

NRA-Water Quality Series 14

ABANDONED MINES AND THE WATER ENVIRONMENT



**Report of the
National Rivers Authority**

March 1994

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NRA

National Rivers Authority

WATER QUALITY SERIES No.14

National Rivers Authority

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Cover photograph: Discharge from Wheal Jane mine after heavy rainfall. The plume of pollution is seen leaving Restronguet Creek and entering the Carrick Roads.

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Report of the
National Rivers Authority

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PREFACE

Pollution caused by abandoned mines is a rather specialized and local problem, but when and where it occurs its impact is spectacular. Areas with a mining history are long-accustomed to the effects which draining mine adits have on the local streams and rivers: many such areas have their "Red Rivers", some of which are naturally occurring and others of which have such a long history that their origin is forgotten. There are many stretches of river affected in such areas and it would be unrealistic to consider that all of these should be cleaned up, even if it was technically feasible. But equally it can no longer be acceptable for an industry to be conducted in such a way that whilst in operation its discharges are strictly regulated and yet when it closes it leaves behind a permanent legacy of poor water quality, without any responsibility for it under law.

This report addresses these issues, some of which have much in common with the legacy of contaminated land. The inherited problem of water from long-abandoned mines is considered, and suggestions made as to the priority and manner with which it could be managed within a catchment management plan context. The legal aspects of the active abandonment of mines is addressed, together with a consideration of mines which have yet to be opened, or are to be re-opened. Together with the report on contaminated land, it is anticipated that this report will assist in evaluating and prioritising the work which has to be done to improve the quality of inland and coastal waters in a pragmatic way.

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EXECUTIVE SUMMARY

Abandoned mines are a source of poor water quality in specific areas of England and Wales. The situation is a long-standing one in many cases, but mines are still being abandoned so that, in a general sense, the situation is continuing to deteriorate. This trend needs to be reversed, but the extent to which remedial measures can and should be taken with regard to long-abandoned mines needs careful consideration and prioritisation. It is a subject upon which the NRA has previously given written evidence to Government.

Dealing with the problem is not helped by the legal position, which is briefly discussed in this report. The nature of mine water is also briefly described, because it determines not only the effects which such waters have on the aquatic environment, but the difficulties which arise when trying to ameliorate such effects which vary from the aesthetic to the toxic.

With regard to existing mines, responsibility remains with the mine owners. The NRA's dealings with British Coal are briefly discussed, and of advice given to Government Departments.

The scale of the problem of long-abandoned mines has yet to be fully evaluated in England and Wales, primarily because many of the effects are most acute in streams and upper reaches which are not routinely monitored, and are thus un-classified. Nevertheless, some attempt has been made to characterise the some 200 km of waters affected by abandoned coal mines, and examples are given of some typical case histories of how specific polluting waters have been dealt with - or have not. Similarly, some 400 km of waters are affected by abandoned metal mines, primarily in the South West of England and Wales, the best known being the Wheal Jane mine.

Other examples are given as to the way ahead. It is suggested that essential requirements are: the clarification of the law with respect to what constitutes an abandoned mine; the need to inform the NRA in good time of the intention to abandon a mine; and full allowance in the planning system for the future opening and closing of mines, including their re-opening. With regard to the standing of long-abandoned mines, however, it is clearly impractical to attempt to ameliorate their effects, by whatever means, until their relative contribution to poor water quality has been fully assessed. It is suggested that priority needs to be given to those mines which:

- are a cause of breaching a surface water quality standard which was already extant and in compliance prior to the mine being abandoned;
- can be shown to be a significant (>1%) contributor to the annual input of certain toxic and persistent (Red List) substances into coastal waters; or
- are a unique cause of poor water quality in an otherwise good quality river.

The biggest problem, however, is how such work should be paid for, and by whom. The NRA's ability to deal with the problem and recover the cost for so doing is limited by law. And other sources, such as by use of the Derelict Land Grant, are also likely to be very limited.

1. INTRODUCTION

- 1.1 Recent events have highlighted both the potential and actual environmental damage resulting from abandoned mines, and the legal and practical difficulties which the NRA faces in its efforts to prevent and clean-up pollution arising from such mines. Although closely associated with the nature and problems of contaminated land, abandoned mines have sufficient characteristics to merit an evaluation in their own right. Many discharges originate from long-abandoned mine workings and their impact relates to the size of the discharges, the contaminants they contain, and the catchments into which they discharge. Thus fire clay and ganister (stone used for furnace lining) mines produce acidic run-off, whilst discharges from coal mines can result in iron deposition and often acidic or saline effluents. In extreme cases, a heavy metal mixture - such as that released from the Wheal Jane mine - can cause widespread pollution with long-term environmental implications. The environmental problems can essentially be divided into two categories, those resulting from coal mining operations and those resulting from the mining of other minerals, particularly metals. The environmental consequences of both will be examined in this report.
- 1.2 The situation can also be examined in managerial terms, because it is possible to differentiate between problems arising from discharges emanating from mines long -since abandoned, and those arising as a result of the active closure of existing mines. Consideration also needs to be given as to what provisions should be made in the future with regard to the opening of new mines, or the re-opening of old ones; indeed the history of mining is one of continual development and redevelopment of mining areas, as the value and marketability of the mined materials has fluctuated.
- 1.3 The NRA's interests are therefore as follows.
- In the first instance, it is necessary to evaluate the extent to which existing discharges from mines already abandoned affect water quality, and would therefore need to be tackled if water quality is to be improved. In this regard, the situation is not greatly different from that of discharges from contaminated land.
 - Secondly, there is a need to ensure that the continuing abandonment of existing mines results in the minimal amount of environmental impact, and that it is carried out within the limited protection of the existing law.
 - And thirdly, in order to maintain the existing quality of waters, and to ensure that the effort currently expended to improve water quality is not hindered - particularly if such improvement programmes are related to meeting Water Quality Objectives which are to be set on a statutory basis - it is important to ensure that mining activities in the future are properly controlled.
- 1.4 These issues are not new to the NRA, and they are not new to Government. In the NRA's short existence the NRA has already given evidence to the following:
- Welsh Affairs Committee on the Future of Opencast Coalmining (March 1991);
 - Welsh Affairs Committee on Water Pollution from Abandoned Mines (March 1992);
 - Department of Trade and Industry on the Privatisation of British Coal (June 1992); and
 - Department of Trade and Industry on its Review on the Prospects for Pits Proposed for Closure by British Coal (November 1992)

In its evidence to all of these the NRA has repeatedly called for changes in the legal position of mine abandonment, and has said that the entire cycle of mine planning, opening, closure and possible re-opening needs to be re-examined. These concerns were echoed in the sixteenth report of the Royal Commission on Environmental Pollution published in June 1992, and the Government has since stated in "This Common Inheritance" - The Second Year Report (October 1992) that it is ".....considering the framework of legal responsibility for pollution in abandoned mines".

For the future, clear and adequate provision needs to be made when mines are opened for the consequences of their eventual closure, and some form of arrangement is needed for the long-term running of treatment plants, where necessary, in order to safeguard water quality. The NRA, as regulator, does not intend to become involved in the long-term operation of after-care provisions for any closed mine. It does, however, have a role to play in examining the potential measures which can be taken to deal with water from abandoned mines and to advise Government of their consequences.

2. WHAT ARE ABANDONED MINES AND WHAT IS THEIR LEGAL POSITION?

- 2.1 The recording of abandoned mines became a statutory requirement in 1870. The Mines Inspection and Regulation Act (1870) required owners of mines or their operators to inform a Mine's Inspector of an abandonment within two months of ceasing operations. Further coal mine Regulations were introduced in 1872, which required that all abandoned mines be recorded for health and safety reasons; an accurate plan of the mine was to be submitted to the Secretary of State within three months for planning control and development purposes.

National Legislation

- 2.2 This basis of defining an abandoned mine has been retained ever since, such that the Mines and Quarries Act 1954 requires notification of the commencement and ending of certain mining and quarrying operations. Thus Section 139 of the Act requires the mine owner to give notice to the district inspector of mines with respect to:

- (a) the abandonment of an entire mine, or a seam or vein within it, within two weeks of the mining activity having ceased; or
- (b) the expiration of a two month period since a mine, seam or vein has been worked, notice must then be given within two weeks.

Such requirements exist only in relation to working conditions and safety within the mines, and appear to have little or nothing to do with the environmental impacts of abandoning a mine.

- 2.3 Discharges from working mines in England and Wales are controlled through consents issued by the NRA under the Water Resources Act 1991. Such consents generally include conditions relating to the quality, quantity, discharge regime, and monitoring of the mine water. Separate consents are given for discharges from related above-ground activities. Once the mine is no longer operational, the mine owner can ask for the consents to be revoked. Should pollution subsequently occur, there is then limited control over the discharges for two reasons. Firstly, with regard to committing a pollution offence, the principal offence under Section 85(1) of the Water Resources Act 1991 (previously Section 107(1) of the 1989 Water Act), is that a person:

".....causes or knowingly permits any poisonous, noxious or polluting matter or any solid waste matter to enter any controlled waters".

A defence under Section 89(3) of the Water Resources Act 1991 is that:

"A person shall not be guilty under Section 85 by reason only of his permitting water from an abandoned mine to enter into controlled waters".

- 2.4 An *abandoned mine* is not defined in the 1991 Water Resources Act, nor in any other relevant legislation. However, a mine is said to have the same meaning as that in the Mines and Quarries Act 1954. As can be seen, the defence relates only to permitting, which in the case of long-abandoned mines implies that action need not be taken to ameliorate the effect of past practices. It could be argued, however, that the act of abandoning a mine *causes* pollution if, subsequent to such action, contaminated mine water enters controlled waters. Nevertheless, it is likely to be only one link in a chain of events. There has only been one successful prosecution in the UK with respect to pollution from an abandoned mine, and its success rested entirely on the proof of such a chain of events. In 1981 the Crown argued under Section 22(1) of the Rivers (Prevention of Pollution) (Scotland) Act 1951 that the National Coal Board (NCB) had caused pollution when it closed a Scottish mine it had opened and operated from 1951 to 1977. There was thus irrefutable evidence that the pollution resulted from the fact that the NCB had created a mine,

pumped water out of the way in order to mine it, and then allowed the mine to fill again and overflow with poor quality water. In the case of the Wheal Jane tin mine in Cornwall in 1992 the NRA - after obtaining detailed legal advice - did not seek to prosecute the mine operators because of the very long and complicated history of the large mining complex which had been abandoned. Similarly, where poor water quality occurred in the river Rhymney when British Coal abandoned a Welsh coal mine, the NRA again decided not to take legal action because the source of poor water quality was primarily that of workings which had not been owned or operated by British Coal. The Anglers Cooperative Association did subsequently take this case to the High Court, but was unsuccessful.

- 2.5 Where pollution is occurring, the NRA has general powers under what is now Section 161 of the Water Resources Act 1991 to carry out works which may be necessary to prevent the contaminated water from entering controlled waters, or to remove, remedy, or mitigate any pollution, and restore the waters to their previous state. The NRA is also entitled to recover expenses reasonably incurred in such work from those who caused or knowingly permitted the pollution *but not*

“.....from a person for any works or operations in respect of water from abandoned mines which that person *permitted*..... to enter into controlled waters.”

Thus, taking this and the situation with regard to prosecution together, the NRA is clearly somewhat limited in what it can do. Prosecution for polluting is difficult, and the cost of remedial action would have to be borne by the NRA. As the abandonment of a mine is often concomitant with the owner being in financial difficulties, any financial reimbursement is likely to be limited anyway. But an owner may have other sources of income, or have the capability of actual or potential development of the site from which an on-going revenue may be raised. The mine could also be re-opened within a relatively short period of time. The powers available to the NRA under Section 161 are nevertheless clearly of value in those circumstances where a polluting event has occurred and action can be taken to prevent or remedy the situation without any future commitment falling on either the NRA or the owner. More difficult are those situations where remedial action would require long-term management of works installed to prevent further pollution: the NRA could rapidly acquire a long list of sites to manage in this way.

- 2.6 There is also the question of cleaning up the site above the ground, and the possibility of a mine being mothballed for subsequent re-opening. Such questions involve the complicated situation which exists with regard to land ownership, mineral and development rights, mining rights, and the planning law. Briefly the situation is as follows.

Ownership, Mineral Rights and Mining

- 2.7 The Crown holds all of the mineral rights for uranium, and for all precious metals in the UK. Mineral rights for coal rest with British Coal. Other mineral rights, these were traditionally handed down by the Crown, attached to the ownership of the land. As land has since passed successively from one owner to another, however, the two may have become detached as a result of owners retaining the mineral rights when they sold the land. (If there is no clause in a deed of sale which specifies that mineral rights are to be retained by the vendor, the mineral rights automatically pass to the new owner of the land. Nowadays, more often than not, in mining areas, they are retained by the vendor).

A further complication is that neither the owner of the land nor the holder of the mineral rights may necessarily be the developer of a mine. In order to develop a mine in such a situation, it is necessary for the would-be miner to apply to the owner for the lease of the land, the possessor of the mineral rights - to whom he will pay royalties - in order to exploit them, and to the

relevant Planning Authority in order to develop a mine on site. In Cornwall the situation has historically been particularly complicated by Stannary Parliaments and Stannary Laws.

Planning Legislation

- 2.8 Planning permission is required to work minerals. Policies for the development and other use of land, including the extraction of minerals, are set out in statutory development plans drawn up under the Town and Country Planning Act 1990 (TCPA '90) as amended by the Planning and Compensation Act 1991. Mineral Planning Authorities are required to draw up mineral local plans for their area; each Authority may also decide, subsequent to necessary consultations - which include consultation with the NRA - whether or not to grant permission to work minerals above or below ground. An environmental assessment may be required. Permission is, in any case, usually subject to a number of conditions such as requirements to minimise or prevent environmental effects during a site's operation, and to ensure reclamation of the land once work has ceased. Mineral permissions are now time limited and in some cases the applicant or operator may have entered into a voluntary agreement called a 'planning obligation' under Section 106 of the TCPA '90.

British Coal has unique mineral rights. Under Schedule 2 of the Town and Country Planning General Development Order 1988 (1988 GDO) British Coal were granted unconditional permitted development rights for unlimited extensions to underground development at mines started before 1 July 1948, which continued the existing use of rights granted following the Town and Country Planning Act 1947. But Article 2 of GDO Amendment (No 6) Order 1992 now confines British Coal's permitted development rights in these 'GDO collieries' to designated seam areas which can be worked from an access existing on 13 November 1992. Guidance on coal mining and colliery spoil disposal is given in the Department of the Environment/Welsh Office's Minerals Planning Guidance 3, which is currently being revised.

International Commitments

- 2.9 As a member of the European Community (EC), the UK Government is required to comply with EC legislation. Because of the metalliferous content of mine waters, the NRA has specific responsibilities through the Water Resources Act 1991 with regard to their effect on compliance with EC Directives relating to dangerous substances in surface and underground waters. Of specific interest are the two metals cadmium and mercury. The relevant Directives have been implemented into national law by means of the Surface Waters (Dangerous Substances) (Classification) Regulations 1989 (SI 2286) which specifies standards for freshwaters (DS1) and coastal waters (DS2) within respective classification schemes. The NRA has been directed by the Department of the Environment (DoE) to perform various duties with regard to SI 2286, primarily relating to the consenting of discharges containing the substances listed, and the implementation of a suitable monitoring and analysis programme by which compliance with the classified objectives can be demonstrated.
- 2.10 When the NRA has reason to believe that surface waters are liable to fail the requirements of an annual mean standard, it has to provide the DoE with all relevant information as to the nature and circumstances of the reasons for failure, and the steps that the NRA has taken, or proposes to take, to restore the quality of the water. If such steps are unlikely to be effective within 12 months, the NRA has to provide the Department with such information as will allow the Secretary of State to "... determine in relation to any relevant discharge to those waters an appropriate emission standard in accordance with the relevant Council Directive". The EC Directives relate to controllable industrial discharges, but the Department's direction is less clear about whether or not the classification scheme contained in the SI relates only to areas influenced by controllable discharges. It has been the practice, however, for the previous Water

Authorities - and thus subsequently the NRA - to include in their monitoring programme those sites influenced by discharges from mining operations, but not necessarily those close to contaminated land. The NRA has also to send to the Department, by 30 April each year, information on the discharges, sampling, and analysis for the previous calendar year, and details of variations and additions to related discharge consents.

- 2.11 Other Directives of relevance to the topic of abandoned mines are the Freshwater Fisheries Directive, the Abstraction of Drinking Water Directive, the Shellfish Water Directives, and the Groundwater Directive. Compliance with all these requirements will be affected if the issue of abandoned mines is not, in the longer term, addressed.
- 2.12 There are also international agreements with respect to reducing the totality of certain substances entering coastal waters, as briefly discussed in the NRA's report on contaminated land (NRA, WQ Series No 15). The extent to which abandoned mines contribute to such inputs has yet to be fully evaluated.

3. THE NATURE OF MINE WATER AND ITS ENVIRONMENTAL IMPACTS

- 3.1 Water enters most mines in England and Wales and in working mines it therefore has to be actively removed by pumping. In addition to the direct downward movement of rainwater reaching the underlying aquifers, water may also enter via faults, galleries and adits, many of which may extend well beyond the surface watershed of the catchment. The quantity of water can thus be very large and very variable. The chemical nature of such waters varies from mine to mine, but a common feature is the presence of a reddish-brown suspension. Many mines contain iron minerals in their reduced form, which become oxidised and precipitate out to give the characteristic ferruginous deposit. A common feature of such mines is the presence of iron pyrites which, upon prolonged contact with water, dissolves to form sulphuric acid. This can lead to further leaching of metals which are naturally present. The final waters emerging may therefore be acidic, laden with metals such as cadmium, copper, and zinc, plus suspended materials which co-precipitate out as a highly coloured floc. Another not uncommon feature of some minewater discharge is that of "saline" water - the salts being of chloride or sulphate.
- 3.2 At working mines, treatment facilities are installed and operated to reduce the potential impact of such mine waters - together with effluent arising from pithead activities. Such treatment, which usually comprises of the neutralisation of any acidity and settlement of solids, ensures that receiving waters are afforded protection from working mines. Not all mine water, however, is necessarily of poor quality; indeed some of it is very good and is used to offset the effects of poor water quality surface waters by providing additional dilution. The closure of mines and their associated discharges could thus be beneficial to the quality of the receiving water in some cases.

The Chemistry of Mine Waters

- 3.3 The nature of mine waters, like those of surface waters and other groundwaters, varies very considerably. Different areas exist where waters draining from mines are alkaline, moderately or highly saline, alkaline and ferruginous, or acidic and ferruginous. The nature and effect of such waters can also differ, within the same mining complex, between that arising from shallow level workings and adits and that pumped or emerging from deeper levels. Understanding the nature of such waters is an essential preliminary to dealing with the discharges of individual mines, and this in turn is usually related to the hydraulic features of the mine. And whilst it is difficult to generalise on this subject, it is useful to examine the causes of one of the most common features - that of ferruginous waters - emanating from coal mines.
- 3.4 Ferruginous mine waters are caused by the oxidation of iron pyrites (pyrite), which is a mineral form of iron sulphide; superficially it resembles gold in appearance, hence the name 'fools gold'. Iron pyrites is common in both the coal itself and in the mudstones, of marine origin, which overlie the coal seams. (It is also common in metal mines.) Up to 10% of such layers may consist of this mineral. They may be continuously, or sporadically, exposed to air in near-surface levels, but in deeper workings such strata will have been below the water table. When the water table is lowered by pumping, these strata become exposed to air. The iron pyrites then rapidly oxidises, although such oxidation can take place in a variety of ways and via a number of intermediate chemical products, depending on the precise environmental conditions. Factors which are known to influence the rate and extent of the oxidation reactions include the sulphide mineral content, its morphology, the availability of oxygen, and the ferric ion concentration. Several of the rates of oxidation are also greatly increased by the catalytic activity of bacteria, principally those of the genus *Thiobacillus*. Other sulphide minerals present may undergo a similar series of chemical reactions when exposed to air and water. The oxidation creates acidic conditions, with the result that sulphuric acid is produced in various quantities and at different rates. This acid may then cause other minerals to dissolve.

- 3.5 In underground workings the pumping of mine water reduces the rate at which leaching occurs from exposed surfaces. Acidic mine waters are treated to neutralize them- if only to protect mining machinery. When mining operations cease, however, and the pumping stops, the water table returns to its natural level - or to a new level as a result of the mining operations. This flooding of the exposed seams stops the oxidation of the iron pyrites, but brings into solution the sulphuric acid and the iron sulphates which are the products of the oxidation reactions. The result of this depends on the nature of the rock strata. If they are calcareous, and particularly of limestone, the mine water may be neutralised; such waters usually have a reduced iron content. If they are not calcareous, however, the mine water may become highly acidic; the acidity of the water may go as low as pH 1 or 2 and become even more loaded with iron, and often with manganese.
- 3.6 When the rebounding water finally reaches the surface it may emerge via old adits, emerge as a spring, or simply emerge as seepage through the ground or even through the bed of an existing river or stream. When the water emerges it may well be clear, because the underground water is low in oxygen and the iron is in solution. As this water mixes with the air - which may occur before it emerges above ground - the iron rapidly oxidises from the ferrous to the ferric form and precipitates out as an orange deposit. In shallow mines, or in adits set in higher ground, such cycles may be repeated continually as the groundwaters fluctuate. In deeper mines connections may be made with underground aquifers. Quite frequently the history and extent of mining is such that neither the hydraulic conditions, nor the chemical state of the water, can be predicted once the last mining activity ceases.
- 3.7 Similar chemical reactions also occur in colliery and metal mine spoil tips above the ground, so that run-off from them may be acidic and ferruginous. A further problem, however, is that they are a source of particulate material, usually of very fine, often colloidal, clay and shale particles which in turn may carry other chemicals, particularly metals, with them. Thus factors such as rainfall can affect the natural variation of waters in surface adits, and the rates of leaching within surface spoil tips.

Biological Impacts

- 3.8 The impacts on aquatic communities may not be immediately obvious, but can have serious environmental consequences. The biological effects include:
- depletion of numbers of sensitive organisms and reduction in the diversity of the community within the river corridor;
 - depletion of numbers and reduction in the diversity of the benthic macro-invertebrate community (organisms living on and in the stream bed);
 - loss of spawning gravels for fish reproduction and nursery streams; and
 - fish mortalities, particularly of indigenous salmonid species.
- 3.9 Clear streams can turn into highly ochreous ones of a vivid orange appearance. Such discharges make rivers virtually fishless by coating the river bed with precipitating iron hydroxides. Depletion of the numbers and diversity of benthic (bottom dwelling) species occurs because the precipitate has a smothering effect, reducing oxygen and covering the river bed with iron oxides. This process also reduces the extent of spawning gravels for fish breeding, by occluding the interstices of the gravels with fine sediment, and therefore limits the availability of nursery streams. Natural game fish populations - salmon, sea trout and trout - are particularly susceptible to such pollution. The low pH can be directly toxic, causing damage to fish gills. Solubilized metals, not only those which emerge from the mine water, but those - such as

aluminium, the third most abundant element within the Earth's crust - can become dissolved within streamwater because of the acidic conditions. Such conditions are extremely toxic to fish.

- 3.10 In certain locations the natural fish and invertebrate populations of Welsh streams have suffered high mortalities due to mine water pollution; for example, the River Pelenna (known locally as the Yellow River, because of sulphur and iron deposits) is essentially lifeless for 17 km due to acidic discharges. Perhaps the greatest impact of mine water pollution, however, occurs in the smaller streams which are not classified under the river quality assessment scheme. These streams, which typically form the headwaters of rivers, are vitally important as fish breeding grounds and nursery areas for developing juveniles. The loss of these areas is undoubtedly a major contribution to the decline in fish populations which has been demonstrated in some locations; for example, in the Nant Melyn (a tributary of the River Aman at Cwmgors) actual trout populations are no more than 25% of those predicted by a well developed fisheries model (HABSCORE III). Similarly, the River Rhymney shows signs of being adversely affected by mine drainage in that the number of invertebrate taxa encountered is only 37% of that expected.

Impacts on Other Water Users

- 3.11 Other impacts include the imposition of restrictions on legitimate users of the water body, who may find the water unsuitable for irrigation, livestock watering, industrial, or potable water supply. There may also be significant consequences for shell fisheries, conservation areas, and recreation and tourism. The immediate cessation of pumping may also have the following consequences:
- where pumped mine water is of good quality, it can affect the available dilution for consented effluent discharges, resulting in pollution which had not previously occurred nor been anticipated;
 - it can reduce the availability of water for abstraction;
 - it may adversely influence the amenity value of the watercourse; and/or
 - lead to localised flooding problems or exacerbate such problems in vulnerable downstream areas, once uncontrolled discharges occur from flooded mines.
- 3.12 The aesthetic impact of ferruginous mine waters on rivers and streams, by the presence of a high colouration, immediately reduces the amenity value of an area. Many complaints are received from the public on this matter and people genuinely find such a situation of great concern. A direct consequence of this visual damage is a reduction in the use of a waterbody for recreational and watersport activities. Again, this reduces the economic and social value of the water resource to the local community.
- 3.13 An impairment of the quality of a river because of mine water pollution may also render it unsuitable for industrial and potable water supply, and often unsuitable for irrigation. With the recent years of drought experienced in England and Wales, this only serves to put additional pressures on an already stretched water resource. Nevertheless, it is important to note that water from abandoned mines is not always of poor quality. In the NRA's Yorkshire Region the cessation of good water being pumped from a closed coal mine can have serious consequences on the volume of water which enters an old canal feeder reservoir, which is now a feature in the centre of a country park, and a popular fishery. In dry years a single temporary pump can be used to augment the flow but, fortunately, in 1993 this was not required as there was sufficient rainfall to recharge the system.

- 3.14 Predicting the effect of mine closure is extremely difficult: the time taken for groundwater to rebound to a more-or-less equilibrium value can take from a few months to quite a few years. Part of this is due to the point of entry, particularly via various mine shafts. Indeed, a knowledge and care of mine shafts is an integral part of dealing with the problem. Planning decisions are often made which fail to take full account of mine shaft location. Shafts are often inadequately infilled prior to redevelopment of the land. Shafts may be left uncapped, which not only leads to water entry, but to the use of the shafts for fly tipping an unknown quantity of potentially polluting chemicals and materials.
- 3.15 Finally, it is also important to consider that changed flow regimes which are a consequence of the cessation of pumping can affect the flow rates on the surface. Changed flow patterns can affect the availability of water for abstraction or, more seriously, can lead to localised flooding problems as old wells and springs become reactivated, or exacerbate existing flooding problems within vulnerable downstream areas.
- 3.16 As with all other situations involving the pollution of a natural resource, there is also an economic cost as well as an environmental one. In this case, there are many economic costs. The reduction in the quality of water will affect the wide variety of uses which are demanded of it and ultimately there is a price to pay. The environmental consequences thus cannot be separated from the economic impacts and the two must be viewed in parallel.

4. ESTIMATING THE SCALE OF THE PROBLEM - ABANDONED COAL MINES

- 4.1 One would have thought that, with legal requirements in place to record abandoned mines, estimating the number of such mines should be a straightforward exercise: this is not the case. The Mines and Quarries Inspectorate holds only non-coal records, and the data are not in a form which is easily accessible to the public. And there are no records of any mines abandoned prior to 1872. British Coal holds its own data base of approximately 10,000 abandoned mine workings, but this figure is only an estimate and complications arise as a result of recent trends to re-open mines for commercial, recreational, and educational purposes. As with contaminated land sites however, the absolute number of abandoned mine workings is not in itself of concern to the NRA; indeed, strictly speaking, it is not in the abandoned mine workings but in the mine waters that the NRA's interests lie. Thus it is only that proportion of abandoned mines which are causing water pollution, or have the potential to do so, which this report addresses.
- 4.2 It also comes as no surprise that the problem of water from abandoned mines does not follow an even geographic pattern, but is concentrated in specific areas of England and Wales. The principal coal fields and mined mineral deposits are indicated in Figure 1. Of the ten former NRA Regions, six (North West, Northumbria, Yorkshire, Severn Trent, Welsh, South West) can identify significant water quality problems arising, or likely to arise, from abandoned mine discharges (Figure 2). For example in the Northumbria Region - where there has been a decline in the largely coastal coalfields - the NRA is faced with 15 significant discharges, and with some 100 discharges in total. Similarly, Yorkshire Region has 36 abandoned mine workings currently causing serious or significant pollution. The South West has a very large number of abandoned mines. And in other NRA Regions, the existing problems experienced from abandoned coal mines are likely to be greatly exacerbated in the future if pumped de-watering ceases at sites due for closure.

Numbers of Discharges and Lengths of Rivers Affected.

- 4.3 The number of discharges from coal mine workings causing significant pollution (ie. subjects of complaint, deterioration in water quality and failure of Environmental Quality Standards (EQSs) or of non-statutory River Quality Objectives (RQOs)), together with estimates of the lengths of rivers affected, are given in Table 1. This information has been obtained from a survey which was carried out as part of a national R&D project on abandoned coal mines. A full list of watercourses affected is given in Appendix 1. (Less serious discharges, of which there are many, are excluded. Natural ochreous discharges are also excluded). Close to 100 discharges, mostly originating from underground workings, are currently causing considerable concern. Some 200 km of rivers, streams, or brooks are affected. Some also contain metal deposits which contribute to the overall abandoned mine water pollution problem.

Table 1: The extent of the problem: Discharges from coal mines which cause significant pollution problems (by original NRA region).

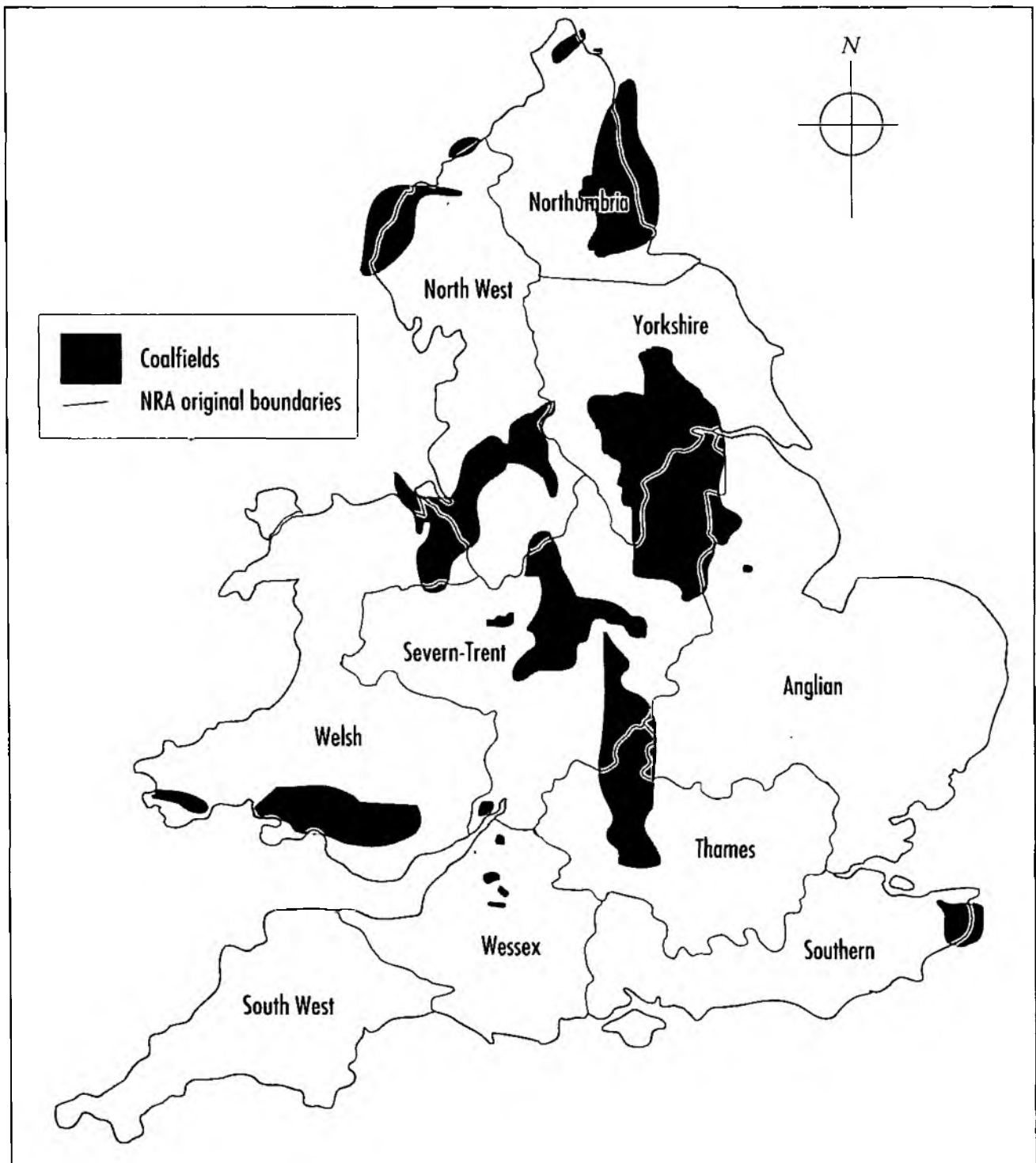
Region	Discharges by Number ¹	km Affected ²	British Coal	Other Coal	Working	Abandoned
Northumbria	15 (all)	18 (12)	11	4	4	11
North West	24 (14)	57 (25)	19	5	Nil	24
Severn Trent	4 (all)	19 (4)	Nil	4	Nil	4
Welsh	21 (all)	54 (22)	6	15	Nil	21
Yorkshire	36 (most)	50 (11)	Most	Few	Nil	36
Total	100	198				

Notes

¹ Main occurrences from coal mines (originating from underground mines in brackets)

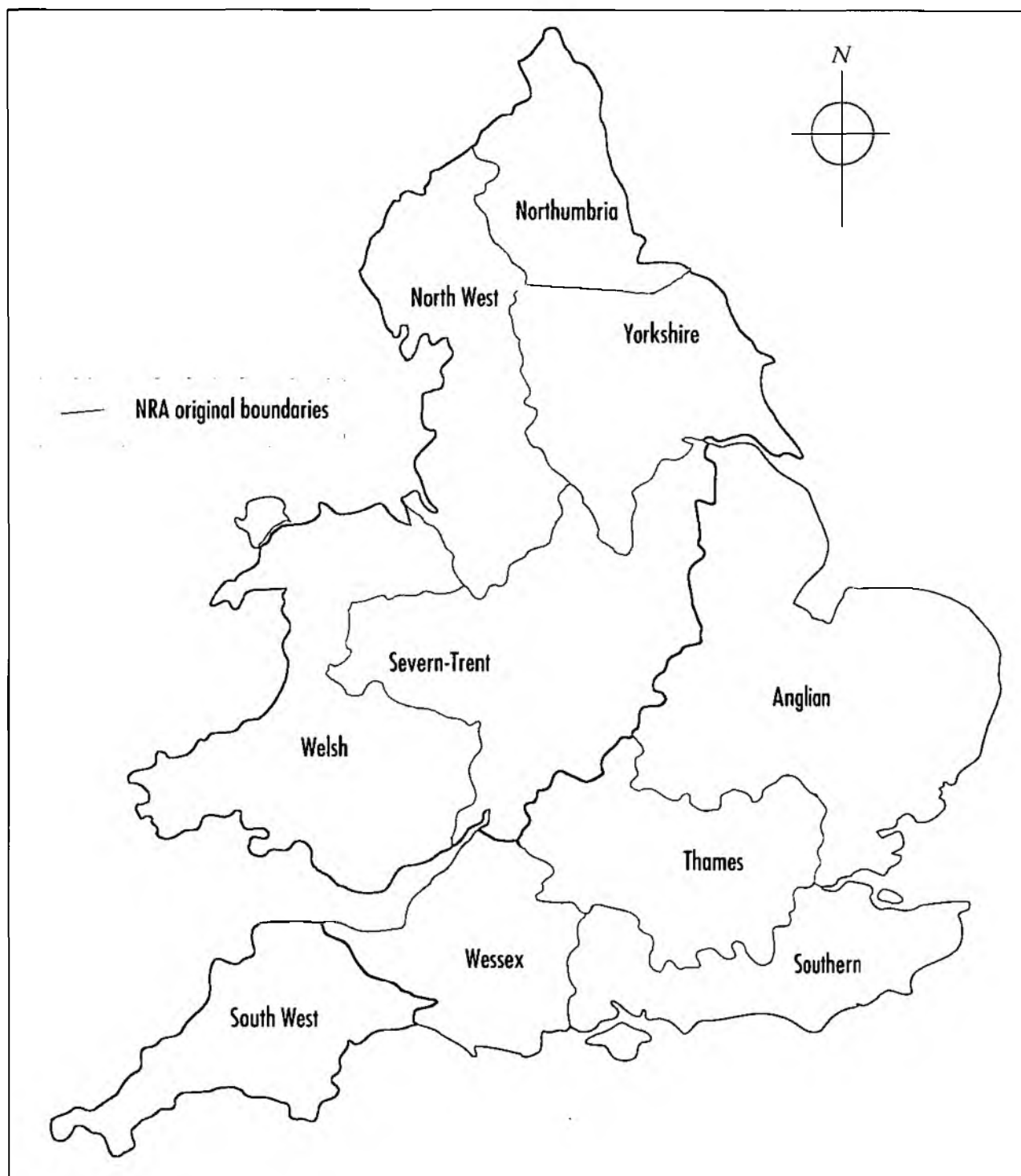
² Estimated total for main occurrences (numbers of waterways listed in brackets)

Figure 1: British Coal: Coalfield Groups and Original NRA Boundaries



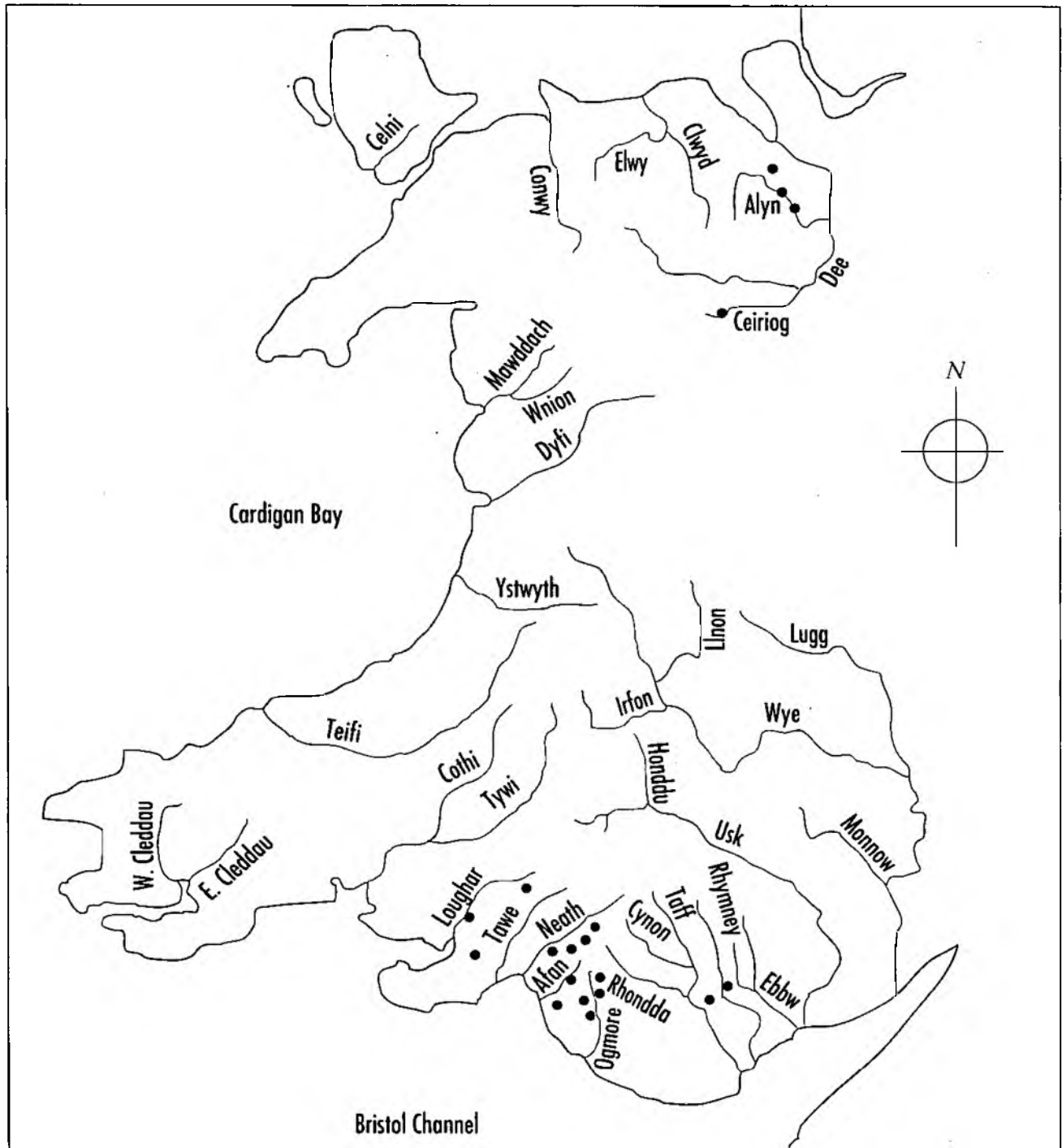
- 4.4 The data in Table 1 have nevertheless to be seen in perspective. For instance in Welsh Region there are 21 discharges into classified rivers, affecting about 1% of the Region's total classified river length but equivalent to 4.5% of the classified river length within the South Wales coalfield (Figure 3). More importantly, however, of the river length in this coalfield which does not achieve its current non-statutory River Quality Objectives, at least 25% of the failure is caused by mine water discharges. There are many instances of breakouts of ochreous water into rivers, which were previously clean, causing fish kills. Open cast mines are presently treating some mine waters, but this is only a short term measure. Figure 3 illustrates the more significant discharges which are well known to the NRA, but there are also probably many more discharges

Figure 2: NRA Regions Experiencing Water Quality Problems arising from Abandoned Mines.



to minor watercourses. In addition to the impact of major, largely British Coal owned, collieries there are also about 50 privately owned small mines, predominately in the Swansea and Neath Valleys. Historically there have been many hundreds of these private mines, generally exploiting the valuable anthracite coal seams of the western part of the South Wales Coalfield. Discharges from these mines play a significant part in pollution of small streams. A fuller survey is currently being undertaken by the NRA, funded by the Welsh Office, to locate and assess the impact of all abandoned coal mines in Wales, including that on unclassified streams.

Figure 3: Significant Mine Water Discharges in Wales (Coalmines)



- 4.6 As could be expected, the extent to which abandoned coal mines have affected surface water quality has in the past been differently appraised in each NRA Region. Local experiences differ. Thus there has been a significant decline in the Northumberland and Durham Coalfields for a number of years and most of the present discharges are located on the coast. In the twelve rivers most affected, the main pollutant from coal mines is iron. Tipalt Burn has an additional problem because of discharged particulates. (All but Elsdon Burn, Maglin Burn and Allerdean Mill Burn are also variously polluted with sewage effluent and urban drainage.) Problems are also experienced with lead and zinc in the Upper Tyne, where levels of 1 to 2 mg/l of these metals contribute to the quality of the river being National Water Council (NWC) Class 3 in the 1990 survey; some 50 km of river were in this Class because of such workings.

- 4.7 Similarly there are 24 significant discharges from abandoned mines in the North West Region, mostly from coal mining but also from abandoned ore workings. In some areas ochre has been present for such a long time that there is little public reaction. There have recently, however, been new outbreaks of iron-rich waters which have caused discolouration of some streams leading to public complaint. The northern area of this Region in Cumbria and North Lancashire is characterised by high quality waters with low levels of pollution; visual pollution therefore attracts a high public profile. There are also some lengths of contaminated canal water, especially in the Trent and Mersey Canal and in the Bridgewater Canal.
- 4.8 The NRA's Yorkshire Region has some serious problems with mine waters, many of which originate from long-abandoned mineworkings. Ganister and fireclay mines have produced very acidic run-off, but discharges from these tended to be small, whereas coal mines had substantially larger discharges - some up to 4500 cubic metres per day. These larger discharges have been responsible for significant reductions in river quality due to iron deposition and salinity. There are no significant discharges of other metals from mine workings in the Region, although there is run-off from lead workings in the Pennines during extreme weather conditions. Eleven watercourses are affected. In addition to iron contamination from mines, there are other industrial sources of pollution which are reducing water quality. The Severn Trent Region also has significant problems with abandoned mines, as well as a number of problems from operational mines. Most of the pollution results from iron deposition, but some mine effluents are also very saline.

Typical Case Studies of Abandoned Coal Mines

- 4.9 There is of course nothing novel about waters arising from abandoned coal mines, and this is not a problem which has been completely ignored in the past. Indeed several attempts have been made by the NRA's predecessor bodies to ameliorate their effects, and it is therefore of value to examine briefly the extent to which they have been successful.

Black Clough, River Calder, North West Region

- 4.10 The River Calder has its source at Calder Head, some 6.4 km south east of Burnley. At a distance of 1.2 km from its source it receives its first tributary, Black Clough, just upstream of the village of Holme Chapel. Black Clough rises on Deerplay Moor and has a total length of 1.8 km. After 0.5 km, mine water seeps up through the ground at the upstream toe of an embankment crossing the valley. A further 0.1 km downstream it receives drainage via a "water loose" (the adit or outlet from the colliery workings) from the three now abandoned coal mines known as Black Clough, Deerplay and Hilltop. Below this the Black Clough flows for another 0.1 km before joining the River Calder (see plates i to iv). The river flows through the villages of Holme Chapel and Walk Mill and then passes through Towneley Park before, in the area of Burnley Town Centre, it is joined by the River Brun. The catchment up to this point is approximately 2,240 ha with a population of 21,600. The area surrounding Towneley Park through which the Calder flows is used for recreation, leisure, and tourist purposes.
- 4.11 On the basis of the NWC classification scheme used in the NRA's 1990 River Quality Survey, the River Calder upstream of the Black Clough is a class 1B river, and Black Clough itself is a Class 4 river. Below the confluence, the River Calder becomes Class 4 for a distance of 1 km to the junction with Easden Clough. It then becomes Class 3 for a distance of 2.5 km to Everage Clough at Towneley Park, and then becomes Class 2 below this point where it merges with the River Brun.
- 4.12 The last of the three collieries to close - Hilltop - ceased production in 1968. As a result, pumps which formerly lifted water from this mine to the River Irwell were dismantled. The old

interconnected workings quickly filled with water and an outflow to the Black Clough re-occurred in May 1969. The last previously recorded discharge via this outlet was in 1953, although local history indicates that a discharge commenced about 1840.

- 4.13 The water discharging from Black Clough "water loose" has been found to be slightly acidic with an average iron concentration of between 70 mg/l and 100 mg/l. It is understood that the iron content of the water when the discharge re-occurred in 1969 was approximately 1000 mg/l. On exposure to the atmosphere, and meeting the slightly alkaline surface water forming Black Clough, heavy deposits of iron hydroxide form wherever the velocity of the water is insufficient to keep it in suspension. The flow in the Black Clough constitutes a significant proportion of the flow in the Calder (up to 50% immediately below their point of confluence) and so the river Calder itself, including its bed and banks, acquires the colour characteristics of the Black Clough. These are noticeable through the villages for a distance of about 8 km. Even if all the polluting flow from the Black Clough was removed, existing deposits would remain until natural scouring by high flows removed them.
- 4.14 In 1980, the then North West Water Authority produced a report on the pollution of the River Calder at Cliviger, near Burnley, which identified a number of possible solutions to the mine water problem. These were as follows:
- the provision of settling ponds on the floor of the Calder Valley at Cliviger, with or without the addition of secondary (chemical) treatment, and with or without the addition of high gradient magnetic separation;
 - a similar set of treatment processes but located at the Black Clough water loose;
 - connection to the Burnley sewerage system from Black Clough water loose (2.6 Ml/d);
 - connection to the Burnley sewerage system from the Black Clough/River Calder confluence (10 Ml/d);
 - groundwater control; or
 - "daylighting" - removal of iron bearing strata as part of a major opencast coal mining exercise.
- 4.15 What happened to the proposals? The Calder Valley settling pond schemes have since been considered environmentally unacceptable and aesthetically damaging to the area, and it is now considered that the similar scheme for Black Clough would be difficult to construct and operate because of site and access problems. Groundwater control would not ensure that the problem would not simply be transferred to the River Irwell, whilst "daylighting" was rejected by the then National Coal Board (NCB), who did not regard the mining of coal under such circumstances as economic. The remaining schemes would require a connection to the Cliviger sewer. Connection from the Black Clough/River Calder was originally preferred, but following further investigations it is now the less favoured option. The effect of the large flow (10Ml/d) on sewers in Burnley, and on the sewage treatment works, would create a pollution problem further downstream unless extensive enlargement of the system and the works was carried out. In addition, Black Clough would remain polluted and on approximately fifteen occasions every year the capacity of the transfer pipe would be exceeded. This would result in excess flows entering the River Calder at a time when their quality was low due to scouring of the deposits on the stream bed.
- 4.16 In order to achieve the only remaining solution - connection to Burnley sewers from Black Clough loose - a satisfactory agreement would have to be reached by all interested parties on



Plate i: The Black Clough and Colliery Spoil Tip.



Plate ii: The Black Clough South of the Spoil Tip.



Plate iii: The Black Clough, Deeplay Moor.



Plate iv: The Black Clough and River Calder.



Plate v: Bullhouse Minewater -Adit discharge to the River Don at Millhouse Green, Penistone.



Plate vi: Sheephouse Wood Adit discharge between Langsett and Midhopestones.



Plate vii: Wheal Jane Mine.



Plate viii: Clemows Valley Tailings Dam.



Plate ix: Plume of contaminated mine drainage at Carrick Roads.



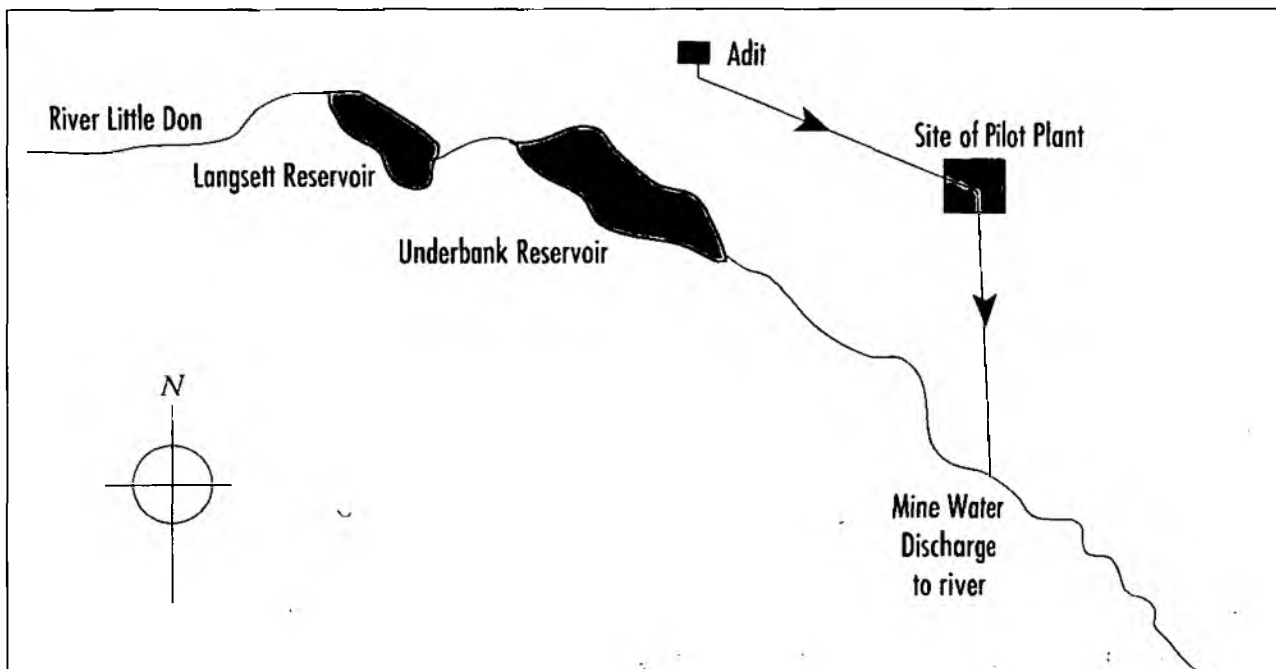
Plate x: Restronguet Creek and Penpol Creek two days after the major incident.

financial contributions towards relaying and increasing the size of the Cliviger sewer. At the moment there are no plans to divert the stream to sewer.

Sheephouse Wood & Bullhouse Collieries, Upper River Don, Yorkshire

- 4.17 The Sheephouse Wood and Bullhouse collieries have been discharging into the Upper River Don and River Little Don for many years. Work to improve the quality of the discharges has been undertaken for almost a decade. In 1984, the National Coal Board (NCB) and South Yorkshire County Council produced a paper investigating the discharge from Bullhouse colliery (NBC, 1984). More recently both the Bullhouse and Sheephouse Wood adits have been extensively investigated by the NRA and the BOC Foundation (BOC Foundation for the Environment and Community) as part of a NRA national R&D project. Hence this case study is of significance from both a water quality and a managerial point of view.
- 4.18 The catchment of the River Don has had working mines for centuries, not only for coal but for other minerals such as fire clay, gannister and iron ore, and in the Peak District for lead and fluorspar. The Halifax Hard Seam along with ganister and fireclay has been worked at the Bullhouse Colliery from the early 1800s until its abandonment in 1915. During the life of the colliery old uncharted workings from the outcrop were encountered at several places, and their date of origin is not known. From 1916 the mine was developed from a new entry, School Works Drift, and eventually connected with Hand Bank and Hollingwood Collieries' workings. Operations continued following nationalisation, by General Refractories under licence to the National Coal Board, until abandonment in 1963.
- 4.19 The Sheephouse Wood mine effluent emerges from the hillside above Underbank Reservoir and is diverted from there in an open channel to the River Little Don downstream of the reservoir. This channel is maintained by Yorkshire Water and was constructed under an Act of Parliament (Sheffield Corporation Water Act 1885). The Bullhouse mine effluent enters the River Don directly. Present activity in the area involves the Hepworth Iron Company which is extracting a clay bed to a depth of 7.6m below the Halifax Hard Seam. Although several water drainage adits exist, the only two operating are Bullhouse, discharging to the Upper River Don, and Sheephouse discharging to the River Little Don (Figure 4).

Figure 4: Sheephouse Wood Mine Discharge and Pilot Plant.



- 4.20 The mine effluents at Sheephouse and Bullhouse have been investigated and found to have levels of iron up to 75 mg/l (Table 2). In the case of Sheephouse Wood adit, this was almost entirely dissolved, but had settled out to a large extent by the time it was released to the River Little Don. Both effluents colour the receiving waters bright orange for some distance downstream and lower the quality to (NWC) Class 3. The Bullhouse adit discharges into the Upper River Don, reducing it from (NWC) Class 1B to Class 3 and the river remains in this class for approximately 4km. The effluents in themselves (plates v and vi) are not particularly toxic to fish and invertebrate life, but the smothering effect of the released iron oxides on the bed of the stream results in a significant reduction in the macro-invertebrate fauna and consequently very low fish populations are present in both rivers.

Table 2: Partial analyses of mine water samples

Samples Taken	Results Obtained
Sheephouse Wood (15/7/91) Adit (clear effluent) Adit (sediment) River Level (suspension)	75 mg/l Fe Almost entirely hydrated iron (III) oxide 300 mg/l Fe (sample probably unrepresentative)
Sheephouse Wood (1/10/91) Adit (clear effluent) River level (suspension)	45 mg/l Fe, pH 6.4, 0256% of saturation 56 mg/l Fe (3 mg/l in solution), pH 7.8, 02, fully saturated
Bullhouse (1/10/91) Drainage (clear effluent)	44 mg/l Fe, pH 5.9, 0263% of saturation
Sheephouse Wood (8/11/91) Adit (clear effluent) River level (suspension)	21,23 mg/l Fe 34,35,36 mg/l (0.44 and 0.14 ppm in solution) Fe
Sheephouse Wood (11/12/91) River level (suspension)	27 mg/l (<0.2 mg/l in solution) Fe
Sheephouse Wood (6/2/92) Adit Midhope River level	33 mg/l Fe 32 mg/l Fe 24 mg/l Fe, approx. (0.9 - 1.3)x103m3/day
Bullhouse (6/2/92)	48 mg/l Fe, approx. (2.2 - 2.6)x103m3/day
Sheephouse Wood (2/4/92) Adit River level	29,23,22,172 mg/l Fe, Mg, Ca, Na, resp. 23,23,22,145,450,20, nil mg/l Fe, Mg, Ca, Na, sulphate, chloride, phosphate respectively.
Bullhouse (2/4/92)	52,68,66,113,934,54,7 mg/l Fe, Mg, Ca, Na, sulphate, chloride, phosphate respectively.

- 4.21 To reduce the high iron concentration in the mine water some form of treatment was obviously required using aeration and/or chemical processes. The 1984 study sought to examine the possibility of directing the two separate flows into one, emerging via the Sheephouse adit and to install a treatment plant prior to the discharge to the River Little Don; however, the research concluded that this was not feasible and that treatment of the two water outlets would be required.

- 4.22 The NRA/BOC R&D project examined the existing physical and chemical methods, which generally involve sedimentation in lagoons, or flocculation methods which often necessitate raising the pH of the effluent. Research showed, however, that in Langsett Water Treatment Works impurities from raw water are adsorbed onto hydrated ferric oxide gel particles, which is almost identical to those produced in the Sheephouse Wood effluent as it precipitates out. It would seem that the best treatment for the Sheephouse Wood effluent would be to route it through the water treatment works. A further suggestion to reduce costs was to use wastes from local industries to assist in flocculation and polishing. The NRA/BOC established a pilot plant, near the present outfall from Sheephouse Wood with the co-operation of Yorkshire Water in March 1993. This objective was achieved. As research had suggested, some wastes from local industries were used to assist in flocculation and polishing. Filter pressed sludge from Yorkshire Water was used and also "Red Dust" from an engineering steel works. Smelter slag dust was also used, although further research is needed to refine this practice as levels of cadmium in the dust used caused concern. The main conclusion of the study is that the pilot scheme was a success and could be scaled up to deal with larger volumes. The NRA is also sponsoring a PhD studentship to examine further the microbiological activities associated with treatment of the effluent. The objective of the pilot plant was to reduce the iron content of the effluent to 5 mg/l - this was achieved and subsequently would allow the Don to meet its Environmental Quality Standard for dissolved iron (which is a national UK standard for iron of 1 mg/l, set in 1989).

Acid Mine Drainage in the River Pelenna, Welsh Region

- 4.23 The River Pelenna is a major tributary of the River Afan in West Glamorgan, South Wales and has been severely affected by a number of minewater discharges since the closure of collieries in the early 1960's. The river is very well known due to the bright yellow-orange colouration caused by the deposit of iron ochre along its length and has been described in the national press as the "Yellow River".

Studies undertaken by the Institute of Hydrology in 1992, with support from the BOC Foundation for the Environment and the NRA, identified several key discharges that would need to be treated to enable restoration of salmon and trout fisheries in the Pelenna. At present fish are virtually absent from 17 kilometres of the river and the general river ecology is severely affected by the minewater discharges. Use of the river model QUASAR (Quality Simulation Along Rivers) has demonstrated that concentrations of iron in the Gwenffrwd and Blaenpelenna tributaries need to be significantly reduced if fish populations are to thrive once again in these streams.

The Welsh Region of the NRA and West Glamorgan County Council entered into detailed planning for a remedial scheme during 1992 and in March 1993 consultants undertook a detailed feasibility study to ascertain whether a constructed wetland treatment system would achieve the targets identified by the Institute of Hydrology modelling work. It was concluded that a series of wetlands would be feasible and a scheme involving 5 phases was proposed. This formed the technical component of an application for funding support under the EC LIFE programme. The application was initiated and led by West Glamorgan County Council with the NRA as a project partner and the Welsh Development Agency as a co-funding body. The EC Funding support for the project was confirmed in November 1993 and the project commenced in January 1994.

Construction of the first wetland will take place during the summer of 1994 and the NRA will be undertaking detailed environmental impact assessments to establish the precise benefits of the scheme.

The project is a full scale demonstration of the technology and is likely to be of considerable national and international importance as it may have many direct applications for the rehabilitation of streams in mining areas across the European Community.

Welsh Region Abandoned Coal Minewaters Survey

- 4.24 Following the Welsh Affairs Committee Inquiry into the problem of abandoned minewaters in Wales in 1992, the Region succeeded in obtaining funding from the Welsh Office for a thorough survey. The NRA also contributed to the cost. Phase 1 was completed in December 1993 when 90 ferruginous discharges were relocated and their environmental impact assessed. This enabled them to be ranked in order of priority for possible remedial action.

The total length of river adversely affected by discharges from abandoned mines is 59.4 kilometres while the area of river bed affected is 220,000 square metres. The survey report is nearing completion and will be sent to the Welsh Office very shortly. The Welsh Affairs Committee will also receive a copy of the report.

Phase 2 of the project is now underway and the top 15 discharges will be further investigated to examine the causes of the problems, the potential solutions, the approximate costs and benefits. The work is being jointly funded by the Welsh Office and the NRA and is expected to be reported in May 1994.

Abandoning Mines in the Future

Procedures for closing mines operated by British Coal

- 4.25 In addition to evaluating the current impact of waters arising from coal mines already abandoned, the NRA is concerned to ensure that the procedures for closing existing coal mines are such that the impact on the aquatic environment is as minimal as possible, and that such action is carried out within the limited safeguards provided by existing legislation.
- 4.26 Where a colliery closure programme is implemented, British Coal has regard to future activities and the need for a consented discharge to controlled waters. A proportion of mines and associated tipping lands is held on a leasehold basis and the requirements of the lease may restrict the opportunities available. In freehold situations British Coal is generally required by specific planning consent conditions, or by an arrangement with the Department of the Environment with respect to collieries closed in the four years beginning 1 April 1990, to restore colliery surfaces after abandonment, unless alternative forms of development are accepted by the Planning Authority. When mines are not closed permanently, they will be retained on a "care and maintenance" basis, pumped and ventilated, and subjected to regular inspection. Little or no change in discharge regimes will be anticipated, although above ground work may be stopped.
- 4.27 British Coal is also obliged to restore the above ground condition of mines opened since 1948 - as a result of it inheriting obligations from its predecessor body, the National Coal Board, which was set up by the Coal Industries Act 1947. Mines opened prior to this date, however, are exempt.
- 4.28 Close and constructive liaison has usually obtained between British Coal and the NRA with respect to operating mines. As a result of the announcement in 1992 with respect to the possible closure of some 31 pits, the NRA made a limited assessment of the possible consequences. Evidence was also given to the Department of Trade and Industry at their request, and to the Department of the Environment.
- 4.29 Because of its experience with the Wheal Jane tin mine, and the very limited scope to deal with abandoned mines within the existing legislation, the NRA has sought to be as proactive as possible in order to minimise the impact of the growing legacy of abandoned mines. Of particular concern has been the possibility of pumps being switched off without its knowledge, because adverse situations might arise which it was then too late to correct. British Coal agreed to give the NRA at least 14 days notice of their intention to cease pumping operations at a mine,

and this agreement was strengthened by the drawing up of a Memorandum of Understanding (MOU) between the two parties on 18 November 1993 (Appendix 2). The MOU specified that regular regional meetings would be required at which British Coal would provide the NRA with particulars of the likely consequences of a cessation of pumping, how they planned to treat shafts and adits, and their consideration of any alternative proposals that NRA staff may put forward. Then at least 14 days notice (except in an emergency) would be given to the NRA in writing of British Coal's intention to cease pumping at a specific mine, together with a note summarising the exchange of information which had already taken place. Should a fundamental disagreement exist, then a national meeting would need to be held within 7 days in an attempt to resolve it. The NRA made it clear that British Coal retained responsibility for preventing pollution and therefore the NRA would expect it to obtain information on where and when groundwater would emerge, its quality, and what contingency arrangements British Coal had in place should their predictions prove to be inaccurate.

- 4.30 In view of the fact that groundwater rebound can take from months to several years, and that the ownership of the mine could change during that period, the NRA also stated that allowance should be made for preventative action to be taken at any time -such as provision for submersible pumps to be used to control water at different depths. Discharged water would continue, where necessary, to be consented.

5. ESTIMATING THE SCALE OF THE PROBLEM - ABANDONED METAL MINES

- 5.1 The mining of metals has a very long history in some areas, and many mines have been more or less continually worked for centuries. As a result, underground workings can be extremely complex and the extent of them is rarely fully known; above ground contamination with various metals can be equally extensive, and again this is rarely fully known. Entire water catchments may be affected, and delineating the precise source of contamination is in many cases virtually impossible, leading only to the conclusion that the contaminant is ubiquitous within a very large area, including the spoil tips above ground.

Number of Discharges and Lengths of Rivers Affected

- 5.2 Some NRA regions have problems with waters emanating from both abandoned metal mines and coal mines. With the abandoned coal mine discharges, estimates can be made of the number of discharges occurring and the lengths of classified rivers which they affect; such an estimate is given in Table 3. Again, as with the data presented in Table 1, many smaller watercourses are excluded from the analysis and there is thus much loss of detail.

Table 3: Discharges from metal mines which cause significant pollution problems. (by original NRA region)

Region	Discharges by Number	km Affected	Working	Abandoned
Northumbria	20	43	2	17
North West	5	36	1	4
Severn Trent	2	5		All
South West	Unknown	212	1	About 1700
Welsh	44	114	1	43
Total	> 71	410		

- 5.3 Both the nature and extent of the problem varies from one Region to another. Thus for example, although the main problems in the Northumbria and Yorkshire Region are associated with coal mines, the Region nonetheless has significant problems with abandoned metal mines, the main pollutants being iron, lead, and zinc. The majority of the discharges take place along stretches of rivers, which vary between NWC Class 2 and 3; the full extent of the problem is not known because unclassified stretches have not been adequately quantified. More detailed studies of these discharges, their locations, and their impacts, are currently being undertaken.
- 5.4 In contrast, abandoned metal mines in the Severn Trent Region are primarily a localised problem; for the most part, discharges are few and insignificant. Those which are of importance are situated along the Welsh border. The majority of problems result from the associated mine waste tip sites and are therefore considered primarily as part of the contaminated land problem.
- 5.5 It is the South Western Region which has the principal problems with water from abandoned metal mines. There are at least 1700 abandoned metalliferous mine workings in the region, many of which were small operations which produced ore for a short time only. At present there is only one metal mine still in operation, on the Red River in Cornwall, and this is currently not causing significant pollution problems. Most mines produced several minerals - principally copper, tin, zinc, arsenic, lead and some silver - with many minor minerals also being present. Some 22 of the 32 catchments in the region are affected by non-ferrous mining activities, and about 6% of the non-compliance with water quality standards result from such pollution. In classified waters this amounts to 212 km being significantly affected, but does not include the lengths of unclassified - unmonitored - streams many of which are significantly affected. Because of the extent of the problem, individual rivers are not listed in this report. The actual numbers of

polluting discharges is not quantified, and a very considerable effort would be required for them all to be catalogued. Some discharges are semi-saline, some are warm, and some contain substantial quantities of naturally occurring radionuclides. Work has now started to produce a regional data base of abandoned mines and shafts.

- 5.6 The Welsh Region, too, has serious problems with abandoned metal mines - problems equally as serious as those arising from abandoned coal mines. There are over 500 abandoned metal mines in west and north Wales, the majority arising from the mining of lead, zinc and silver in North Ceredigion near Aberystwyth and north east Wales. In Meirionnydd, copper and gold were extracted, the gold being associated with mineralised veins containing zinc. There are also extensive abandoned copper workings at Parys Mountain on Anglesey. In some cases the most serious pollution problems are related to the discharge of contaminated water draining from the abandoned mine workings. The most affected major rivers are Ystwyth and Rheidol near Aberystwyth. Both have significant stretches in NWC Class 3 and Class 2. This water quality is maintained all the way to the sea and has had a severe impact on game fisheries. The poor water quality is due to zinc derived from underground drainage water from the abandoned mines. There are also significant problems with water quality on the Conwy, upper Teifi, upper Towy, upper Dovey and upper Mawddach. At Parys Mountain, the Afon Goch is seriously polluted, elevating near shore copper concentrations very close to quality limits set out in the EC Dangerous Substance Directives.
- 5.7 A number of mines in the area have been re-opened for short periods of time and there is also a proposal to reprocess mine spoil in mid Wales. Whilst these operations have been relatively small in scale, they do pose serious long-term pollution threats when operations cease and the sites are again abandoned.

Case Studies of Abandoned Metal Mines - Wheal Jane, River Carnon, South Western Region

- 5.8 West Cornwall is rich in minerals and the Carnon valley (Figure 5) has been mined for hundreds of years. Originally, Wheal Jane was one of many shallow mines in the area, producing tin, copper, zinc and lead, and was drained by the Jane's Adit. The mine has a history of intermittent operation, with closures being caused by the tin ore being of low grade and poor economic circumstances. Following exploration, a deep mine shaft - Jane's No. 2 - was sunk between 1969 and 1971, when the mine was re-opened by Consolidated Goldfields Ltd. De-watering was by pumps at the base of No. 2 shaft. A neighbouring deep mine, Wellington, to which Wheal Jane is linked underground, operated briefly between 1976 and 1978 (Figure 6). On its closure, the additional burden on de-watering fell on Wheal Jane. This, together with the declining grade of tin ore, led to Wheal Jane's closure. However, de-watering was maintained using Government funds until RTZ Ltd. took over both mines in 1979. Wheal Jane re-opened in 1980 and quickly became the largest tin producer in the UK. The collapse of the tin price in 1985 created severe economic difficulties and in 1986 financial assistance was obtained from the Department of Trade and Industry (DTI). A management buy-out was effected in 1988, and increased financial assistance was provided by the DTI and RTZ Ltd. Despite this the decision to close Wheal Jane was taken by the company for operational reasons.
- 5.9 On 6 March 1991 operations at Wheal Jane ceased and the pumps which had been de-watering the mine were switched off. As a result, the water in the mine, which was acidic and contained significant levels of metals (including cadmium, zinc, nickel, arsenic, copper and iron) started to rise. The NRA identified the possible impacts of the mine flooding and a special project team was set up to monitor, identify, and predict the impact of the rising water levels on surface water quality. On 18 April 1991 the NRA warned the public through a press release of pollution risks from water building up in the mine and estimated that a discharge would occur before the end of the year. The mine was formally abandoned by Carnon Consolidated Limited under the Mines

Figure 5: The River Carnon Catchment

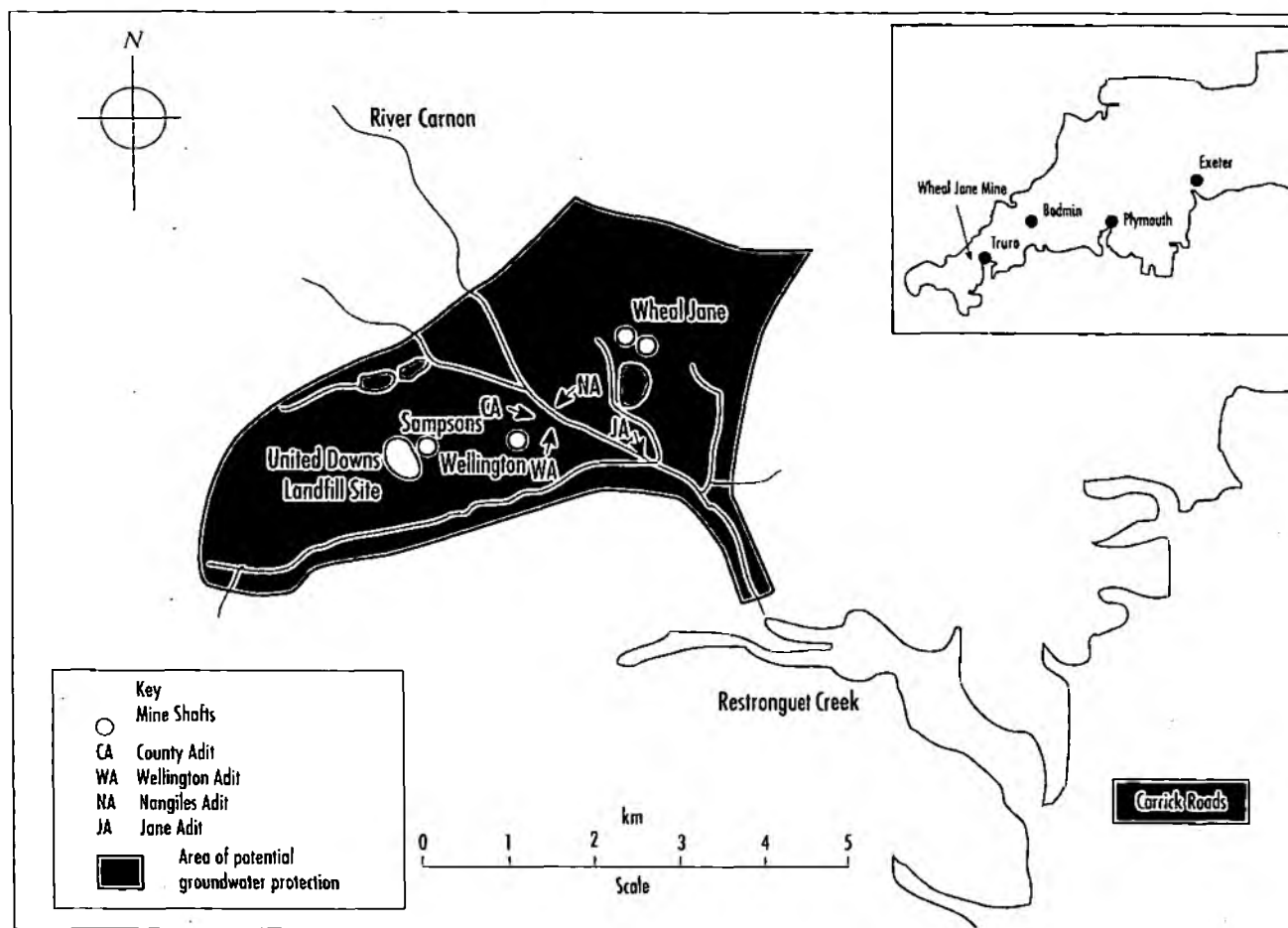
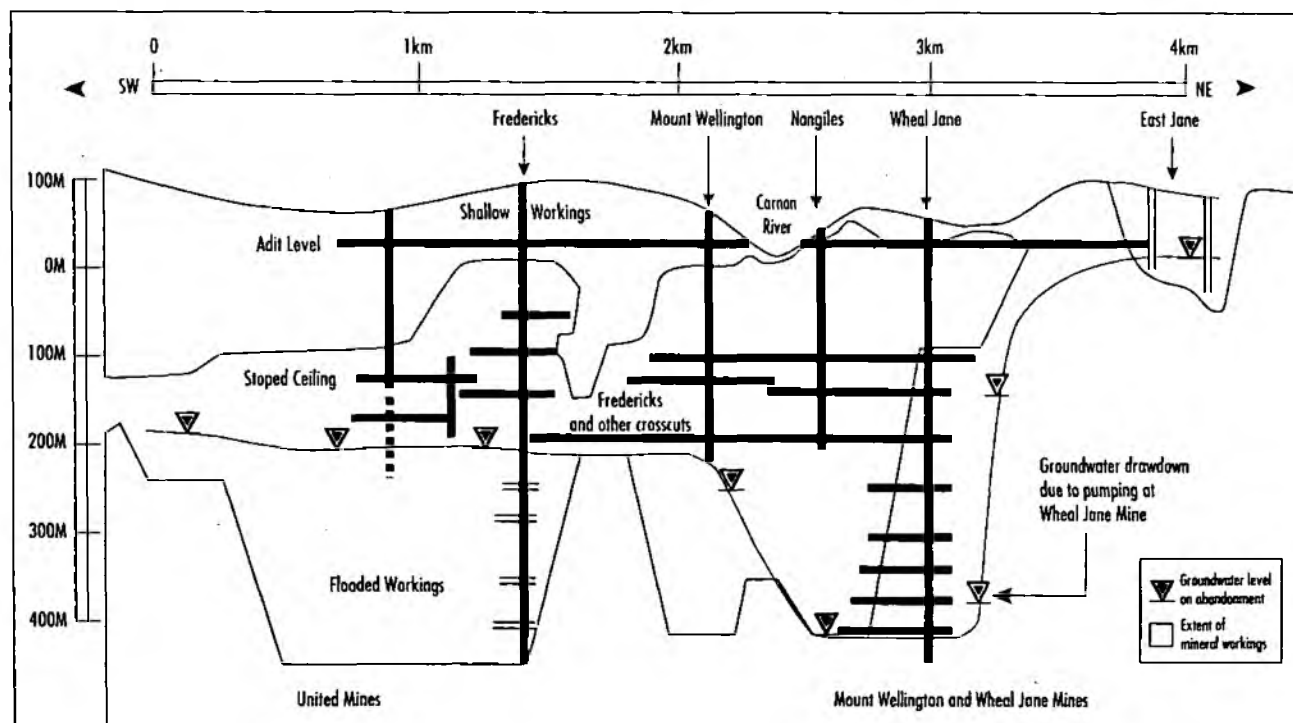


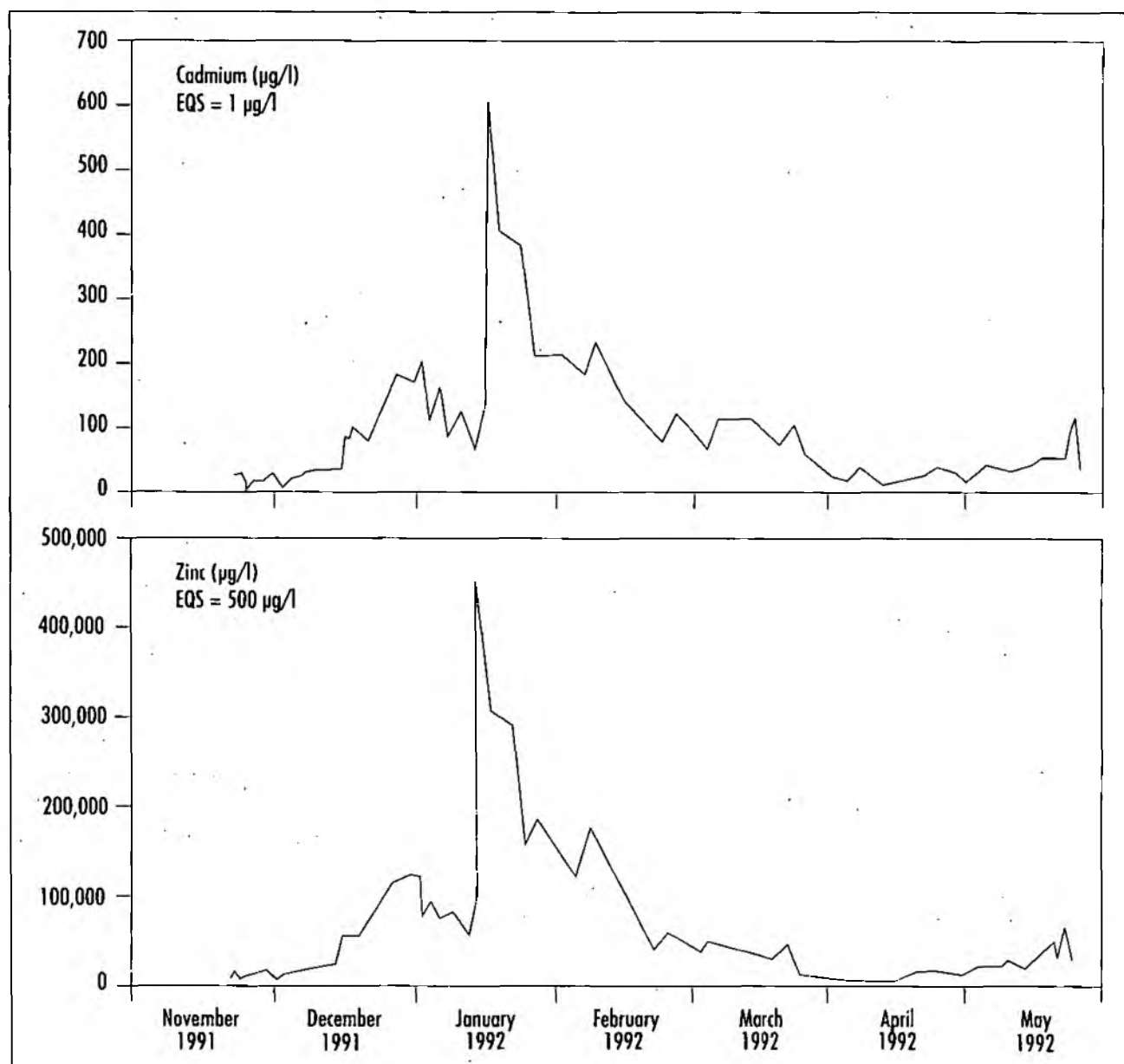
Figure 6: Schematic Long Section Between United and East Jane Mines.



and Quarries Act 1954 on 9 September, and the NRA was notified of this on 31 October 1991 (Plate vii). The Company was under no obligation to carry out any works in relation to water with respect to planning conditions - the original mine's activities in any case pre-dated such requirements by, literally, centuries - and thus its only legal requirement was to declare the mine abandoned. Throughout 1991 the NRA met with Carnon Consolidated to discuss the mining company's contingency plan. The NRA considered the plan to be inadequate and eventually agreed to meet the costs associated with the installation of more appropriate treatment facilities under Section 115 of the Water Act 1989. The extra treatment facilities included increased pumping capacity and liming in an attempt to minimise the environmental impact of any discharge. On 17 November 1991 the first discharge occurred and the improved contingency plan was put into action.

- 5.10 The initial plan was only an interim measure while data were collected to enable medium and longer term plans to be developed and implemented. It involved treating the water with lime and pumping it for settlement to an area known as the "tailings dam" (Plate viii). This treatment continued for some time. On 4 January 1992 the mine owners stopped pumping to the tailings dam because high winds and rain had prevented the precipitation of the floc, and the dam was considered to be nearing its operational volume limit. While investigations were taking place on alternative methods of treatment, a presumed underground collapse led to water which had backed up in the hill above the mine, breaking out via an old adit plug (the Nangiles adit) on 13 January. Pumping and treatment in the tailings dam began again on January 21. Nevertheless, the release of millions of gallons of contaminated mine water from the Nangiles Adit on January 13 had dramatically reduced surface water quality in both the Carnon River and Restronguet Creek, leading to serious deteriorations of quality relative to EQS values previously set for specific monitoring sites in 1986.
- 5.11 There is no doubt that the geology and hydrology of the area contributed to the development of acid conditions within the mine water, with consequent dissolution of metals from the ore bearing strata. The subsequent discharge from the mine therefore contained significant concentrations of heavy metals - particularly iron, zinc and cadmium - resulting in a major pollution incident in the Carrick Roads, not far from the discharge point. As with most mine water discharges, the most obvious impact was aesthetic. The discharge was probably one of the most visual pollution incidents ever recorded in the UK; the full extent of this may be seen in Plates ix and x. The visual impact extended over a large area, covering the Carnon Valley, Restronguet Creek, Carrick Roads, and Falmouth Bay.
- 5.12 The area around the Carnon Valley has been subject to poor water quality, because of its history of mining, for hundreds of years. Nonetheless, the impact of a contaminated discharge of this magnitude had both short-term and long-term consequences. The extent of the short-term effects may best be put into perspective by examining the concentrations of metals in the Carnon River before, during, and after the incident; Figure 7 shows concentrations of cadmium and zinc respectively in the river for the period November 1991 to May 1992. Marked peaks clearly indicate the rise in concentrations of both metals immediately after the incident; cadmium levels in January 1992 exceeded the EQS for the river by a factor of 600. Similarly, zinc concentrations exceeded the EQS by 900 times. It should however be emphasised that the Carnon River had been failing its EQSs for many years, specifically because of the localised mining activity. And because of the already poor water quality in the area, the aquatic life was not generally abundant.
- 5.13 There were, therefore, no known significant impacts on aquatic life in the Carnon River itself following the Wheal Jane discharge. In tidal waters, a comprehensive baseline survey of Restronguet Creek had been carried out in July 1991, before any discharge from Wheal Jane. Benthic fauna in the upper and middle stretches of the Creek was sparse, again due to the mining history in the area, with only two resident species dominating - a polychaete *Nereis diversicolor*, and a bivalve, *Scrobicularia plana*. Both species are considered to be tolerant of metals. At the

Figure 7: Zinc and Cadmium levels in the River Carron (Nov 91 - May 92)



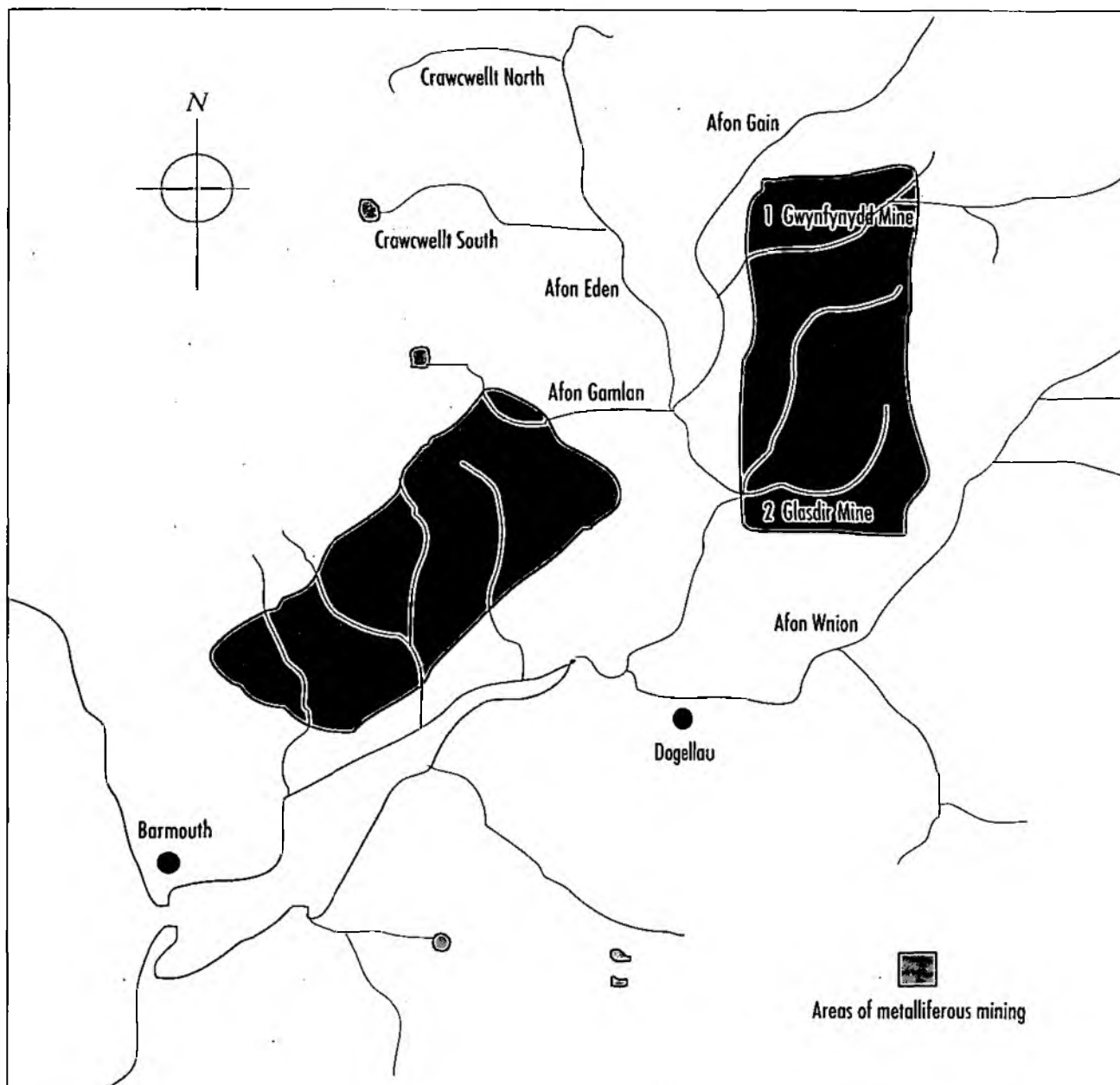
mouth of the creek, the fauna was more diverse, with up to 25 species present. Following the incident, a series of surveys has shown only minimal impact on the biological community.

- 5.14 Bioaccumulation studies were carried out on shellfish by MAFF and on fucoid seaweeds by the NRA. Zinc concentrations in oysters were elevated in the summer of 1992, but this may have been linked with their susceptibility to bioaccumulate during the breeding season. Results indicate a limited accumulation of some metals in the fucoids but this is not exceptional when considering the historical contamination of Restronguet Creek or the levels found in fucoid algae from other areas. Studies are continuing to assess the long term impact on these marine organisms.
- 5.15 Fortunately there were few private water supply boreholes in the immediate area of the discharge, and following the incident Carrick District Council took over monitoring the quality of the water in these boreholes. Although the Local Environmental Health Department suggested that there was no real threat to public health, local residents were nonetheless advised by the Department to drink bottled water as a precaution. The NRA carried out its own

investigations and concluded that there was no contamination in local water supplies as a result of the Wheal Jane discharge. Immediately after the incident, water recreation users were advised by Carrick District Council to keep away from the area until further notice and the Council posted signs at Restronguet Creek. These were removed during the summer of 1992 and the use of private boreholes for human consumption was also resumed.

- 5.16 Following the initial warnings given by the NRA to both Carnon Consolidated and the public on the potential for a discharge from Wheal Jane, the NRA funded a temporary treatment plant, based on the settlement of the metals in the old tailings dam; however, the scale of the discharge proved to be too much for the plant. Following the massive discharge in January 1992, improvements were made to the treatment system whilst doubling its capacity to over 9,000 million cubic metres per day. This system was again only an interim measure, and the NRA simultaneously commissioned a number of studies into the possible long term solutions for treating the discharges. A visit was made to the USA to examine treatment processes there, and evaluate how they might be adapted for the Wheal Jane discharge. Additional pumping facilities were installed in November 1992, but due to adverse weather conditions, the Nangiles Adit discharged again. However, impacts on water quality were minimal, as the high river flow ensured good dilution of the mine water.
- 5.17 Because of the complicated history of the mine, the NRA, after taking detailed legal advice, concluded that they would not be successful in bringing a case against Carnon Consolidated Ltd for causing pollution in abandoning the mine. Thus the only purpose in attempting to bring about a prosecution would have been to demonstrate the deficiencies in the law. This would not have been a correct use of the NRA's position, and it has since - sought and continues to seek - to secure legal changes by making direct approaches to Government.
- 5.18 In December 1992 the Department of the Environment approved the expenditure of £8 million by the NRA for a pilot scheme to develop a long term solution to the Wheal Jane problem, and for the continued operation of the short term treatment system and disposal of the sludge arising from it. Over the next three years, a pilot plant capable of treating around 4,500 cubic metres per day will be established and alternative methods of treatment will also be evaluated. Much of the excess flows will be treated using the existing plant or an equivalent system. Key elements of the pilot study will include:
- (i) flow control to limit the quantity of contaminated water needing treatment;
 - (ii) primary treatment to reduce acidity - methods will include anoxic limestone drains and organic slurry ponds;
 - (iii) secondary treatment to achieve the controlled deposition of metals - methods will include oxidation ditches and possibly sludge recirculation systems and sludge drying; and
 - (iv) tertiary treatment to provide final polishing - methods will include constructing artificial marshes to test different species of plants.
- 5.19 The success of the pilot scheme will not be known for some time. The NRA is nevertheless optimistic that it will provide essential knowledge on this form of low cost, passive treatment, whilst improving water quality in the Carnon Valley area. Local people are hoping that the treatment plant will create increased interest in the area and provide for both education and recreation. Should the scheme as initially envisaged prove unlikely to be satisfactory, recourse may be made to a more conventional form of chemical treatment plant.

Figure 8: The Mawddach catchment



Metal Mining in the Mawddach Catchment, Welsh Region

- 5.20 The River Mawddach (Figure 8) has a history of pollution incidents related to metals (Copper, Zinc, Aluminium and low pH) usually associated with discharges from metal mines. A major fish kill (2,000 salmon and sea trout) in August 1984 led to action being taken against the then mine owners Gwynfynydd Goldmine, which was settled out of court, resulting in the formation of the Mawddach Trust administrating a fund that allowed the construction of a hatchery in 1987; £100k was made over by the mine owners, who did not accept liability for the pollution incident. (A treatment works consisting of lime dosing and settlement was being set up at the time of the 1984 incident). The Mawddach mine had been abandoned earlier this century, but by the late 1970s was being surveyed with the intention of re-opening it if it was considered economically viable. Thus in the 1970s scientific surveys on the Mawddach were made to examine the impact of the mine, and of other derelict mines in the catchment, on salmonid fisheries.

- 5.21 The mine was subsequently being prepared for abandonment in late 1989 when the NRA obtained formal samples of the discharge. Because the treatment tanks were being backfilled and disconnected (and the drainage redirected away to a soakaway) the mine discharge was effectively untreated. A prohibition notice was then served by the NRA in relation to the drainage from the soakaway. Subsequent to the prohibition notice, the mine company produced an abandonment notice.
- 5.22 The mine changed ownership in 1992 and the new owners decided to reassess the mining potential, applied successfully for a new mineral extraction licence, and is still securing funds to redevelop the mine. It is understood that they are exploring the possibilities of opening the mine as a tourist attraction. As part of the purchase arrangements, a sum of £50k has been made available by the previous owner to ensure that the treatment plant continues to operate effectively, and a further £50k (at £10k per annum) made available to the NRA for a full environmental impact assessment to be carried out. The environmental assessment work began in August 1992 and will set the impact of Gwynfynydd Mine in context with several other impacts thought to limit fisheries on the river. The discharge consent was never revoked, and the effluent from the treatment plant continues to be monitored on a regular basis.

A special environmental impact assessment is needed because of the variety of different pollution and accessibility problems affecting migratory fish populations in the Mawddach catchment. These include:

- a munitions dump in the Afon Gain catchment;
 - acidification, exacerbated by forestry development in the upper Mawddach and Eden catchments;
 - derelict mines on the Babi and Wen tributaries;
 - flow regulation in the Eden catchment; and
 - impassable waterfalls at several main river sites.
- 5.23 The overall objectives of the assessment are to identify and rank the main environmental impacts within the catchment, in terms of their effects on fish populations, other aquatic life and chemistry (with special reference to Gynfynydd mine); and to make practical recommendations for treatments and controls to secure the long term future environmental quality within the catchment. Cost-benefit analysis will be included. An initial review has been completed and detailed studies are now being carried out.

Devon Great Consols, River Tamar, South Western Region

- 5.24 Devon Great Consols Mine is on the east bank of the River Tamar, (Devon) 1.5 km north of Gunnislake (Cornwall). The mine is located above the tidal limit, some 4.5km upstream from the port of Morwellham and 6 km from Tavistock. In the 19th century it was the richest and largest mine in the Tamar valley, its workings extended over an area of 57 hectares. The mine had 35 shafts and contained 67 km of underground levels. Although some minor prospecting had taken place in the mid 18th century, the Devon Great Consols sett began to be explored extensively only in 1844. In that year the old 18th century shaft was widened and deepened, and a thick lode of copper-rich ore was found. The main copper lode was 10 m in width and nearly 4 km in length. This was to form the basis of the mines' prosperity for the next 25 years. By 1865 the mine was nearly 400 m in depth, 420,000 tons of copper ore had been raised, and the mine was employing 1200 people.

- 5.25 In the late 1860s and early 1870s copper ore became less plentiful and more difficult to extract. At the same time the price of copper fell substantially as greater amounts began to be mined outside the UK at lower costs. To off-set the falling revenues from copper, the company invested on a large scale in arsenic production. An agreement to construct and operate arsenic works was signed in 1866 and by 1869 production had reached a maximum of 160 tons of refined arsenic a month - half the world's total arsenic supply at the time. Despite efforts in the 1870s to find tin and extraction of copper from a new mine, by 1899 arsenic had become the main product. Thus, when the price of arsenic slumped heavily in 1900-1901, pumping and production ceased and the mine finally closed in June 1902. A copper precipitating works remained in operation until the 1940s. Metallic copper was extracted from the copper enriched watercourses which flowed through the waste tips.
- 5.26 The mine is drained by several adits and these have been routinely monitored, along with associated watercourses. Whilst high concentrations of arsenic, copper and zinc are found in these drainage waters - As 1 mg/l, Cu 12 mg/l, Zn 3 mg/l - the substantial dilution available in the River Tamar reduces the environmental impact. Arsenic is at its limit of detection, copper less than 125µg/ and zinc less than 56µg/l. The greatest pollution risks from the site are from underground collapses, the instability and erosion of waste tips, and surface water run-off from waste tips. South West Water has a major abstraction point on the River Tamar 1 km below the mine, licensed to abstract 130Ml/day for a population of 300,000. An assessment of the pollution risk from the mine tips has been completed by consultants.
- 5.27 The site is now generally contaminated with metals and is thus also a contaminated land site (WQ Series No 15). It is part of a privately owned estate and the NRA is currently in discussion with the owners with regard to the state of the site and its potential risk of further contaminating surface waters, particularly in relation to the stability of waste tips.

6. THE WAY AHEAD

- 6.1 Although abandoned mines adversely affect the quality of only a small fraction of inland waters, where such effects do occur the impact is considerable. In considering what to do about them, however, it is important to differentiate between problems arising from mines long-abandoned, and from those which are likely to be abandoned. The law, too, should be clear on this matter.

Legal Changes

- 6.2 Under the Water Resources Act 1991, it is not an offence to permit water from an abandoned mine to enter controlled waters. This, on the face of it, seems perfectly reasonable in view of the hundreds of adits draining water from mines which were dug hundreds of years ago. As such, these waters have much in common with waters which drain sites which have been contaminated as a result of a miscellany of activities from the past. Indeed in some cases these are one and the same site, because the areas where mines have been dug have also been subject to contaminative uses, and abandoned mine sites have subsequently been the subject of waste tipping and further contaminative uses, such that water draining both the surface and sub-surface layers of the site may be the cause of poor water quality downstream. And as with many contaminated land sites, the circumstances surrounding the closure of many mines have been such that the ability of those responsible to ameliorate their effects, either directly or indirectly, is virtually nil.
- 6.3 It is of course still an offence to *cause* pollution of water as set out in Section 85 of the Water Resources Act 1991, whether from an abandoned mine or from anywhere else. In order to carry out mining activities, it is also evident that any water present in the mine has to be pumped out of the way. In order to ensure that an offence is not committed under the Water Resources Act 1991, such waters - depending on their quality - may have to be treated, and may only be discharged into controlled waters within the conditions of a consent. Once mining operations cease, however, the water rebounds to its pre-mining level, more or less, and may then be permitted to flow into controlled waters without treatment and without a consent. Would not the removal of pumping operations therefore constitute causing pollution? As stated above, permitting water from an abandoned mine to enter controlled water is not an offence under the Water Resources Act 1991. However, what permitting constitutes has never been fully tested in the Courts. Allowing the water to rebound may be construed as simply permitting the water to return to its previous level and thus natural state. The unnatural state may therefore be seen as having been caused not by switching off the pumps, but by the need for having them switched on in the first place. In short, the principal cause for the pollution which does arise from the abandoning of a mine is the creation of the mine itself. Thus it may reasonably be inferred that the sequence of opening a mine, pumping it, closing it, and then no longer pumping it so that pollution occurs, is the *cause* of the resultant pollution. Unfortunately, mining operations are seldom so clearly defined. Mining has been conducted in many areas for centuries and mine operators therefore make opportunistic use of any preceding activities. Quite frequently this involves pumping water shafts and levels dug by others, the quality of which may vary considerably from one part of the mining complex to another. Matters are dealt with pragmatically, but the end result may be that the last mine in the area to close may well have been pumping water from a complex of levels which neither the current mine owners, nor even their immediate predecessors, had actively mined.
- 6.4 In the case of the abandonment of Wheal Jane for example, the last mine operator was pumping water from a complex which had a history of some eight centuries of mining. Water was being pumped from many levels which the last owners had themselves not mined, although connections with some previously mined levels had been deliberately made.
- 6.5 Nevertheless, it would appear to be reasonable to consider that there may be cases when the *manner* in which the mine was abandoned was such that the resultant affect was worse than it

might have been. Certain materials or chemicals which could have been removed may have been left in the mine and then shown to be the origin of the subsequent cause of pollution. Certain deliberate steps may or may not have been taken below ground, which adversely affected the condition and location of the emerging water, when it was known that the subsequent pollution was likely to be worse than it might otherwise be. This "foreseeability" aspect was a key feature in the House of Lords ruling on the Cambridge Water Company v Eastern Counties Leather Plc case, although it did relate there to civil liability. Obtaining satisfactory evidence to prove such cases would, however, be difficult in the extreme.

- 6.6 Responsibility for the environmental consequences of abandoning any active mine must clearly remain with the mine owner. The NRA has therefore stated that it will not hesitate to take legal action where it considers that certain steps which could reasonably have been avoided had caused pollution and, where pollution could be caused, will seek to prevent it - for example, by way of a High Court injunction.
- 6.7 Perhaps the most unsatisfactory aspect of the law as it now stands is that an abandoned mine is not defined anywhere; although a mine is defined for the purposes of the Mines and Quarries Act 1954, this is only with respect to the health and safety of those who operate it. An abandoned mine is therefore not defined for the purposes of the laws relating to environmental protection. So do they need to be? In view of the fact that mines may be abandoned with respect to active mining, but subsequently used for other purposes - such as tourist attractions - and that groundwater rebound may take many years to occur, some clarification of the definition is essential.
- 6.8 The law must therefore clearly differentiate between a mine which has been permanently abandoned for all purposes, and one which is still used for non-mining (eg recreational, educational) purposes, so that discharges from the latter are not exempt when the site in all other respects is actively managed.
- 6.9 Especially important is the need for other relevant authorities - in this case the NRA - to have advance information that a mine is to be abandoned, pumps switched off, and thus the hydraulic and water quality conditions in the area subject to change, so that they can prepare for it in a considered manner. A duty therefore needs to be placed on a mine operator such that he must:
- prepare a complete mine abandonment programme which includes an assessment of the likely subsequent impact on water quality and/or provisions made should these prove to be inaccurate;
 - inform the NRA at least three months prior to the proposed actual cessation of active pumping; and
 - carry out such below or above ground works, including any which the NRA may also reasonably request, in order to ameliorate the effects of the abandonment.

The last of these should of course be appealable to the Secretary of State, the pumps being kept running whilst the appeal is being considered. Grants should be available to the mine operator to carry out such works when financial conditions warrant their application.

The Planning System

- 6.10 Perhaps the most useful legal changes which could be made, however, are those which relate to the future opening or re-opening of mines such that full provision is made at the outset for the ultimate effects which the mining operations could have on the water environment in particular, and on the environment in general.

- 6.11 As with contaminated land sites, the NRA has some limited influence on the protection of the water environment through the planning system; it has consultee status with regard to mining activities, and it comments widely on planning issues relating to mining. However, for the most part, these consultations relate to the operational life of the mine and have little influence over the mine once operations have ceased. In any case, the Planning Authority is not obliged to include conditions recommended by the NRA.
- 6.12 Recent years have seen a general improvement in planning policy guidance related to mining activities, particularly with regard to the reclamation of mineral workings for recreational purposes. Appropriate outstanding environmental issues, such as spoil disposal, coalfield dereliction, and permitted development rights, have all been dealt with via the planning system. But the exception to what is otherwise a comprehensive consideration of the issues is the exclusion of aqueous discharges from abandoned mines. Of particular value is the fact that Section 106 of the Town and Country Planning Act 1990 makes provision for the Local Authorities to enter into a legally binding agreement with a would-be developer, for the purpose of restricting or regulating the development or use of land. The agreement is integral to the planning permission, and allows for requirements made by the Planning Authority in addition to standard planning conditions. The agreement is legally binding, not merely to the landowner but to the land such that essentially the conditions of the agreement run with the land. The main purpose of the agreement is to supplement regular planning conditions. Such agreements are widely used in connection with mining applications. The main factor which influences the agreement is that of conditions subsequently relating to the site. A financial bond may be required from the developer as part of the agreement, and in the event of default the Planning Authority itself then has the necessary funds to commission the necessary work. It seems however that relatively few mineral permissions have had bonds attached - only 61 were recorded in a local authority survey of permissions given since 1982. The survey showed that most of the agreements with bonds attached would not result in a ready release of funds if failure to restore resulted from technical default, because this would be difficult to prove and would require detailed specifications of what was intended in the planning condition. The conclusion was that financial bonds were thus only clearly of value in the case of financial failure of the operator - and even here, if there were other creditors, it would be difficult to separate competing claims. It would therefore seem that the bonds would need to be specific to subsequent water quality problems. With respect to restoration of certain types of sand and gravel workings, for example, the DoE Circular 25/85 (WO Circular 60/85) refers to a financial guarantee on the cost of pumping of the restored site after a mineral operator has completed restoration and aftercare, and is likely to have no further interests in the site.

What, practically, can be done?

Research and Development

- 6.13 It is clear that adequate provision needs to be made for the consequences of mine closure upon the aquatic environment as soon as mines are opened, and some form of arrangement is needed for the long-term running of treatment plants, where necessary, when a mine has been closed in order to safeguard receiving water quality. The NRA, as a regulator, does not intend to become involved in the long-term operation of facilities for attaining good water quality for any closed mine. It does, however, have a role to play in examining the potential measures which can be taken to deal with water from abandoned mines and of their consequences. There are actually a number of options available to deal with the polluting aspects of mine waters. Much of the ameliorative research and experimental work has been carried out in the United States of America; less is known about similar work in Europe. The NRA is extensively involved in R&D for the treatment of abandoned mine water; some of this work is described in Appendix 3.

- 6.14 The principal objectives of treating abandoned mine waters are to remove the iron floc and associated metals, and to adjust their pH. The potential treatments fall into three categories, as follows.

- Physical systems - these are processes in which oxidation of the water is accomplished through engineered cascades, together with facilities for sludge settlement. The costs involved are largely capital expenditure, but revenue costs arise for the disposal of the contents of settlement tanks and desludging processes.
- Chemical systems - active processes are well established, but are expensive to run because of both the cost of the treatment chemicals, and the disposal of the resulting sludge; passive processes are used in the USA and appear to be much less expensive.
- Biological systems - these processes include bacterial oxidation and the use of reed beds. Recent work in the USA has demonstrated the use of such beds to be a relatively low cost approach; over 400 wetlands, resembling miniature marshes, have been constructed to treat acidic coal mine drainage. The wetlands reduce the need for subsequent chemical treatment of the water, and a fifth of the sites have no chemical treatment at all. Savings in the costs for chemical treatment and storage pond maintenance have apparently paid for the wetland construction in less than one year (US Bureau of Mines, 1991). But there are drawbacks to the adoption of this system in the UK; for example, there may not be sufficient land area close to the mines, and the ability to use natural UK wetland species has yet to be demonstrated.

- 6.15 Only limited information is available on the likely costs of such treatment facilities, but it has been estimated that an average mine water, discharged at a rate of 4,500 cubic metres per day, would cost between £0.2 and £0.7 million per annum to operate when treated by physical aeration and sedimentation, and the equivalent chemical treatment would raise the cost to between £0.4 and £3.5 million per annum.

So what should be done?

(a) Long-abandoned mines

- 6.16 As with contaminated land, it is important to place the problem of water emerging from long-abandoned metal and coal mines in perspective. In order to do so, further work is required to assess the extent of the problem in relation to abandoned metal mines in general, and to the currently unclassified stretches in particular which are affected by both metal and coal mines, because it is in such streams that fish, particularly anadromous salmonids, spawn. There is little point in expending large sums of money to improve the quality of downstream water in such rivers if fish cannot spawn in their upper reaches. Such assessments can only usually be made as an integral part of Catchment Management Plans (CMPs), and it is through such plans that the NRA is recommending to Government the setting of Water Quality Objectives on a statutory basis. Priority therefore needs to be given to those abandoned mines in catchments which:
- are a cause of breaching, or would prevent the achievement of, a surface statutory Water Quality Objective;
 - can be shown to be a significant (>1%) contributor to the annual input of substances into coastal waters listed for targeted reduction, as identified by the NRA's Paris Commission/North Sea Conference sampling programme; or
 - are a unique cause of poor water quality in an otherwise good quality river.

- 6.17 Other sites identified via the CMP process will be characterised with regard to the perceived level of risk, or relative contribution which the discharge makes, to the downstream water quality.
- 6.18 Because no offence is committed by permitting water from an abandoned mine to enter controlled waters, and the NRA cannot recover its costs for treating such waters from the persons responsible, it is extremely unlikely that any land owner could be persuaded to address the problem. Derelict Land Grant is not a solution since grant may only be paid on works connected with a comprehensive reclamation scheme. Even if grant were to be available, the long term costs would have to be borne by someone. Derelict Land Grant could not be paid on the running costs of any remedial treatment plant. Equally, the NRA could spend its own monies under Section 161 of the Water Resources Act 1991; but again, as with contaminated land, the NRA should only make such a spend on condition that the owners will subsequently be responsible for the running of the treatment plant. In the case of Wheal Jane, the massive scale of the problem is such that the NRA is overseeing the implementation of the treatment plant on an experimental basis, the long-term running of which has yet to be determined.
- 6.19 The NRA would therefore only use its own resources (recoverable or not) in order to carry out *short-term* remedial work involving capital monies and/or time-limited operational activities. Such remedial work would only normally be undertaken if it had been identified via the CMP process. The longer-term consequences of the NRA's activities would in any case be subject to Government control because approval of the Department of the Environment, under the Financial Memorandum, has to be obtained for sums in excess of £0.5 million.

(b) Active mines

- 6.20 Currently active mines could, if the law was changed, make provisions for the treatment of their resultant surface waters if they were liable to cause long-term pollution problems. This should be assessed first against the possibility of their degrading the existing water quality, plus consideration of the fact that if and when the receiving waters were to be improved by other measures, what contribution the mine waters would then continue to make to the water quality.
- 6.21 In the case of the coalmining industry, if mines now in public ownership were subsequently to be privatised such that a legacy of water pollution was to remain, then some form of residuary body (the Coal Authority?) should take responsibility for ensuring that long-term remedial measures are implemented and run. Indeed such a residuary body could form the basis for overseeing the necessary running of previously abandoned coal mines - as determined by the NRA, or subsequently the proposed Environment Agency, through the introduction of statutory Water Quality Objectives within a Catchment Management Plan framework.
- 6.22 And finally, with regard to mines which have yet to be opened, or mines which could be re-opened, full provision needs to be made in advance for the treatment of any waters which might finally emerge; these provisions need to be incorporated into Local Mineral Plans.

Conclusions and Recommendations

6.23 As with the problems which face the NRA with respect to contaminated land, those associated with abandoned mines have to be kept in perspective. And also in common with the problem of contaminated land, the issue has to be considered in two parts: how best to ensure that the problem will not get worse, and what to do about the long-standing inherited problem. To these perhaps a third could be added - how best to ensure that everyone operates within a sensible and transparent legal framework. The following is therefore required.

- Consideration must be given to the definition of an abandoned mine and the steps which are required to be taken in order to convert a currently active mine into one. Such steps should include a duty placed on the mine operator, so that he needs to:
 - prepare an abandonment programme which includes the perceived impact on water quality;
 - inform the relevant authority at least three months beforehand; and
 - carry out works which could ameliorate the effects of permanent abandonment.
- Consideration must also be given to changes to the planning system with regard to the opening, or re-opening, of mines in order that full provision is made in advance for its aftercare with respect to groundwater rebound.
- With respect to water emanating from long-abandoned mines, the effects of these need to be assessed by the NRA through the Catchment Management Plan process to determine statutory WQOs, in a manner similar to that which should be used for dealing with the assessment of contaminated land. Thus priority should be given to those mine waters which:
 - are a cause of breaching a Water Quality Standard previously set;
 - result in significant (>1%) contribution to the annual input of Red List substances into coastal waters; or
 - are a unique cause of poor water quality in an otherwise good quality river.
- The scale of the national problem with regard to adverse water quality arising from both contaminated land sites and water emanating from abandoned mines would therefore be viewed on a common basis. Dealing with the combined problem may be on such a scale that, if sustained progress is to be made which provides value for money relative to other monies being spent to improve water quality, some form of co-ordinated approach may well be needed. This approach should ensure that the correct combination of both private and public money is spent on capital and current schemes; it should also ensure that regulating bodies do not - by default and via last-ditch efforts - take on responsibilities for operating treatment plants themselves. The separation of 'regulators' and 'operators' in pollution control must be retained. The Environment Agency, once formed, should therefore consider the historic problems of abandoned mines in a manner similar to that of contaminated land.

APPENDIX 1

WATER COURSES AFFECTED BY DISCHARGES FROM ABANDONED COAL MINES AND ASSOCIATED SPOIL TIPS

NORTHUMBRIAN REGION

(Tipalt Burn)
(River South Tyne)
Elsdon Burn (River North Tyne)
River Gaunless (River Wear)
South Burn (River Wear)
Old Durham Beck (River Wear)

NORTH WEST REGION

Trent and Mersey Canal
Bridgewater Canal
Pendle Water
River Brun
Green Brook
Black Clough
River Calder
Copy Clough
Everage Clough
White Ash Brook
Hyndbun Brook
Lottuce Brook
Woodnook Water
Valley Brook
Trent and Mersey Canal
River Dane
River Irwell
River Sett
Lydgate Brook
Ealees Brook
Naden Brook
Small Brook
Cutacre Brook
Hindsford Brook
Ghyll Beck
Westnewton Beck
River Keekle

SEVERN TRENT REGION

Cannop Brook (tributary of River Severn)
River Amber (tributary of the River Derwent)
River Wye (tributary of the River Derwent)

SOUTH WEST REGION

Restrouguet Creek
Carrick Roads
Falmouth Bay

WELSH REGION

River Tawe
River Teifi
River Clyne
River Rhymney
River Sirhowy
River Ebbw
River Pelenna

YORKSHIRE REGION

River Don
River Little Don
River Drone
River Rother
River Doe Lea
River Dearn
River Hipper
River Sheaf
River Calder
River Holme
River Cononley Beck

APPENDIX 2:

MEMORANDUM OF UNDERSTANDING BETWEEN BRITISH COAL CORPORATION AND THE NATIONAL RIVERS AUTHORITY

1. There shall be regular meetings between technical representatives of the National Rivers Authority and British Coal at regional level to discuss issues relating to groundwater pumping that are likely to arise from the abandonment of a mine in England and Wales. Such meetings shall be held at least at six monthly intervals (or more frequently if deemed necessary) and will be minuted, with copies provided to the Headquarters offices of the NRA and British Coal. Where these and other discussions relate to mine closures British Coal will provide particulars of the likely consequence of a cessation of pumping and the method of treating the shafts or adits. Consideration will be given by British Coal to any alternative proposals for treating the shafts and adits which are put forward by the NRA at regional level.
2. Where the NRA considers it necessary to engage external consultants to verify British Coal's analysis of the groundwater situation British Coal will provide particulars of recent mining activity. Details of past mining activity can be obtained from the abandonment plans; these are currently held at British Coal's offices at Bretby, Staffordshire. Any mine plan information provided by British Coal shall be regarded as commercially confidential unless otherwise agreed in writing by British Coal.
3. The Director of Non-Operational Collieries, British Coal will provide, except in an emergency situation, at least fourteen day notice in writing to the Director of Operations, NRA Bristol, of British Coal's intention to cease pumping at a mine. The notice will include brief particulars of the steps to be taken in relation to the treatment of the shafts and adits and the likely outcome of British Coal's action. This notice will summarise the detailed exchange undertaken as per paragraph 1. The Director of Operations of the NRA will provide acknowledgement within seven days of such notice to the Director of Non-Operational Collieries, British Coal, and will inform all relevant NRA staff.
4. Where a colliery closure programme is implemented, due regard will be given by British Coal and the NRA to the future activities and the need for a consented discharge to controlled waters. A proportion of British Coal's mines and associated tipping lands are held on a leasehold basis and the requirements of the lease may restrict the opportunities available to British Coal. Where British Coal own the freehold, it is generally required by specific planning consent conditions or by an arrangement with the Department of the Environment to restore colliery surfaces after abandonment unless alternative forms of development are accepted by the Planning Authority.
5. Where there is fundamental disagreement between British Coal and the NRA at any stage, either party can call a meeting at national level which must be held within seven days in an attempt to resolve such disagreement.

18th November 1993.

APPENDIX 3:

NRA R&D - ABANDONED MINES

Treatment Processes for Ferruginous Discharges from Disused Coal Mines

This project is jointly funded by the NRA and the British Oxygen Company (BOC) Foundation for Environmental and Community Research. The study is being undertaken by Imperial College, London. The brief for the study was as follows:

- to conduct a literature survey to determine current treatment technology;
- to establish contacts with British Coal and other local industries to discuss treatment technologies;
- to investigate the mine effluent from two selected abandoned mines (Sheephouse Wood and Bullhouse, see map) using field and laboratory experiments, to suggest suitable treatment methods for these effluents, which would be low cost and low maintenance; and
- to construct a pilot plant to test the selected treatment process and operate the plant for several months.

The literature survey is now almost complete and several techniques have been identified. In this case wetlands have not been investigated as this is being researched in a separate study in Severn-Trent Region

Acid Mine Drainage in the River Pelenna: Modelling and Pollution Control

The project is again jointly funded by the NRA and the BOC Foundation. The work is being undertaken by the Institute of Hydrology. The main objective of the study is to assess the impacts of pollutants from acid mines draining into the upper Pelenna and its tributary, the Gwenffrwd. Currently, European Inland Fisheries Advisory Commission (EIFAC) water quality standards for salmonoid fisheries are not being met. Consequently, the QUASAR (QUALity Simulation Along Rivers) model has been used to assess the level of treatment required to allow repopulation of the Pelenna by salmon. Reductions in the concentrations of iron in the mine water discharges will have to be in the order of 90% in the Gwenffrwd and 55% in the Blaenpelenna. Three of the five mines studied are regarded as requiring treatment, and it is recommended that the installation of a wetlands scheme, in order to achieve these significant reductions, be investigated.

The study will investigate the amount of mine water which needs to be treated in order to achieve and sustain a fish population and get the river back to its true natural ecological status.

The Use of Wetlands to Ameliorate Metal-Rich Mine Waters

In addition to the operations being carried out at Wheal Jane, the NRA is also undertaking national R&D work in this particular field. This is the first phase of a collaborative study being undertaken by the Welsh Development Agency to investigate the use of wetland systems for the removal of metals and acidity from mine adit drainage. The first part of the study involves a literature review detailing the use of constructed wetlands for the treatment of metal-contaminated mine drainage. Man-made constructed wetlands have been used extensively and successfully to treat municipal sewage and drainage from coal mines. The literature review details several case studies of constructed wetlands where effective removal

of cadmium, copper, lead, manganese and zinc have been observed. The review also provides details on design and construction of such wetlands.

The second stage of the project will involve the construction of a wetland as part of a pilot scheme. The scheme will involve two sites and the study will examine the optimum combination of type and plant species to suit the situation in the UK.

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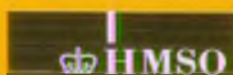
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