Chapter 4.9

Minewaters

Summary

Many of the largest discharges of metals into our rivers and coastal areas arise from mining sources, mainly from abandoned mines. The majority of significant failures to achieve water quality standards for zinc, copper, lead and cadmium occur within mining areas. Parys Mountain Copper Mine on Anglesey discharges 24 tonnes of zinc and 10 tonnes of copper every year. The Restronguet Creek in Cornwall annually discharges 52 tonnes of zinc, 12 tonnes of copper and 60kg of cadmium into the Fal Estuary, mostly from a single mine adit draining a very large area. Parc mine, together with others in the Conwy Valley, is reported to discharge 8% of the total cadmium load in English and Welsh Rivers.

Pollution from minewaters is putting 9% of the rivers in England at Wales at risk of failing to achieve good chemical or ecological status and 10% of our groundwater bodies are classified as poor chemical status. Seven of the eleven River Basin Districts (RBDs) recognise the impacts of abandoned mines as a significant water management issue.

Owners of mines that closed before 31st December 1999 are exempt from responsibility for discharges from the mines under the Water Resources Act 1991. As very few mines are still operating there, no persons are liable for the vast majority of polluting discharges. Any remediation options are likely to fall to the public purse. The Water Framework Directive provides a new onus and opportunity to deal with abandoned mine pollution, in addition to our existing obligations under the Dangerous Substances and Freshwater Fish Directives.

The Coal Authority has powers under the Water Act, 2003 to develop suitable control measures for remediating minewater discharges from coal mines. They have put in place a world-leading programme to tackle coal mine discharges over recent years. They currently 38 minewater treatment plants and pumping stations in England and Wales which manage 140000 cubic metres of minewater every day and prevent up to 1600 tonnes of iron entering our rivers every year. 80 mine sites remain on their priority list for remediation, 59 of which are existing sites The are discharging 1900 tonnes of iron every year. The remainder are sites which are forecast to start discharging into rivers or sensitive groundwater before 2027.

The Coal Authority's remit does not extend to the impacts from non-coal mines and progress for remediating these mines is less advanced. 32 river catchments in England and 38 in Wales are known to be impacted by non-coal mines and are at risk of failing to achieve good ecological status. It is expected that this number will rise as a result of Defra's identification and prioritisation project currently under way. In Wales alone the total loading of cadmium, copper, lead and zinc from known abandoned mine sources is over 250 tonnes.

Four scenarios for managing the impacts of abandoned mines are considered in this report. These explore the costs of established minewater treatment methods and more innovative solutions, and of implementing measures over one or three river basin planning cycles. The scenarios are summarised in the following table.

Scenario	River Basin Plan	Capital £million	Operational £million	Cumulative Total £million
1 Deliver all measures by 2015 High Certainty	2009-2015	132	71	203
	2015-2021	0	142.1	345.1
	2021-2027	0	142.1	**487.2**
2 Phase delivery of measures to 2027 High certainty	2009-2015	53.5	46.1	99.6
	2015-2021	39.7	44	183.3
	2021-2027	39.1	52	**274.4**
3 Deliver all measures by 2015 Low certainty	2009-2015	132	71	203
	2015-2021	0	142.1	345.1
	2021-2027	0	142.1	**487.2**
4 Phase delivery of measures to 2027 Low certainty	2009-2015	53.5	46.1	99.6
	2015-2021	39.7	44	183.3
	2021-2027	39.1	52	**274.4**

Non Coal Mines

Scenario	River Basin Plan	Capital £million	Operational £million	Total £million
1 Deliver all measures by 2015 High Certainty	2009-2015	154	157.5	311.5
	2015-2021	0	315	626.5
	2021-2027	0	315	**941.5**
2 Phase delivery of measures to 2027 High certainty	2009-2015	50.6	51.75	102.35
	2015-2021	50.6	102.5	255.45
	2021-2027	52.8	155	**463.25**
3 Deliver all measures by 2015 Low certainty	2009-2015	77	17.85	94.85
	2015-2021	0	35.7	130.55
	2021-2027	0	35.7	**166.25**
4 Phase delivery of measures to 2027 Low certainty	2009-2015	25.3	5.865	31.165
	2015-2021	25.3	17.595	74.06
	2021-2027	26.4	29.58	**130.04**

The costs for dealing with the remaining pollution problems from coal mines over three river basin planning cycles are estimated at £274 million for coal mines

including operational costs until 2027. This figure rises to £487 million if all measures are implemented by 2015 because of the increased annual operating costs.

To remediate all priority non-coal mines within a single planning cycle would require reliance on tried and tested measures such as the Wheal Jane chemical treatment plant at a large number of sites. This would cost up to £154m in capital costs and £90 million per annum in operational costs. Investigations into innovative measures at Welsh sites have indicated that sites could be treated at a reduced cost of £1.1 million per site, including development costs, with operational costs of £85,000 per site per annum. Phasing of remediation, targeting the high priority sites first, would allow costs to be spread but also allow innovative treatment methods to be developed at a significant saving. Total costs with this approach would be £130 million to 2027.

There are a number of uncertainties with remediating pollution form mines. Further investigative In many areas of England the exact scale of the problem and the locations of the sources are unknown. Efforts are being made to address this through a project funded by Defra and supported by Welsh Assembly Government. Further investigative work is needed into sustainable treatment systems for non-coal mine discharges to enable the inherent value of the sites for their biodiversity or heritage to be retained. Climate change is also likely to increase the effects and extent of abandoned minewater pollution.

Background

England and Wales have a heritage of mining for various minerals which dates back to the Bronze Age. Lead and copper have been extracted on an industrial scale since the Roman occupation. The peak time for the mining industry was in the 18th and 19th centuries following the industrial revolution when demand for coal and metal ores was at its highest. As a result there are several thousand abandoned coal, metal and other mines in England and Wales, dating back 4000 years.

There is no definitive estimate of the exact number of mines in the UK, though the Environment Agency has identified over 1400 metal mines in Wales, and 2300 in Devon and Cornwall alone. Many of these mines impact on rivers, groundwater, sediment and land quality, and are causing significant changes in the chemistry and ecology of affected water bodies. Metalliferous discharges from abandoned mines are the cause of some of the most significant failures of environmental quality standards in our rivers.

Water from mines and associated waste heaps is often highly acidic and contains toxic and polluting substances. Some of these substances are designated as Priority Substances (lead and nickel) and Priority Hazardous Substances (cadmium). Others, such as iron, zinc, arsenic and copper are designated under List II of the Dangerous Substances Directive, and are likely to be designated as Specific Pollutants for the WFD in future.

Much of the pollution associated with mines emanates from a diverse range of diffuse sources which are often hard to identify and difficult to remedy. Diffuse minewater discharges account for between 35% and 95% of metal loads in catchments impacted by abandoned mines.

Pollution from mines is caused by:

- Large scale land disturbance associated with mining

- Rising groundwater dissolving minerals within the workings and causing high metal concentrations in groundwater across large areas (many km^2).
- Polluted mine water entering surface waters as rising groundwater within the mines reaches the surface.
- Leaching of metals and sediments from spoil heaps into groundwater and rivers.
- Transport of contaminated sediments from spoil heaps in flood flows, resulting in widespread contamination of floodplain soils and river sediments.
- Historic waste disposal practices, for example the discharge of tailings from ore processing direct to rivers.

Relevant WFD Objectives

- **No deterioration**.

Minewater is still rebounding in many coalfield areas following the cessation of pumping on mine closure. The metal-laden groundwaters are likely to cause deterioration of surface water and groundwater quality if they are left to rise unabated.

- **Protected Area Objectives.**

Pollution associated with abandoned mines may cause Protected Areas to fail their objectives. The Protected Areas at risk from minewaters are those designated under the Freshwater Fish Directive, Habitats and Birds Directives, Bathing Waters Directive and Shellfish Waters Directive, and Drinking Water Protected Areas designated under the WFD.

- **Progressively reduce pollution from Priority Substances**
- **Cease or phase out discharges, emissions and losses of Priority Hazardous Substances**

Minewaters and discharges from mine spoil heaps often contain cadmium, lead and nickel which are designated as Priority Substances under Annex 10 of the WFD. Most of the very significant failures of existing environmental quality standards (greater than ten times the standard) for these substances are in mining areas. Under the WFD we must aim to progressively reduce pollution from these Priority Substances. Cadmium is also designated as a Priority Hazardous Substance and we must aim to cease or phase out discharges, emissions and losses of such pollutants by 2025. Abandoned metal mines discharging to the River Conwy, north Wales, contributed 8% of the total cadmium load in English and Welsh Rivers (2002 OSPAR data).

- **Aim to achieve Good status (ecological and chemical) by 2015**

Minewater discharges contain significant loadings of copper, zinc and iron. These are designated as specific pollutants under the WFD and are used to determine ecological status. Pollution from abandoned mines will significantly impact on the achievement of good chemical and ecological status in surface water bodies, and good chemical status in groundwater. The main impacts will arise through the significant unregulated loadings of metals from abandoned coal and metal mines. During the late 1990's, the Government was involved in an infraction case with the EC on the 'non-implementation of the Dangerous Substances Directive as applied to mines'. This led to a Pollution Reduction Programme under Article 7 for Iron (and manganese and cobalt). Failure to continue to implement this programme may have implications for further infraction proceedings.

- **Prevent or Limit the input of Pollutants to Groundwater**

Reversal of Significant and Sustained Upward trends in Pollutants to Reduce Pollution of Groundwater

Groundwater levels are still recovering in the coalfields that closed in the past decade. In certain RBDs, notably Northumbria, North West and Midlands, rising groundwater contaminated by minewater is a pollution threat to overlying aquifers, including public supply aquifers. Significant and sustained upward trends in pollutants are being observed in these aquifers and more will occur unless action is taken.

Extent of Pressure, trends and associated uncertainty

The impacts of mining extend across large parts of the UK. Seven of the eleven River Basin Districts (RBDs) in England and Wales have included mining as a significant water management issue, either in its own right (South West, Western Wales, Northumbria and Humber river basin districts), or as a significant contributor to a broader category of pollution (Severn, Dee, and North West river basin districts). Small areas of two other districts (Solway Tweed and Southern) have documented problems. Problems arise in particular 3-10 years after a mine has been abandoned when overflow water form the abandoned mine shaft contaminates surface waters, lasting for about five years.

Many of the largest discharges of metals into our rivers and coastal areas arise from mining sources. The majority of significant failures to achieve water quality standards for zinc, copper, lead and cadmium occur within mining areas. Parys Mountain Copper Mine on Anglesey discharges 24 tonnes of zinc and 10 tonnes of copper every year. The Restronguet Creek in Cornwall annually discharges 52 tonnes of zinc, 12 tonnes of copper and 60kg of cadmium into the Fal Estuary, mostly from a single mine adit draining a very large area. Parc mine, together with others in the Conwy Valley, is reported to discharge 8% of the total cadmium load in English and Welsh Rivers.

The WFD River Basin Characterisation 2 (RBC2) project has identified 128 (1.6%) river water bodies in England and Wales to be ‘At Risk’ from mining pressure. A further 325 (4.1%) river water bodies are defined as being ‘Probably At Risk’. For water bodies identified as being ‘*At Risk’* there is sufficient evidence that they are likely to be failing good chemical or ecological status. For water bodies that are *’Probably At Risk’* there is some evidence of likely impacts but we do not have sufficient data to be confident that they are likely to fail good status. These figures translate into 9% of the total length of river water bodies being *At Risk or Probably At Risk* from mining pressures in England and Wales. These figures are much higher in areas of significant mining activity. For example, 11% of surface water bodies in the Western Wales river basin district are designated in the at risk categories.

10% of groundwater bodies, or some 22% by area, have sufficient evidence of minewater impacts to classify them as being of poor chemical status.

The long-term trend in pollution from minewaters is rising. Large areas of coalfields in County Durham, Yorkshire and Nottinghamshire have rising groundwater which will threaten surface waters and groundwater in the future. The timescales for this pollution to occur range from several months to over twenty years.

The following uncertainties make it very difficult to quantify future impacts of minewater pollution:

- Prediction of volume and quality of rising minewater
- Source locations and relative contributions to diffuse pollution

- Increased pollution due to climate change

Climate change

We can expect increased pollution from mines due to climate change. An increase in flood events would increase erosion of contaminated sediments, either from the spoil heaps themselves or from the river sediments, and their re-deposition on agricultural land in downstream floodplains. Deposition of these sediments has been shown to cause illness and fatalities in livestock in Shropshire and Yorkshire.

Uncontrolled discharges due to increased flows in response to increased intensity of rainfall can cause infrastructure damage such as at Sheephouse Wood in Yorkshire where an outburst of minewater washed away a section of the A616 trunk road.

Prolonged dry spells encourage mineral salts to form within the mine workings and spoil heaps. These salts are very soluble and can cause a significant pollutant load during the first storm event following the dry spell. Such an event was documented at Frongoch lead mine in Mid Wales for the first time in 2006.

Increased atmospheric carbon dioxide will also increase the acidity of rainwater so causing increased dissolution if minerals.

Apportionment and associated uncertainty

Responsibility for the problems associated with mining is complicated by a defence against a charge of knowingly permitting a discharge of polluting matter from abandoned mines which was included in our water pollution legislation until 1999 (s89 Water Resources Act 1991). As a result of this there is little legal liability on any person to deal with the discharges from mines that closed before this time.

Existing mines do not benefit from this defence and operators have a responsibility to ensure that pollution does not occur when they close.

In 1994 the Coal Authority was formed and given the remit to deal with the legacy of pollution from abandoned coal mines. This remit was strengthened when powers to deal with the issue were included in the Water Act 2003. They do not however have any legal liability to deal with the problem in England and Wales because of the legal defence mentioned above. Neither does their remit extend to the many non-coal mines which cause a similar if not greater pollution problem, or to colliery spoil heaps, which can also cause significant pollution.

Pollution from non-coal mines and spoil heaps can be dealt with through existing pollution legislation, primarily the Water Resources Act 1991, and Part 2A Environment Protection Act 1990 Contaminated Land Regulations. In most cases the person who caused the pollution will no longer exist and any residual responsibility will fall to the current landowner. Complexities of ownership and defences, and exclusion tests in the legislation make any enforcement action to achieve environmental improvements difficult. For example the Part 2A Regulations include a defence for discharges from abandoned mines which reflects that in the Water Resources Act. Unless the landowner can be proven to have caused or knowingly permitted the presence of the contaminating substance then it is not possible to enforce a remediation notice for pollution of controlled waters. Even where liability can be proven to rest with the landowner, hardship can be taken into account if the costs are beyond their means.

Section 161 of the Water Resources Act 1991 allows the Environment Agency to carry out works to forestall or remedy pollution and some significant works have been done using this (Wheal Jane tin mine in Cornwall, Greenside mine in Cumbria, Cwmbrwyno in Wales).

It should be noted that funding for S161A WRA91 and Part 2A contaminated land work is through the same mechanism and they are therefore in competition with each other. Local authorities and the Environment Agency can apply to government for funding from a designated budget to carry out works to deal with contaminated land or water pollution.

Given the lack of enforceable legislation to deal with historic mining pollution, responsibility for pollution from mining will rarely, if ever, fall to the polluter. Remedial measures are therefore expected to fall entirely to the public purse.

Measures

i) Coal mines

Considerable work has already been done to reduce the impact of abandoned mines. There are 45 minewater treatment facilities and pumping stations currently operating in England and Wales. 38 of these are owned and operated by the Coal Authority, the remainder being owned by local authorities. They manage over 140000m3 of minewater every day and prevent as much as 1600 tonnes of iron from entering rivers and groundwater each year. The Coal Authority prioritise their remediation schemes from a list of 172 mining sites in England and Wales. Their remediation schemes cover existing minewater discharges and prevention of new discharges.

The majority of the Coal Authority's treatment plants are based on a semi-passive system of aeration, settlement and aerobic wetlands, which successfully treat the typical iron-rich coal minewaters present in the UK. These systems remove iron from the minewater before it discharges to controlled waters. In some cases additional treatment is necessary to deal with very high iron concentration, high acidity or salinity. This is normally through chemical addition, to increase the efficiency of iron removal.

ii) non-coal mines

Remediation of pollution from non-coal mines is less advanced, with only one operational minewater treatment plant at Wheal Jane in Cornwall, which prevents the discharge of 670 tonnes of iron and 150 tonnes of zinc into the environment every year. This plant relies on the import of lime from the Peak District to adequately treat the 350 litres per second discharge of minewater. It is a one-off design built as a response to the single worst pollution incident from an abandoned mine in the UK which occurred when the tin mine was closed in 1992. The remediation scheme will have to operate indefinitely as the pollutant source will not decline for centuries. The technology used at Wheal Jane could be applied to the majority of abandoned mine discharges in England and Wales.

Research is being undertaken in Wales and Cornwall into more innovative and sustainable treatment options using waste materials including seaweed, manure, waste steel slags, whelk shells and even ochre from coal mine treatment plants. If successful, these methods would increase effectiveness, reduce costs and the need for raw materials. They could be applied to sites across England and Wales.

Several non-coal mine sites have undergone civil engineering works to reduce the input of metals and other pollutants from spoil heaps and waste facilities. At

Cwmbrwyno near Aberystwyth fine ore processing waste was encapsulated in clay cell to stop it discharging metals. At Greenside Mine in Cumbria the tips were stabilised to prevent erosion and the risk of a catastrophic collapse. Though we do not have adequate data to quantify the volume of metals removed we can show significant improvements in water quality.

In Wales the Metal Mines Strategy has successfully drawn in funds to identify priority sites and the feasibility of remediation, including innovative treatment methods to allow sustainable management of the problem. Four of the top fifty metal mines in Wales four are sufficiently understood that we can consider remedial works for the first river basin planning cycle. Further studies are planned to allow a phased cost effective remediation approach across three river basin planning cycles.

Funds to investigate the feasibility of metal mine remediation schemes in Wales have been secured from various sources including Welsh Assembly Government (WAG), European Objective 1 funding, INTERREG and Welsh Part 2A/Section 161 Capital Projects fund. However, a secure funding stream for the construction or operation of remediation plants in Wales is yet to be identified. The Objective 1 funding for remedial schemes is only available until 2013 and requires match funding of 60% from the Welsh Assembly Government. This funding only covers capital costs.

Defra, supported by WAG, commenced a national project in April 2007 to identify and prioritise the water bodies most impacted by non-coal mines across England and Wales and the sources of the pollution. The £200K, two-year project will build upon the Wales Metal Mine Strategy and lay the foundations for any national strategies in England and Wales for dealing with these pollution sources.

In some locations local authorities are investigating individual mine sites to determine if they are contaminated land under Part 2A of the Environment Protection Act. If no appropriate person can be found (as is normally the case with abandoned mine sites), they can apply to Government for funding to carry out remediation. The primary contamination pathway under investigation is the effect of windblown dust on human health.

Much work has been carried out around the country using derelict land grants, particularly in Wales. There are successful examples eg Van mine near Llanidloes. But many of the sites were reclaimed for human health or aesthetic purposes and continue to cause significant water pollution. In some instances disturbance of tipped material during reclamation has resulted in increased pollution, eg Cwmsymlog and Bwlch mines near Aberystwyth.

Costs of Measures

i) Coal Mines

The average capital build cost for the 39 Coal Authority minewater treatment plants constructed to date in England and Wales is £800,000, with average operational costs of £85,000 pa. Actual build costs range from £23,000 to £2.9 million, with operational costs from £7,000 to £600,000 per annum.

In some areas, notably County Durham, minewater is controlled by continued pumping following mine closure, usually through existing infrastructure. This allows relatively clean water to be discharged and so a treatment facility is not always needed. Costs are dependent on energy supplies for the pumps. Ongoing pumping

costs at the existing sites are approximately £1.2 million per annum. This option is not suitable in all areas of the country.

Projected overall costs to deal with the remaining priorities in the Coal Authority environment programme across England and Wales are £274m, including design, build, maintenance and operation costs to 2027. At the time of writing the Coal Authority's budget has been reduced by DTI and no new schemes can be confirmed beyond 2008.

ii) Non-Coal Mines

Capital costs of remediating non-coal mines vary from £350k for the civil engineering works at Cwmbrwyno to £3.4m at Wheal Jane. It is unlikely that a scheme on the scale of Wheal Jane will be necessary elsewhere in England and Wales, though the technology is applicable to most minewater discharges. To this end an average cost of £1.7m has been assumed for similar technological approach at other non-coal mines. If similar approaches are taken at remaining priority non-coal mines in England and Wales, projected capital costs are £140 million. Operational costs will rise to £60 million per annum by 2027 on completion of all priority schemes.

In Wales a projected average cost is assumed to be approximately £1m per site, with similar ongoing operational costs to coal mines (£85k per annum average). This cost estimate is based on applications to European strategic funds for remediation schemes in Wales, and experience elsewhere. The figure relies on the introduction of innovative treatment methods which are currently being researched and tested. Assuming development costs of 10% of the capital cost, introduction of these measures would result in a capital cost of £77 million with total annual operational costs of £6 million to 2027.

Minewater treatment schemes are generally expected to have a lifetime of twenty years before they will need a major refurbishment or rebuilding. The ongoing operational costs are based on a 20-year lifetime for a scheme.

Benefits

The benefits of remediation extend beyond simply achieving chemical targets in water bodies such as:

- An improvement in chemical quality results in increased biodiversity within the river corridor
- Increased biodiversity from the minewater treatment plants themselves by creating wetland habitats.
- Improved river health leads to increased economic benefits, for example revenue brought in by anglers and informal recreation.
- Sustainable regeneration of otherwise depressed areas. An improved environment has a positive effect on property values and can be a factor in inward investment by business.
- Treated minewaters can provide dilution in watercourses impacted by urban or agricultural diffuse pollution.

At Taff Merthyr colliery in South Wales the remediation of the minewater was key to the creation of a riverine park, including canoeing and fishing lakes and a climbing centre. Providing new amenities for local people and attracting outsiders who contribute to the local economy. Many metal mine sites have an intrinsic value as part of the heritage of the community and the landscape, as recognised by the recent creation of the Cornish World Heritage Site. Dealing with the pollution can be a catalyst to improve the infrastructure and facilities for other visitors, for example the

remediation of the arsenic flue at Botallack tin mine in Cornwall, or the work of the industrial heritage trust at Parys Mountain copper mine on Anglesey.
The combined treatment of sewage effluent and minewater at Lamesley Wetlands near Newcastle is expected to show additional benefits of enhanced removal of phosphates and ammonia.
Minewater, once treated, could also be a substantial water (supply) resource in its own right.

Scenarios

Low reference case
At the time of writing there are no minewater remediation measures agreed, costed and funded other than the existing minewater treatment plants operated by the Coal Authority, and the Wheal Jane scheme. This is considered to represent the Low Reference Case for the purposes of the PCEA project. The annual operating costs of these sites is approximately £6.5 million. The gap remaining to achieve WFD-related outcomes is considered to be:

- the remainder of the Coal Authority's environment programme
- the priority sites identified through the Wales Metal Mines Strategy
- the identification and remediation of sites in England, identified through the current Defra project.

Four scenarios are set out below for controlling pollution from mines. These are based on the Scenarios outlined in the following summary table.

	Uncertainty	
Phasing	**No "**higher certainty of achieving outcomes"	**Yes "**lower certainty of achieving outcomes"
No "do all technically feasible measures as soon as possible"	**1** All measures completed by 2015 Tried and tested methods applied, including chemical treatment and land reclamation at non-coal mines. Costs incurred by lack of efficiency in innovation and loss of ecology, heritage value at sites.	**3** Implement innovative treatment options at non coal mine sites without suitable testing or complete characterisation. Lower overall costs than **1** but potential for reduced sustainability Costs incurred by loss of ecology, heritage
Yes "do what is reasonable as soon as possible"	**2** Coal Mines: new impacts prevented in timely fashion, existing impacts treated according to priority using tried and tested methods. Non-coal mines: research into sources completed, tried and tested methods applied to their treatment.	**4** Coal Mines: new impacts prevented in timely fashion, existing impacts treated according to priority Conduct further research on non-coal mine sources, pathways and possible measures, retain inherent value of ecology and heritage. Phase in innovative remedial measures after suitable testing. Devise management options for diffuse sources.

Scenario 1 - High Certainty of achieving outcomes in RBP 1
<u>i) Coal Mines</u>

For coal mines our knowledge is sufficiently advanced that we know where to invest in minewater treatment and the treatment methods are well developed through the expertise of the Coal Authority. Given the resource this could be achieved in a single round of river basin planning. This would cost £274m in total across England and Wales including ongoing operational costs to 2027. The practicalities of delivering such a large programme by 2015 may make this option difficult to achieve; though they could be overcome by allocating sufficient resources. Issues of land availability may delay schemes.

ii) Non-Coal mines

To achieve a high level of certainty for non-coal mines would require a significant investment in established technology such as active chemical treatment plants for the most significant discharges, and land reclamation on spoil heaps. Though these measures could achieve good status they would not take into account the inherent ecological and heritage value of many sites, which would be lost to local communities.

The majority of sites cause pollution through a combination of direct and diffuse sources so it is a reasonable assumption that one treatment plant and one civil engineering solution would be required for each river water body currently At Risk of failing good status. Some water bodies, (e.g. in the Western Wales or South West RBDs) may require several remediation schemes. At an estimated cost of £1.7million per treatment plant, based on the Wheal Jane experience, and of at least £300k for civil engineering works, the likely capital cost per water body is £2million, or £140 million for all At Risk water bodies in England and Wales. This cost is recognised as an underestimate due to the lack of information on non-coal mines available for England, a situation which will change during the course of the current Defra identification and prioritisation project. Ongoing costs will be in the region of £750,000per treatment plant per annum, a total of £630 million to 2027 assuming all plants are operational by 2015.

Scenario 2 - High certainty of achieving outcomes over 3 RBP cycles

i) Coal Mines

The Coal Authority has already proposed a phased approach for the remaining priority sites in their environment programme for England and Wales. This approach will deal with rising minewaters in a timely fashion before they cause significant pollution and will treat existing discharges, dealing with the most polluting discharges first, over three river basin planning cycles at a total cost of £274 million. The total capital cost over the 3 river basin planning cycles is expected to be the same as delivering all schemes in the first river basin planning cycle, although some savings may be achieved if new, more cost-effective, remediation schemes options become available. Sustainable treatment methods are well developed.

ii) Non-Coal Mines

A similar approach could be proposed for non-coal mines. This would allow a suitable strategy to be drawn up and the costs of providing tried and tested methods, i.e. chemical treatment and land reclamation could be spread over three river basin planning cycles. Savings would be made by reducing uncertainties over the location and magnitude of the pollution sources. The ecological and heritage value of the sites could be preserved by allowing time for greater characterisation and protection within the remedial schemes.

In Wales it is proposed that management options for four of the most polluting metal mine sites are developed and implemented by 2015. This is estimated to be at a cost

of £1.1 million per site, plus operational costs, but it is dependant on the development of innovative treatment methods. The four sites, to include Parys Mountain Copper mine and Cwmrheidol lead mine, contribute at least 50% of the metal load to Welsh rivers between them.

Scenario 3 - Lower certainty of achieving outcomes in RBP1
Sustainable treatment options are less well developed for non-coal mines. Untested innovative treatment techniques could be applied to all non-coal mine sites, but these will provide a lower certainty of delivering WFD objectives in the first river basin planning cycle. There is a great risk that the methods will fail either in the short or long term and so the benefits of remediation will not be realised. The inherent value of many of the sites will be lost due to a lack of suitable characterisation and planning.

Scenario 4 - Lower certainty of achieving outcomes over 3 RBP Cycles

i) Coal Mines
Though sustainable treatment systems are well developed for coal mines, a phased approach would allow newer and more cost-effective innovative treatment and management methods to be developed and implemented.

ii) Non-Coal Mines
A phased approach for non-coal mines would allow further research into cost effective, innovative, sustainable treatment systems. It is estimated that this could reduce the cost of remedial schemes to approximately 30% (£1m) of the existing active treatment plant at Wheal Jane. It would also allow a suitable management approach to be formulated for dealing with large areas of diffuse pollution that cannot be dealt with using currently available technologies without disproportionate cost. The phasing would allow suitable alternative standards to be developed based on the needs of the impacted water body ecosystems.

In Wales four non-coal sites are sufficiently understood that we can consider providing a remedial treatment and management scheme within the first round of river basin planning, subject to funds being made available (see Scenario 2). Between them they account for a significant proportion of the total metal load being discharged. Investment to determine a treatment and management regime for these sites at an early stage would pave the way for sustainable management options for the remaining sites in England and Wales, without damaging the inherent value of many of the sites for their industrial heritage and metal-tolerant ecosystems. The capital costs for these sites have been estimated at £1.1m per site, including development costs, with ongoing annual costs of £85,000 per annum similar to coal mines.

To deal with the all of the water bodies at risk of failing good status in England and Wales would cost £77 million in capital expenditure with total operating costs £30 million to 2027. Maintaining the Wales Metal Mine Strategy, which identifies and develops plans for remediation, currently costs £68000 per annum.

Costs for implementing the four scenarios are summarised in the tables below.

Coal Mines

Scenario	River Basin Plan	Capital £million	Operational £million	Cumulative Total £million
1 Deliver all measures by 2015 High Certainty	2009-2015	132	71	203
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	2021-2027	0	142	**487**
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Non Coal Mines

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	2015-2021	51	103	255
	2021-2027	53	155	**463**
3 Deliver all measures by 2015 Low certainty	2009-2015	77	18	95
	2015-2021	0	36	131
	2021-2027	0	36	**166**
4 Phase delivery of measures to 2027 Low certainty	2009-2015	25	6	31
	2015-2021	25	18	74
	2021-2027	26	30	**130**

Measures to reduce uncertainty

- Sustainability of treatment methods.

We must continue to investigate the longevity and sustainability of existing minewater treatment methods by programmes of research and routine monitoring. Academic research is encouraged and access granted to sites and data.

- Prediction of volume and quality of rising minewater.

The Coal Authority and Environment Agency extend and maintain a network of monitoring locations in recovering minewater areas which add to our knowledge and allow modelling and predictions to be made with increasing confidence. Academic research is again encouraged.

- Source locations and relative contributions to diffuse pollution.

One of the most significant uncertainties is the lack of knowledge in some areas of the sources of pollution from non-coal mines. This is being addressed by a two-year project funded by Defra (with contributions from Welsh Assembly Government and DCLG, and managed by the Environment Agency) to identify and prioritise water bodies impacted by abandoned non-coal mines and the sources of pollution within those bodies. This will report in March 2009 although information on some RBDs will be available sooner.

- Definition of Good Ecological Status.

Many mine sites and impacted waterbodies have distinct ecological systems, with several designated as SSSIs due to elevated metal concentrations, particularly on spoil heaps. Communities of organisms have adapted to the pollution to an extent and further research is necessary to characterise these communities and how they will fit into the definitions of good ecological status. This work would contribute to the setting of alternative standards.

- Innovation in treatment methods.

Abandoned minewater treatment has only been undertaken in the UK in the last 12 years. Sustainable, semi-passive treatment methods for dealing with they typical iron rich coal minewaters are well developed. Further research is being done on new methods to make treatment more efficient. This is not the case for non-coal mines where the contaminants of concern often have higher solubilities and toxicity, making long-term passive treatment difficult. Considerable academic research is being put into this problem in the UK and internationally with some success, though it has yet to be tested at full-scale in the UK. Two pilot treatment trials are being built in Wales and expect to report during 2007/08.

- Climate Change.

The impact of climate change is expected to cause a deterioration in the problem of abandoned mine pollution. Increased storminess will cause increased erosion of contaminated spoil heap material and sediments and deposition on agricultural land in downstream floodplains. Prolonged dry spells allow soluble minerals salts to form, which are then rapidly dissolved and discharged in storm events. Increased acidity due to raised atmospheric carbon dioxide levels will increase the solution of minerals. Academic research is being encouraged into these effects but also into the prevention or reduction of the climate change itself.