 µm fraction of the surface 0-1 cm of the sediment.

5.14 DoE(NI) survey of the North Channel sewage-sludge disposal site, 1995

(a) Sediment samples were collected from the sites shown in Figure 37 using a 0.1m^2 Day grab. Where it was not possible to collect sediment using a Day grab because of the nature of the substrate, a large pipe dredge was used to collect semi-quantitative samples.

(b) Samples were collected from the 10 sites (F1-F10) for microbiology (*Clostridium perfringens* spores, faecal streptococci, total coliforms and faecal coliforms), trace metals (Zn, Ni, Pb, Cu, Cr, Hg, Cd, As), CHN, trace organic compounds and benthic infauna.

(c) From a further 11 sites (M1-M10) samples were collected for microbiology, CHN and trace organic compounds.

(d) A visual inspection of the sewage sludge disposal site was conducted using a video equipped remotely operated vehicle (ROV).

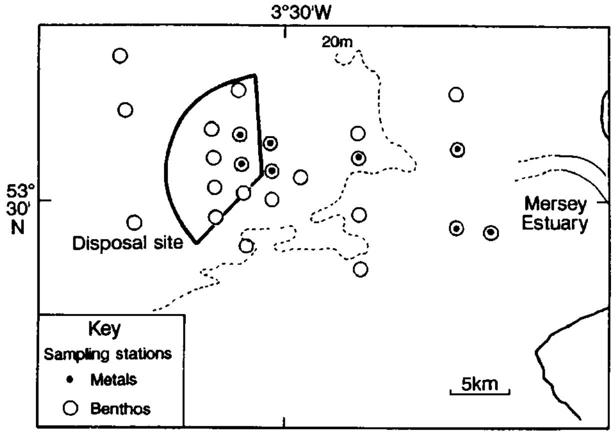

Figure 35. North West Water survey of the Liverpool Bay sewage-sludge disposal site, 1995

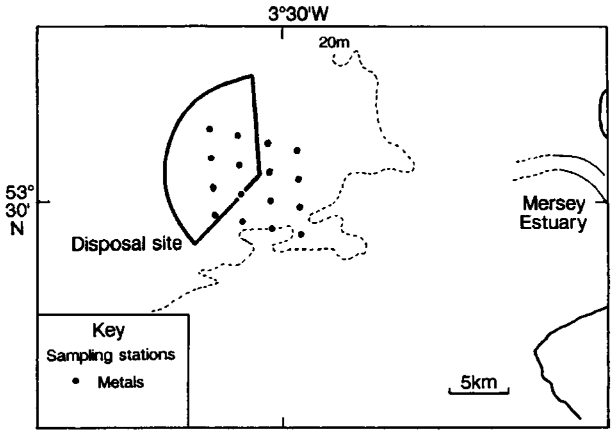

Figure 36. MAFF survey of the Liverpool Bay sewage-sludge disposal site, 1995

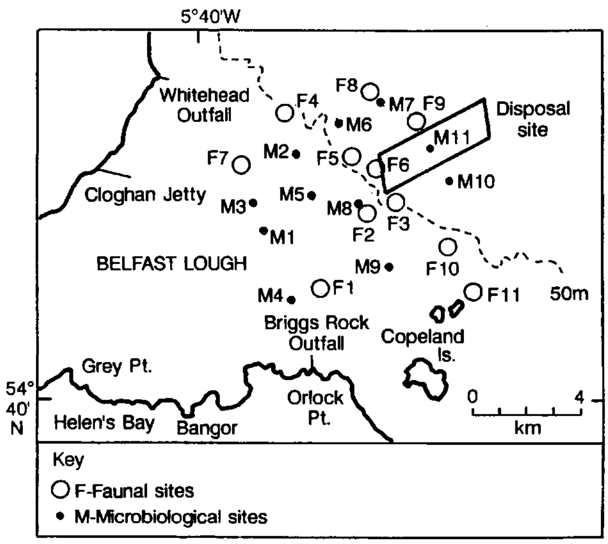

Figure 37. DoE(NI) survey of the North Channel sewage-sludge disposal site, April 1995

5.15 Scottish Marine Biological Association/Strathclyde Regional Council survey of the Garroch Head sewage-sludge disposal site, 1995

(a) Sediment samples were collected from the sites shown in Figure 38.

(b) Metals (As, Cd, Cr, Cu, Fe, Hg, Ni, Pb, and Zn) were determined in whole samples of the surface 0-1 cm of the sediment. Carbon, nitrogen, PCBs and pesticide residues were also determined in these samples.

(c) Additional grab samples were collected from eight stations and sieved on a 1 mm mesh. Benthic infauna were identified to species level and enumerated.

(d) Otter trawls were deployed at two stations. Epifauna will be identified to species level and enumerated.

(e) Histopathological and microbiological investigations will be carried out on fish collected from the trawls.

5.16 Scottish Office Agriculture, Environment and Fisheries Department (SOAEFD) survey of the Garroch Head sewage-sludge disposal site, 1995

(a) Forty-six sediment samples were collected for heavy metal and particle size analysis. In addition, two samples were collected at each of the control sites.

(b) A total of 43 sediment samples were colected for the determination of faecal coliform, faecal streptococci and *Clostridium perfingens* spores.

(c) Fish and shellfish samples were collected from the Garroch Head area. Samples of nine species were retained for heavy metal analysis.

(d) Sea water samples were collected from three discrete depths at 26 sampling stations (including control satations) for suspended solids measurements and the enumeration of faecal coliform and faecal streptococci.

5.17 Scottish Office Agriculture, Environment and Fisheries Department (SOAEFD) survey of the Bell Rock sewage-sludge disposal site, 1995

(a) Thirty-one sediment samples were collected for heavy metal and particle size analysis. All sediments were sub-sampled for faecal coliforms, faecal streptococci and *Clostridium perfringens* spore determinations.

(b) Samples of four fish species were collected for heavy metal analysis.

(c) Sea water samples were collected from three discrete depths at five sampling stations for suspended solids measurements and enumeration of faecal coliforms and faecal streptococci.

(d) A RoxAnn™ survey of the sewage sludge disposal site was completed.

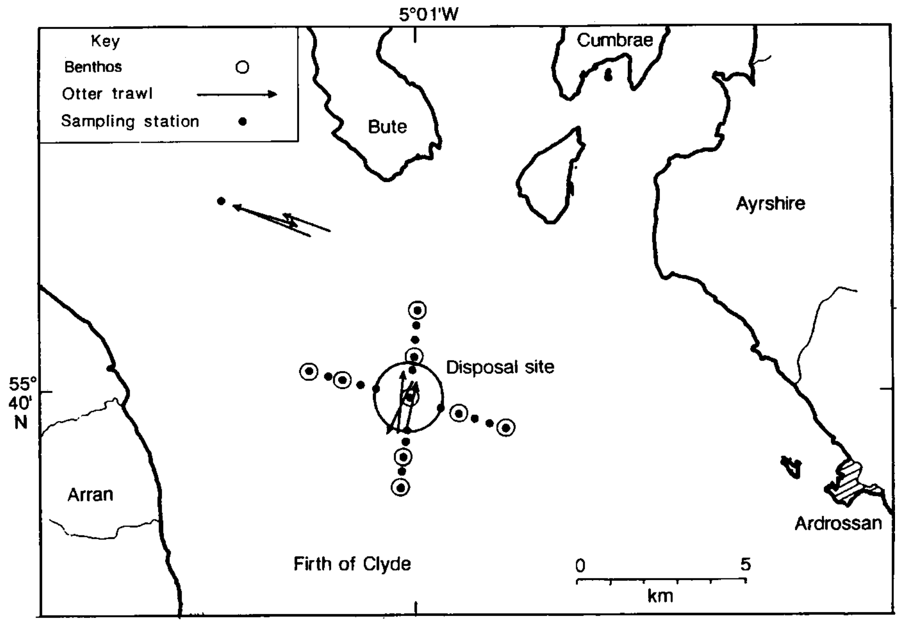

Figure 38. Scottish Marine Biological Association/Strathclyde Regional Council survey of Garroch Head sewage-sludge disposal site, April 1995

5.18 Forth River Purification Board/ Lothian Regional Council survey of the Bell Rock sewage-sludge disposal site, October 1995

(a) Sediment samples were collected from the stations shown in Figure 39.

(b) Metals (As, Cd, Cr, Cu, Fe, Hg, Pb, Ni, and Zn) particle size analysis, carbon and nitrogen, and faecal bacteria were determined in these samples.

(c) Additional sediment samples were collected from stations C, 1, 3, 9, 11, 13, 15, 23, 25, and 27 for the identification and enumeration of benthic fauna.

(d) Sediment samples from stations C, 1, 3, 9, 11, 13, 15, 17, 23, 25, 27 and 29 were analysed for organochlorines.

(e) Aggasiz trawls were carried out at stations C and 13, for the identification and enumeration of fish species. Adult fish were examined for lesions, histopathology and microbiology.

5.19 Scottish Office Agriculture, Environment and Fisheries Department (SOAEFD) survey of the St Abbs Head sewage-sludge disposal site, 1995

(a) A total of 2301 common dab from the St Abbs Head and Bell Rock disposal sites and the relevant reference areas were examined for disease (Lymphocystis, ulcers and hyperplasia) by standardised ICES methods (ICES, 1989).

(b) Thirty-two sediment samples were collected for heavy metal and particle size analysis. All sediments were sub-sampled for faecal coliforms, faecal streptococci and *Clostridium perfringens* spore determinations.

(c) Sea water samples were collected from three discrete depths at five sampling stations for suspended solids measurements and enumeration of faecal coliforms and faecal streptococci.

(d) Samples of four fish species were collected for heavy metal analysis.

(e) A RoxAnn™ survey of the sewage sludge disposal site was completed. The seabed maps produced supported the sediment sampling programme.

5.20 Forth River Purification Board/ Lothian Regional Council survey of the St Abbs Head sewage-sludge disposal site, July 1995

(a) Sediment samples were collected from the sites shown in Figure 40.

(b) Metals (As, Cd, Cr, Cu, Fe, Hg, Pb, Ni, and Zn) particle size analysis, carbon and nitrogen, and faecal bacteria were determined in these samples.

(c) Additional sediment samples were collected from stations C, 1, 3, 9, 11, 13, 15, 17, 23, 25, and 27 and 29 for the identification and enumeration of benthic fauna and the determination of organochlorines

(d) Otter trawls were carried out at stations C and 13, for the assessment of fish diseases.

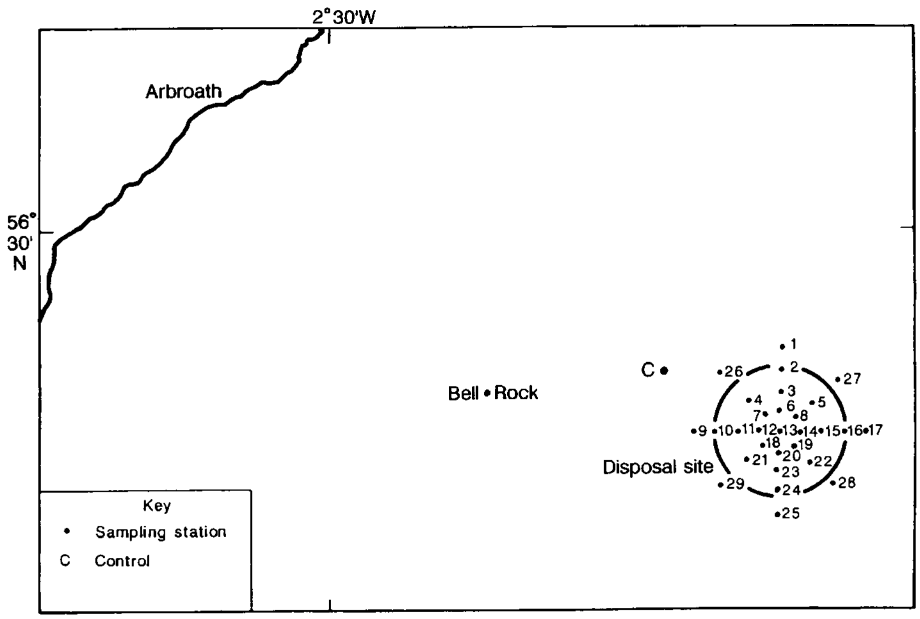

Figure 39. Forth Purification Board/Lothian Regional Council survey of the Bell Rock sewage-sludge disposal site, October 1995

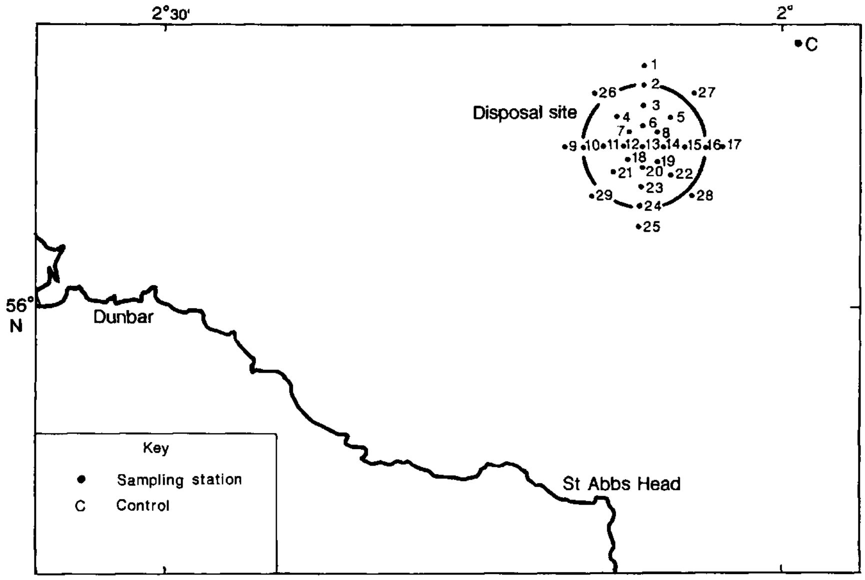

Figure 40. Forth River Purification Board/Lothian Regional Council survey of the St Abbs Head sewage-sludge disposal site, June 1995

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