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An evaluation of some mining related SSSIs within the context of Part IIA of the Environmental Protection Act

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BRITISH GEOLOGICAL SURVEY

COMMISSIONED REPORT CR/04/075N

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(English Nature)

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Summary

This report describes the results of jointly funded project by the British Geological Survey and English Nature to develop a GIS approach to prioritising mineralogical SSSIs. The object and rationale was to prioritise sites for follow on studies aimed at assessing pollution potential within the context of the Environmental Protection Act, Part IIA.

The first part of the report introduces the main elements of the Part IIA legislation of relevance to abandoned mining. A brief account of the forthcoming EU Mine Waste Directive is also presented to set this study within a European context.

The second part of the report deals with a description of the main environmental hazards linked to abandoned mining. The report goes on to briefly describe the English metallogenic setting relevant to the SSSIs and the minerals; both ore and gangue, of potential environmental concern are noted.

An account of the GIS decision support application is then presented and the development of the scoring scheme based on the concept of ranked pollutant linkages.

The final section of the report presents the GIS outputs in ranked tabular form and recommendations are made for prioritising follow up work based on this output. The site prioritisations for each site are presented on the CDs in the Appendix.

1 Introduction

This report presents the results of a desk-based study to assess ninety SSSIs on behalf of English Nature. English Nature is responsible for advising government on SSSIs and their monitoring. The ninety SSSIs considered in this study are of mineralogical interest and most of them are related to abandoned mining throughout England. The object of the study is to assess whether or not the sites might be classified as contaminated land under the contaminated land regime.

Contaminated land is defined in Part IIA of the Environmental Protection Act 1990, inserted into the act by Section 57 of the Environmental Protection Act 1995, as any land which appears to the local authority in whose area it is situated to be in a condition, by reason of substances in, on or under the land that:

(a) Significant harm is being caused or there is significant possibility of such harm being caused; or

(b) Pollution of controlled waters is being, or is likely to be, caused;

Categories of significant harm for different types of receptor are set out in Table A, Part 2 of Annex 3 of DETR Circular 2/2000: Guide to Contaminated Land (England) Regulations. This table identifies four types of receptor and a description of harm that is regarded as significant harm. Its contents may be briefly summarised as follows:

1. For humans significant harm is described as death, serious injury, genetic mutation, birth defects or the impairment of reproductive functions.

2. In the case of ecosystems as a receptor significant harm is described as:

    - resulting in an irreversible adverse change in the functioning of the ecosystem within any substantial part of the location.

    - harm which affects any species of special interest within that location and that endangers the long term maintenance of the population at that location.

Such a location could be a notified SSSI or a declared national nature reserve. It is an inevitable paradox that the SSSI status of many of the 90 sites under study owe their status, in part, to the presence of ecosystems adapted to high concentrations of heavy metals and that might well constitute contaminated land.

3. Harm to property in the form of animals and produce, which includes substantial diminution of crop yields, death or disease of domestic pets, animals and livestock, and wild animals that are the subject of shooting or fishing rights.

4. Harm to property in the form of buildings, including structural failure or substantial interference with any right of occupation.

Table B in the same DEFRA document tabulates descriptions of significant harm and the conditions for there being a possibility of significant harm. In terms of human health effects and ecological system effects it introduces the idea of formal risk assessment. The concept of there being a pollutant linkage underpins any assessment of human health, ecological risk, animal and crop effects and all building effects. It is axiomatic that if a pollutant linkage does not exist then there is no risk.

Looking at the wider picture the European Union have been conducting consultations on a Mines Waste Directive and the third consultation document was released in June 2002. The following is the proposed text of Article 15 of the Directive and covers the requirement for the creation of inventories of closed management facilities.

Member States shall ensure that:
(1) within three years from the entry into force of this Directive, an inventory of closed management facilities classified under Article 7 as class 1 or category A (including disused facilities) located on their territory is carried out. Such an inventory, to be made available to the public, shall at least contain information on the following elements:

(a) the geo-referenced location of the site;
(b) the type of mineral or minerals formerly extracted;
(c) the types of waste present on the site;
(d) the physical and chemical stability of any management facility;
(e) whether any acid or alkaline drainage, or metal concentration, is being generated;
(f) the environmental conditions of the site, with particular regard to quality of soil, surface water and its receiving catchment area including river sub-basins, and groundwater;

(2) the sites listed in the inventory referred to in the previous paragraph are classified according to the degree of their impact on human health and the environment. The upper tier of the inventory will thus include closed management facilities causing serious negative environmental impacts or which have the potential of becoming in the near future a serious threat to human health, the environment and/or property. The lower tier of the inventory will include those management facilities with no significant negative environmental impacts and no potential of becoming in future a threat to human health, the environment and/or to property;

(3) within four years from the entry into force of this Directive, rehabilitation is started on sites classified in the upper tier in order to satisfy the requirements of Article 4 of Directive 75/442/EEC. Where the competent authority cannot ensure that the necessary rehabilitation measures are started at the same time, the competent authority shall be entitled to decide which sites must be rehabilitated first;

(4) the financial costs for complying with the requirement of paragraph (3) are to be borne by the waste producer, insofar as the latter is known and available. Where the waste producer is unknown or unavailable, national or Community rules on liability apply.

The principal criteria for site classification are set out in Article 7 and application is relatively straightforward. Two classes based on the volume of waste piles or tailings lagoons are defined. Class 1 consists of those sites where waste dumps exceed 500000 cubic metres or tailings lagoons exceeding 250000 cubic metres and Class 2 is any facility not in Class 1. There is also a classification based on potential risk. Category A sites present a significant accident hazard, while Category B sites include all other sites not in Category A. Annex III of the consultation document gives the criteria for a Category A citation. The implementation of this directive is likely to have a more profound effect than the Contaminated Land Regulations on mineralogical SSSIs since it specifically targets mining waste and under the terms of Directive 91/689/EEC much of it will be classified as hazardous and therefore in Category A.

Within the UK context a lot of work remains to be done, not least identifying the competent authority. Furthermore, implementation will require a significant financial commitment since a site visit; environmental sampling and analysis will be required in all cases in order to satisfy the information requirements of the proposed register and Annex III.

2 Mining Impacts

In setting out to conduct a pathway analysis for a particular site a conceptual model of sources, pollutant linkages or pathways and receptors is useful. The one employed in this study is shown in Figure 2.1. The main elements of the mine impact model are summarised in the following table.

Table 2.1 Source – Pathway – Receptor Analysis of a Simple Conceptual Model

SOURCE	PATHWAY	RECEPTOR
Waste Rock and Tailings	Airborne, deposition and inhalation.	Agricultural land, Surface water, Livestock and humans
Acid Mine and Acid Rock Drainage	Surface and groundwater flow (Catalan et al.)	Groundwater, surface water, agricultural produce through irrigation and humans through ingestion
Contaminated soils	Ingestion and leaching	Human, agricultural produce
Contaminated food	Ingestion	Humans and animals
Contaminated water	Irrigation and ingestion	Human and agricultural produce

The source characterisation is very much dependant on the past history of the site. The most common sources of contamination related to mining and mineral processing are mine wastes in the form of waste rock, tailings, water discharges or process water. Additionally some mineral processing operations can give rise to slags and ashes, gaseous and particulate emissions through, for example, grinding and ore roasting and smelting. At abandoned mine sites, acid mine drainage and acid rock drainage that develops as a consequence of the weathering of sulphide rich wastes may represent one of the main contaminant sources along with the legacy of past mineral processing activity.

2.1 WASTE ROCK AND TAILINGS

In general the first stage of mineral processing involves reducing the ore grain size so that mineral grains are no longer locked in a rigid aggregate of gangue, the waste being dumped or used as mine backfill.

The second stage of mineral processing involves the separation of the mineral grains from the gangue, which may proceed via physical, surface chemical or bulk chemical means. In the past such treatments were physical relying on crushing and ore washing. The waste products from these operations would generally have been piped to a tailings dam facility. One of the outcomes of ore crushing and a major contributing factor to possible environmental impact is the increased surface area of the source rock that potentially leads to an increase in chemical reactivity and weathering rates.

At many of the 90 SSSIs in this study the interest derives from the occurrence of primary and secondary minerals on the dumps of such waste rock.

In the mines of SW England and the Pennines techniques used were very similar. On larger mines mechanical crushers or stamps would have been used whereas on smaller mines hand cobbing was more likely. The ore was cleaned on dressing floors that consisted of riffles or buddles that relied on gravity separation in water. The more efficient operations were able to win a high percentage of the ore while in less efficient operations a lot of mineral went to waste in the slimes. A useful account of the processing of lead ore is given by Hunt, (1970).

2.2 PARTICULATES AND GASES

Particulates and gases are a by-product of ore roasting and smelting. Wind erosion of bare tailings piles can also cause mobilisation and dispersion of contaminants.

Once primary ores began to be exploited in SW England there was a quality problem caused by the unwanted arsenopyrite, which made the smelted tin and copper brittle. The general practice to deal with this unwanted arsenic was to roast the copper and tin ores and drive the arsenic off directly to the atmosphere by sublimation prior to smelting. Things changed in the early 1800s when arsenic became a valuable commodity and some mines, e.g. Devon Great Consols, had a new lease of life, up until to the 1930s, producing arsenic.

Initially the arsenic was recovered by installing long flues onto the ore roasters where the condensed sublimate was collected. Various modifications to calciners and collection systems were developed culminating in the introduction of the Brunton calciner and labyrinth condenser system. Remains of these can still be seen at Wheal Busy and Devon Great Consols. Indeed the last Brunton calciner ceased production at South Crofty in the 1950s. These systems relied on tall chimneys to provide the necessary draught and as a consequence became the means to widely disperse contamination of arsenic and sulphur dioxide. To deal with this problem a water tower was installed in the flue line to wash out the particulates and sulphur dioxide. One of these, in ruin, survives at Devon Great Consols. An excellent account of the Devon Great Consols arsenic works is provided by Pye and Dixon, (1989) while Earl, (1996) provides an informative historical account tracing the development of the Cornish arsenic industry.

In the Northern Pennines lead smelting was a major environmental polluter. The process largely relied on the ore hearth process except perhaps for the larger operations where a reverberatory furnace may have been used. Raistrik, (1975) provides a description of lead smelting and describes some of the wastes arising from the process. The ore hearth was a square, vertical furnace blown by water-powered bellows. The hearth was connected to a flue that carried fumes away to a chimney. Smelting was done with peat, chopped wood or coal or a mixture of them. As well as lead the ore hearth produced a grey slag that might have contained up to 25% lead. This was resmelted in a slag hearth, the final waste product being a black vitreous slag. Raistrik, (1975) goes on to state that thirty-two tons of ore produced 23 tons of lead and 2.25 tons of grey slag, this latter producing 9 cwt of lead. It is evident that the whole process produced very little waste (approximately 1.4% of the original ore concentrate).

2.3 ACID ROCK DRAINAGE

Large volumes of broken and crushed sulphide-bearing rock are discarded as waste at some metalliferous mine sites, which can give rise to contamination of surface and groundwater with high concentrations of metals and other harmful elements due to leaching. One of the most common waste by-products of metalliferous mining is pyrite, a sulphide of iron. Its presence in the wastes from ore treatment constitutes a major source of acid rock drainage (ARD) and in flooded abandoned mine workings, acid mine drainage (AMD). This arises from the dissolution of the oxidation products of the pyrite. The acid and heavy metal load may represent a serious hazard for communities living downstream from a mine. Watercourses contaminated by mine water may be used for irrigation or drinking water purposes possibly leading to community and livestock ill health. The scale of the impact of AMD/ ARD is very much dependant on mine hydrology, volume of waste rock on the surface, its age and the acid buffering capacity of other gangue minerals in the waste.

3 Metallogenesis

Clearly the metallogenic setting of the individual SSSI will largely determine the nature of the wastes arising and their composition. The main mineralisation types are detailed below and correspond quite closely with the geographic subdivision of the SSSIs in Appendix 1.

3.1 LAKE DISTRICT

In the Lake District, copper, lead and zinc have been recovered from a variety of small deposits in Lower Palaeozoic sedimentary and volcanic rocks underlain by Caledonian granites. Most of the deposits occur in narrow fractures, but some disseminated deposits are known. Granite-associated Cu, Mo and W mineralisation also occurs in the Lake District, most notably at Carrock Fell, where wolframite, scheelite and sulphides occur in a greisen zone adjacent to a small granite intrusion. Replacement ‘Bilbao-type’ hematite ores occur in Carboniferous Limestone near Whitehaven and Barrow-in-Furness and were formerly worked on a large scale.

3.2 NORTH AND SOUTH PENNINES

Pennine-style mineralisation occurs as fracture-hosted mineralisation in late Dinantian to early Namurian platform carbonates adjacent to Carboniferous shale-dominated basins. The mineralisation comprises a large numbers of long (up to several km), narrow (less than 10 m), steeply dipping ore shoots of limited vertical extent confined to a small number of massive limestone or sandstone beds.

A metallogenic model has been proposed that involves mineralising fluids being generated by dewatering of Devonian to Carboniferous basins. The fluids reacted with the clastic basin infill at depths of 1–2 km to produce saline, metalliferous brines while a cover of early Carboniferous shales provided thermal insulation to enable the brines to reach temperatures exceeding 200°C under an enhanced geothermal gradient. Periodic extension of the basin permitted release of the metal bearing fluids up faults into the Carboniferous sediments.

Fluorite and galena are the main ore minerals with subsidiary, but locally important, baryte, calcite, sphalerite, witherite, chalcopyrite and quartz. Mineralisation probably occurred during early Permian times. There are a number of significant replacement ore bodies, some of which were only partly extracted due to the technologies of the time and the concentration on richer and more easily worked vein deposits. Many deposits, and/or their associated waste tips, have been reworked for fluorite and/or baryte since the demise of the lead mining industry before the beginning of the 20th Century.

3.3 MENDIP HILLS

Similar Pennine-style mineralisation occurs to a limited extent in the Mendip Hills where the mineralisation may be connected to Triassic karst processes. Secondary zinc carbonates (‘calamine’) are an important feature in some parts of the orefield. This mining field was almost entirely worked out by the beginning of the 19th Century.

3.4 CHESHIRE BASIN

Minor red-bed Cu mineralisation occurs in the Triassic rocks of the Cheshire Basin. The Triassic Sherwood Sandstone Group of central England is frequently cemented by baryte and associated with minor red-bed copper mineralisation of pyrite, chalcopyrite and copper secondary minerals, such as malachite. The largest deposit was at Alderley Edge in Cheshire. The mineralisation occurs adjacent to faults that provided pathways for fluids generated during diagenesis of the fault-bounded Triassic basins.

3.5 FOREST OF DEAN

Vein and replacement iron ore (hematite) deposits in Carboniferous Limestone were worked in this area for many years.

3.6 SOUTH WEST ENGLAND

In Devon and Cornwall, tin, copper and other metals have been mined for at least 2000 years from deposits related to Variscan granites. The Variscan orogeny caused deformation and tectonism and culminated in the emplacement of the high-heat-flow, Cornubian batholith that extends for 230 km from the Scilly Isles to Dartmoor. The batholith is exposed as a series of large bosses and minor cupolas with which the major Sn-Cu-W vein-style mineralisation of SW England is associated. The main mineralisation occurs as sets of parallel, high temperature quartz-tourmaline and quartz-feldspar veins containing cassiterite, wolframite, chalcopyrite and arsenopyrite. There are a number of mineralisation phases and later crosscutting fracture sets are found with lower temperature minerals such as sphalerite, galena and baryte, along with minor uranium minerals in some localities, e.g. South Terras Mine.

4 Methodology for site prioritisation

The adopted methodology was to collate and attribute, wherever possible using an ArcView geographical information system (GIS) platform, existing archive materials held by the BGS, English Nature and third parties that are relevant to conceptualising the source - pathway - receptor model for each site.

In conducting the desk-based study on which the site assessments are based an attempt was made to document the existence of the following information:

- The presence of *in situ* exposures;
- The presence of waste dumps and if they are vegetated *;
- The presence of underground workings;
- Any information on recorded output and the ore minerals present *;
- The presence of potentially hazardous minerals *;
- Geology;
- The presence of any discharges from dumps and adits *.

The database of initial assessments is tabulated in Table 1. In the final column an overall hazard value is given based on the relative contribution of some the above criteria (*) that directly contribute to the site hazard. Clearly the metallogenesis of the ore deposits has a key role in determining the presence of a particular ore and the related gangue minerals.

The database is the foundation of an interactive GIS tool (adapted from BGS's successful BGS-ConSEPT integrated GIS methodology, Ander et al. (2003), for prioritisation of contaminated land which is currently being used by many local authorities,) that was used to ensure consistent reporting for each of the sites identified by English Nature.

The BGS drew on the local knowledge of its regional geologists in Exeter and Edinburgh (covers the north of England) to provide and record site-specific information where it was available. An economic geologist provided the interface into the national minerals and mining databases maintained by the BGS and sponsored by the UK Department of Trade and Industry and the Office of the Deputy Prime Minister (ODPM). At the present time the Environment Agency do not hold a database of controlled waters and hence in order to asses if sites are likely to be in breach of Regulation 3 of the Contaminated Land (England) Regulations 2000 recourse was made to digital terrain models and OS data to identify likely impacted surface drainage in the vicinity of the SSSIs.

Within the context of mine waste contamination, risk assessment provides a formalised framework that describes the relationship between the exposure / concentration of a given substance and the adverse effects on a given receptor. Risk can be defined as the likelihood that one or more adverse effects will occur in response to a hazardous situation.

A qualitative approach to risk assessment has been adopted to identify potential sources of hazard, pathways of exposure and receptors likely to be impacted. This is the classic risk assessment paradigm; it is implicit in current statutory guidance on Part IIA that uses the concept of pollutant linkage, i.e. a linkage between a contaminant and a receptor via a pathway.

The procedure adopted in this study was as follows:

(a) Identification of a contaminant (source) capable of causing harm. This was based on information on the mineralogy at the sites.

(b) Identification of any receptor, which may be a person, a piece of property, or controlled water by spatial query using the GIS tool and where available local knowledge. For the purposes of the project it has been assumed that the sites are ecologically distinct as a consequence of the past mining activity. It is assumed that the ecology is one of the defining criteria for SSSI status and as such the category of significant ecological harm to SSSIs in Table A of DETR Circular 02/2000 “Contaminated Land” does not apply. This approach seems to be in line with guidance issued by DEFRA in section A25 of Part 2 of Annex 3 of the same circular, but may not necessarily represent the Part IIA strategies as developed by individual local authorities (or their consultants) in part fulfilment of their obligations under Part IIA.

(c) Identify pathways, and where possible rank pathways, by which a receptor or combination of receptors is being or could be exposed. This data has then been used to systematically identify the potential for pollutant linkages at each site.

(d) Identify those SSSIs where a site-specific risk assessment is required. This goes some way towards remediation in the sense of the Environmental Protection Act, Part IIA, in “doing anything for the purpose of assessing the condition of the contaminated land in question”. Certainly from the information gathered in the desk based study remedial options have not presented themselves. This will require a much more detailed site-specific investigation.

4.1 GIS ASSESSMENT PROCEDURE AND SCORING METHOD

The starting point for assessment of pollutant linkages is identification of sites with the potential to contain contaminants. Pathways are divided into three sub-categories: direct contact, groundwater and surface water. Receptors are identified and evaluated solely on the basis of proximity or interception of polygons in data layers.

The GIS application implements a scoring system that assesses all the likely pollutant linkage scenarios (listed below), these are written back to the source layer.

- Source -> Direct Contact Pathway -> Human Receptor: **(Hum_DC)**
- Source -> Surface Water Pathway -> Human Receptor: **(Hum_SW)**
- Source -> Surface Water Pathway -> Controlled Water Receptor: **(Aqu_SW)**
- Source -> Groundwater Pathway -> Controlled Water Receptor: **(Aqu_GW)**
- Source -> Direct Contact Pathway -> Ecological Receptor: **(Ecol_DC)**
- Source -> Surface Water Pathway -> Ecological Receptor: **(Ecol_SW)**
- Source -> Direct Contact Pathway -> Property Receptor: **(Prop_DC)**

4.2 SOURCES

The aim of the programme is to attribute source polygons according to their likelihood of being classified as 'contaminated land'. The following information was used to calculate the source score in this instance:

- **Contaminant Ranking** (High, Medium, Low, Very Low)
- **Area of site**

4.3 PATHWAYS:

As mentioned earlier the pathway score is made up of three sub-categories.

Pathways: Direct contact

- **Proximity to potential receptors** (based on buffered distances, 50m, 100m, 250m and 500m).

Pathways: Ground water

- **Aquifer vulnerability**
- **Drift permeability**
- **Potential high permeability features**

Pathways: Surface water

- **Proximity to surface waters**

4.4 RECEPTORS:

Receptors: Human

- **Buildings:** the human receptors category is defined by residential areas, however in this study access to digital datasets that distinguish between residential property and other property was not available, therefore all those features marked as buildings in the Ordnance Survey MasterMap dataset have been used as potential human receptors.

Receptors: Aqueous

Controlled waters are receptors as well as pathways for the purposes of pollutant linkage assessment.

- **Surface water**
- **Groundwater**

Receptors: Ecological

- **Scheduled Monuments**
- **Nature Reserves and other Special sites**

4.5 CALCULATION OF POLLUTANT LINKAGE RANKING CLASSES

The application calculates a numeric score for each query that is undertaken, for instance a specified score is assigned if a building is present within 100 metres of a source polygon. The scores are then summed to create an overall score for each of the three components of the pollutant linkage (source, pathway and receptor). These scores are converted from numerical scores to alphabetical ranking classes using the threshold values A to E. The lowest scoring component of the pollutant linkage (source ranking, pathway ranking and receptor ranking) is then used to assign a category to the particular pollutant linkage scenario. For example if a source has a ranking of A, the pathway has a ranking of C and the receptor has a ranking of B, the overall score for this particular pollutant linkage scenario is C, which is the lowest scoring component.

4.5.1 Customisation

SSSI's are treated as both a source and as a receptor. The overall scoring also takes into account the lack of a number of digital datasets that are normally included in the BGS ConSEPT model. These datasets are listed below:

- **Duration of industry:**
- **Food production**
- **Site accessibility**
- **Flood potential**
- **Topography**

4.5.2 Prioritisation and Output

All of the pollutant linkages, in terms of alphabetic ranking classes (A to E), have been assessed. This allows the user to focus on pollutant linkages of particular concern, e.g. those involving human receptors. A single combined pollutant linkage ranking class is also provided as output **(Fscore)**. This provides a single general indicator of pollutant linkages that takes the worst case of the seven potential pollutant linkages.

The prioritisation routine outputs the seven pollutant linkage classes, and the combined pollutant linkage classes (FScore) to an attribute field attached to each site polygon. These results are presented in Appendix 1 as a Microsoft Word report along with maps and the attribute data used to prioritise each site.

5 Conclusions

The GIS site assessments are presented in Tables 2,3 and 4. In Table 2 there are four category A sites all occurring in the Lake District. These should be prioritised for any further follow up fieldwork. Table 3 lists those sites for which there is insufficient data to produce a ranking. The site boundaries for these sites were supplied after the initial assessment had been completed; these sites should be prioritised for data acquisition on the conservative assumption that they may contain A and B sites.

Table 4 ranks the remaining sites in descending order of hazard ranking starting at Rank B. Five of these sites were originally given a high pollution rating in the original data collation presented in Table 1. The current ranking scheme is not field validated as this was outside the scope of the original project. It needs to be established therefore, as a first priority, whether or not sites ranked as A or B satisfy the criteria of contaminated land. This should be tested against the criteria of the significant risk of significant harm benchmark. It is known for example, from work carried out by the BGS, that Devon Great Consoles and Snailbeach have the potential to cause harm, in the case of the latter there are reported cases of cattle deaths linked to the old lead mines and the possible ingestion of contaminated soil. In the case of Devon Great Consoles there is clear evidence of vegetable uptake of arsenic in a domestic garden and contaminated listed buildings that are inhabitied. The question is, “Does this constitute a significant risk of significant harm?”

Based on the results of the field validation exercise a detailed follow up of the A-ranked and B-ranked sites should be programmed. Category C and D sites were generally ranked with a low to medium low risk during the desk study and it is recommended that medium risk sites should be dealt with next only if there are failing A or B-sites.

Table 2 Category A Sites

SSSI_NAME	Ranking	Hum_DC	Hum_SW	Aqu_SW	Aqu_GW	Ecol_DC	Ecol_SW	Prop_DC	FScore	GCRName	Easting	Northing
Skiddaw Group	High	B	A	A	B	B	A	B	A	Burdell Gill, Roughtongill Mine, Red Gill MineDry, Gill MineCarrock Mine, Wet Swine Gill	332273	534456
Moor House & Cross Fell	High	B	A	B	B	B	A	B	A	Sir John's Mine	370588	536250
Coniston Mines & Quarries	High	B	A	B	D	B	B	D	A		329668	498454
Coniston Mines & Quarries	High	B	A	B	D	B	B	B	A	Coniston Copper Mines	328567	498873

Table 3 Non Attributed Sites

SSSI_NAME	Ranking	Hum_DC	Hum_SW	Aqu_SW	Aqu_GW	Ecol_DC	Ecol_SW	Prop_DC	FScore	GCRName	Easting	Northing
Moor House & Cross Fell											376750	531467
Moor House & Cross Fell											376634	530652
Buttermere Fells											323025	521178
Aire Point to Carrick Du											148077	40790
Aire Point to Carrick Du											149791	41163
Skiddaw Group											333850	529303
Skiddaw Group											332356	526502
Skiddaw Group											329650	527070
Skiddaw Group											334457	527559
Moor House & Cross Fell											370009	541044
Moor House & Cross Fell											367249	538963
Moor House & Cross Fell											365543	538828
Moor House & Cross Fell											373650	539409
Moor House & Cross Fell											366726	535300

SSSI_NAME	Ranking	Hum_DC	Hum_SW	Aqu_SW	Aqu_GW	Ecol_DC	Ecol_SW	Prop_DC	FScore	GCRName	Easting	Northing
Moor House & Cross Fell											368645	533492
Moor House & Cross Fell											378178	539223
Moor House & Cross Fell											376154	533537
Moor House & Cross Fell											373654	532601
Moor House & Cross Fell											371101	532429
Moor House & Cross Fell											371195	529224
Aire Point to Carrick Du											141482	36412
Aire Point to Carrick Du											142594	37928
Aire Point to Carrick Du											144297	38808
Aire Point to Carrick Du											145460	39313
Godrevy Head to St Agnes											168967	47393
Aire Point to Carrick Du											142594	37928
Aire Point to Carrick Du											140401	35958
Aire Point to Carrick Du											137882	35757

Table 4 Category B-E Sites

SSSI_NAME	Ranking	Hum_DC	Hum_SW	Aqu_SW	Aqu_GW	Ecol_DC	Ecol_SW	Prop_DC	Fscore	GCRName	Easting	Northing
Moor House & Cross Fell	Medium	E	E	E	E	B	D	E	B		380397	538607
Appleby Fells	Medium	E	E	D	D	B	C	E	B		377290	528820
Appleby Fells	Medium	B	B	D	D	B	B	E	B		378711	530263
Appleby Fells	Medium	E	E	D	D	B	C	E	B		378210	523529
Buttermere Fells	Medium	B	D	E	E	B	D	E	B		324657	517743
Buttermere Fells	Medium	E	E	C	D	B	B	E	B		324286	518960
Helvellyn & Fairfield	Medium	D	D	B	B	B	B	E	B	Eagle Crag	335907	514183

SSSI_NAME	Ranking	Hum_DC	Hum_SW	Aqu_SW	Aqu_GW	Ecol_DC	Ecol_SW	Prop_DC	Fscore	GCRName	Easting	Northing
Helvellyn & Fairfield	Medium	E	E	D	D	B	C	E	B		333951	515587
Helvellyn & Fairfield	Medium	E	E	E	E	B	D	E	B		336635	516791
Helvellyn & Fairfield	Medium	D	D	E	E	B	D	D	B		336217	517836
Helvellyn & Fairfield	Medium	E	E	E	E	B	E	E	B		339405	510031
Moor House & Cross Fell	Medium	B	B	B	B	B	B	E	B	Windy Brow Mine	375887	536497
Appleby Fells	Medium	E	E	C	C	B	B	E	B		374219	529789
Appleby Fells	Medium	E	E	B	B	B	B	E	B		371893	527505
Appleby Fells	Medium	E	E	B	B	B	B	B	B		375590	522468
Appleby Fells	Medium	D	D	B	B	B	B	E	B		379844	527866
Buttermere Fells	Medium	B	B	C	D	B	B	E	B		323614	515320
Buttermere Fells	Medium	E	E	E	E	B	D	E	B		324489	515761
Godrevy Head to St Agnes	Medium	B	B	B	B	B	B	B	B	Wheal Coates	170054	49430
Godrevy Head to St Agnes	Medium	B	B	B	B	B	B	E	B		171253	51621
The Cheddar Complex	Medium	B	B	B	B	B	B	B	B		350248	155341
Buttermere Fells	Medium	B	B	B	D	B	B	E	B		321972	514129
Buttermere Fells	Medium	B	B	B	D	B	B	B	B	Dale Head North and South Veins	322730	517181
Cligga Head	Medium	B	B	B	D	B	B	B	B	Cligga Head Mine	173789	53164
Devon Great Consols	High	D	D	C	C	B	B	E	B	Devon Great Consols	243114	73429
Snailbeach Mine	High	B	D	E	E	B	D	D	B	Snailbeach Mine	337371	302225
Snailbeach Mine	High	B	C	D	D	B	C	D	B	Snailbeach Mine	337453	302257
Dimminsdale	Medium	B	B	B	B	B	B	E	B	Earl Ferrers' Lead Mine	437662	321671
Dimminsdale	Medium	B	B	B	B	B	B	E	B	Earl Ferrers' Lead Mine	437840	322375
Ecton Copper Mines	Medium	B	B	B	B	B	B	B	B	Ecton Copper Mines	409866	358103
Fall Hill Quarry	Medium	B	B	B	B	B	B	E	B	Fall Hill Quarry	435395	362448
Alderley Edge	Medium	B	B	B	B	B	B	B	B	Alderley Edge	385674	377554
Dirtlow Rake & Pindale	Medium	B	B	B	B	B	B	B	B	Dirtlow Rake and Pindale	415643	382167
Seatoller Wood, Sourmilk Gill & Seathwaite Graphite Mine	Medium	B	B	B	B	B	B	B	B	Seathwaite Graphite Mine	323391	512792

SSSI_NAME	Ranking	Hum_DC	Hum_SW	Aqu_SW	Aqu_GW	Ecol_DC	Ecol_SW	Prop_DC	Fscore	GCRName	Easting	Northing
Force Crag Mine	Medium	B	B	B	D	B	B	B	B	Force Crag Mine	319663	521566
River South Tyne & Tynebottom Mine	High	B	B	B	B	B	B	E	B	Tynebottom Mine	373812	542055
Aire Point to Carrick Du	Medium	B	B	B	B	B	B	B	B	Botallock Mine	136179	33277
Smallcleugh Mine	High	B	B	B	B	E	E	E	B	Smallcleugh Mine	378768	542904
Hingston Down Quarry & Consols	Medium	B	B	B	B	E	E	E	B	Hingston Downs Consols	241052	71685
South Terras Mine	High	B	C	D	D	E	E	E	B	South Terras Mine	193439	52369
South Terras Mine	High	B	B	D	D	E	E	E	B	South Terras Mine	193412	52276
South Terras Mine	High	B	B	C	E	E	E	E	B	South Terras Mine	193340	52447
South Terras Mine	High	B	B	D	D	E	E	E	B	South Terras Mine	193392	52295
South Terras Mine	High	B	B	C	D	D	D	E	B	South Terras Mine	193318	52246
Wheal Alfred	Medium	B	D	E	E	E	E	E	B	Wheal Alfred	157950	36994
Penhale Dunes	Low	C	C	C	C	C	C	C	C	Perran Beach - Holywell Bay, Gravel Hill Mine	176760	56870
Belowda Beacon	Low	E	E	E	E	C	C	E	C	Belowda Beacon	197220	62727
Croft & Huncote Quarry	Low	C	C	D	D	C	C	E	C	Croft Quarry	451196	296488
Masson Hill	Low	C	C	C	C	C	C	E	C		429289	357535
Masson Hill	Low	C	C	C	C	C	C	E	C		429063	357988
Masson Hill	Low	D	D	C	D	D	C	E	C		427904	359612
Masson Hill	Low	C	C	C	C	C	C	D	C	Masson Hill Mines	429098	358957
Masson Hill	Low	C	C	C	D	C	C	D	C		426433	359923
Masson Hill	Low	C	C	C	D	C	C	E	C		427641	359998
Portway Mine	Low	E	E	C	D	E	C	E	C	Portway Gravel Pits	412893	381109
Castleton	Low	C	C	C	C	C	C	C	C	Windy Knoll, Treak Cliff	412539	382037
Greenhow Quarry	Low	C	C	D	D	C	C	E	C	Greenhow Quarry	411277	463861
Water Crag	Low	E	E	D	D	D	C	D	C	Water Crag	315291	497312
Black Scar Quarry	Low	C	C	C	C	C	C	E	C	Black Scar, Middleton Tyas	423085	505206
Wheal Gorland	Medium	C	D	E	E	E	E	E	C	Wheal Gorland and Wheal Unity	173269	42904
Florence Mine	Low	C	C	C	C	D	D	E	C	Florence Mine	302145	510481

SSSI_NAME	Ranking	Hum_DC	Hum_SW	Aqu_SW	Aqu_GW	Ecol_DC	Ecol_SW	Prop_DC	Fscore	GCRName	Easting	Northing
Devon United Mine	Medium	E	D	C	D	E	D	E	C	Devon United Mine	252123	79502
Haytor & Smallacombe Iron Mines	Low	D	D	D	D	C	C	E	C	Haytor Iron Mine	277738	76612
Trevaunance Cove	Low	C	C	C	D	D	D	E	C	Trevaunance Cove	172280	51747
Compton Martin Ochre Mine	Medium	C	D	D	D	C	D	E	C	Compton Martin Ochre mine	354205	156685
Coverack to Porthoustock	Very Low	D	D	D	D	D	D	D	D	Dean Quarry	179967	20122
Wheal Penrose	Low	D	D	D	D	D	D	E	D	Wheal Penrose	163574	25078
Wheal Penrose	Low	D	D	D	D	D	D	E	D	Wheal Penrose	163529	25187
Tremearne Par	Very Low	E	D	D	D	E	D	E	D	Tremearne Par	160919	26692
Penlee Quarry	Very Low	D	D	D	D	D	D	E	D	Penlee Quarry	146728	27649
Great Wheal Fortune	Low	D	D	D	D	D	D	E	D	Great Wheal Fortune	162708	28881
St Michael's Mount	Very Low	D	D	D	D	D	D	D	D	St Michael's Mount	151430	29777
Penberthy Croft Mine	Medium	E	D	E	E	E	D	E	D	Penberthy Croft Mine	155627	32478
Hope's Nose to Walls Hill	Very Low	D	D	D	D	D	D	D	D	Hope's Nose	293980	64379
Ben Knowle	Very Low	D	D	D	D	D	D	E	D	Ben Knowle	351380	144953
Wurt Pit & Devil's Punchbowl	Low	E	D	D	D	E	D	E	D	Wurt Pit	354356	153789
Wurt Pit & Devil's Punchbowl	Low	E	D	D	D	E	D	E	D		355868	153914
Banwell Caves	Very Low	D	D	D	D	D	D	E	D	Banwell Caves	338257	158797
Banwell Ochre Caves	Very Low	D	D	D	D	D	D	D	D	Banwell Ochre Caves	340749	159168
Hartcliff Rocks Quarry	Very Low	D	D	D	D	D	D	E	D	Hartcliff Rocks Quarry	353330	166223
Clevedon Shore	Low	D	D	D	D	D	D	E	D	Clevedon Shore	340180	171871
Bardon Hill Quarry	Very Low	D	D	D	D	D	D	E	D	Bardon Hill	445603	313003
Kirkham's Silica Sandpit	Very Low	D	D	D	D	D	D	E	D	Kirkhams Silica Sandpit	421602	354178
Cumpston Hill	Medium	E	D	E	E	E	D	E	D	Cumpston Hill, North and South Ve	378086	497498
Cumpston Hill	Medium	E	E	E	E	E	D	E	D	Cumpston Hill, North and South Ve	378406	497710
Nab Gill Mine	Very Low	D	D	D	D	D	D	E	D	Nab Gill Mine	317342	501376
Comb Beck	Low	E	E	E	E	E	D	E	D	Coombe Beck	318215	514991
Bramcrag Quarry & Wanthwaite Mine	Very Low	D	D	D	D	D	D	E	D	Wanthwaite Mine	332274	522191

SSSI_NAME	Ranking	Hum_DC	Hum_SW	Aqu_SW	Aqu_GW	Ecol_DC	Ecol_SW	Prop_DC	Fscore	GCRName	Easting	Northing
Blagill Mine	Medium	D	D	D	D	E	E	E	D	Blagill Mine	374117	547302
Aire Point to Carrick Du	Very Low	D	D	D	D	D	D	D	D	Priest's Cove	135655	30866
Porthgwarra to Pordenack Point	Very Low	D	D	D	D	E	E	D	D	Nanjizal Cove	136035	22875
Bage Mine	Low	D	D	D	D	D	D	E	D	Bage Mine	429134	354969
Main Quarry, Mountsorrel	Very Low	D	D	D	D	E	E	D	D	Castle Hill Quarry	457718	314854
Newhurst Quarry	Very Low	D	D	D	D	E	E	E	D	Newhurst Quarry	448581	317973
Enderby Warren Quarry	Very Low	D	D	D	D	E	E	E	D	Warren Quarry	454120	300025
Gipsy Lane Pit	Low	D	D	E	E	E	E	E	D	Gipsy Lane Pit	461914	307105
Huglith Mine	Very Low	D	D	D	D	D	D	E	D	Huglith Mine	340447	301599
Lockridge Mine	Medium	E	D	D	D	E	E	E	D	Lockridge Mine	243823	66317
Wheal Emily	Low	D	D	D	D	D	D	E	D	Wheal Emily	254062	49790
Cameron Quarry	Low	D	D	E	E	D	D	E	D	Cameron Quarry	170389	50649
Penberthy Croft Mine	Medium	E	E	E	E	E	E	E	E	Penberthy Croft Mine	155245	32424
Trelavour Downs	Very Low	E	E	E	E	E	E	E	E	Trelavour Downs	196023	57502
Mulberry Downs Quarry	Low	E	E	E	E	E	E	E	E	Mulberry Down	201939	65777
Lidcott Mine	Very Low	E	E	E	E	E	E	E	E	Lidcott Mine	224032	85075
Buckbarrow Beck	Low	E	E	E	E	E	E	E	E	Buckbarrow Beck	313677	490954
Seathwaite Copper Mines	Medium	E	E	E	E	E	E	E	E	Seathwaite Copper Mine	326540	499405
Seathwaite Copper Mines	Medium	E	E	E	E	E	E	E	E	Seathwaite Copper Mine	326636	499692
Birk Fell Hawse Mine	Medium	E	E	E	E	E	E	E	E	Birk Fell Hawse Vein	329294	501544
Highdown Quarry	Very Low	E	E	E	E	E	E	E	E	High Down Quarry	265113	128977

Table Key

The tables below list the seven pollutant-linkage classes for each site along with the combined pollutant linkage class (FScore). The initial contaminant potential ranking (Ranking) assigned to each site is also listed. The grid reference indicated is the centroid associated with each polygon, and not the original GCR grid reference.

Hum_DC= Source -> Direct Contact Pathway -> Human Receptor
Hum_SW= Source -> Surface Water Pathway -> Human Receptor
Aqu_SW= Source -> Surface Water Pathway -> Controlled Water Receptor
Aqu_GW= Source -> Groundwater Pathway -> Controlled Water Receptor
Ecol_DC= Source -> Direct Contact Pathway -> Ecological Receptor
Ecol_SW= Source -> Surface Water Pathway -> Ecological Receptor
Prop_DC= Source -> Direct Contact Pathway -> Property Receptor

Appendix 1 Individual Site Assessments

(See disk)

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