CHARACTERISATION OF HISTORIC MINE SITES IN IRELAND AND THEIR ENVIRONMENTAL RISKS

A Joint Project Proposal by the
Environmental Protection Agency
and the
Department of Communications, Marine and Natural Resources (Geological Survey of Ireland and the Exploration and Mining Division)

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1. OBJECTIVES

The **objectives** of the project are**:**

- to develop a systematic and consistent approach to the remediation, rehabilitation and long-term management of historic mine sites in Ireland in compliance with current and upcoming national and EU legislation;
- to review and document the potential impacts of historic mine sites in Ireland on the environment and human and animal health, and human safety;
- to draw up a list of priority sites for detailed investigation based on existing information;
- to review existing sampling protocols and to select or develop as appropriate, a sampling protocol which will be used at each site to ensure reliability and replication at each site for a range of sampling media (e.g. soil, water, sediment, mine wastes, vegetation etc.);
- to carry out detailed site investigation and characterization on the priority sites identified, including an inventory of all extant surface and underground mine workings and associated buildings;
- following best international practice, to develop a methodology for risk-ranking historic mine sites which would provide a robust scientific basis for making decisions about actions that need to be taken to minimise or manage risks associated with such sites;
- to develop a risk categorisation methodology based on best international practice;
- to categorise the sites investigated according to the system developed; and
- to present the findings of the work in interim and final reports and to compile all information and analytical results obtained for each site during this project into a GIS database.

2. BACKGROUND

An outstanding environmental problem relating to mining in Ireland is that of old mining sites or abandoned mine sites, which were not reclaimed when operations ceased and where past mining activities have lead to serious land degradation and environmental pollution. It was normal practice in the past that mining sites were closed with no or very little consideration given to the need to remediate these sites. As a result, these sites may continue to cause on-going damage to the environment and potential risks to human and animal health in the surrounding areas. There is also the potential that the risks posed by these sites may increase with time as large abandoned tailings dumps, rock dumps and underground workings gradually deteriorate and where no consideration was given to long-term maintenance and aftercare of closed mine sites. There is therefore a need to develop a systematic and consistent approach to the remediation, rehabilitation and long-term management of historic mine sites in Ireland.

In recent years and in response to animal health issues, detailed investigations have been carried out on some of these historic mine sites and recommendations in relation to the long-term remediation and management of these sites have been proposed. However, many factors including the potential costs of rehabilitation on a wide scale,

the lack of specific legislation and clearly assigned administrative responsibility for remedial actions, the absence of criteria and standards for rehabilitation, the issue of liability, have delayed action being taken by Government, public and regulatory authorities and industry. The national situation with regard to historic mine sites is clearly different from the situation that currently exists with operational mines where the need for rehabilitation and adherence to strict environmental standards already exists. The environmental regulation of mining activities has in most cases only been introduced relatively recently. The case for rehabilitation of historic mine sites is, however, the same as that for active mines; the difference is that the assignment of responsibility is different and more difficult to establish.

DEFINITION OF HISTORIC MINE SITES

Many terms have been used to refer to old mines including *abandoned, derelict or orphaned.* There is no widely accepted single definition for classifying old mines that are dormant, may or may not have an identifiable owner, and have not been reclaimed. Perhaps a working definition might be:

"any inactive minesite not in the process of rehabilitation or under active management".

Some common characteristics of historic mine sites are that ownership of the site is difficult to establish, the issue of ownership is also complicated by the fact that ownership of minerals can be held separately from the land in which they lie, that regular maintenance of the site is not undertaken and mining ceased without definitive rehabilitation. In our proposal, the term **historic mine** site will be used to refer to old mine sites which are not regulated by a permit under current mining legislation and which encompasses all infrastructure related to a mine, including, but not limited to tailings facilities, waste rock dumps, buildings and mills.

The fundamental question in relation to historic mine sites in Ireland is how many of these sites actually constitute an environmental problem and/or a risk to human and animal health where they occur. It is important to note that mining sites by their nature will be located in areas where there is a naturally high geological occurrence of constituents of the ore-body e.g. heavy metals, sulphides etc in the bedrock; however, the disturbance caused by mining and the resulting exposure of the ore-bodies and the generation of various waste streams will have resulted in an increased dispersion of these constituents into the wider environment, causing in some cases, environmental pollution. In addition, the chemicals used by the mining industry in the extraction process may have been released into the environment as a result of accidental spillages or poor management practices. The principal concerns at these sites are environmental impacts to lands and watercourses from acid rock drainage and metal leaching; potential human and livestock exposure and ecotoxicity problems; dangers to public health and safety presented by openings, shafts, tunnels and underground workings that open to the surface and ground stability in general.

IMPACTS FROM HISTORIC MINE SITES

The construction and operation of metal and coal mines over the centuries in Ireland has caused varying degrees of environmental damage locally, often in remote and sometimes scenic rural areas. Mining, unlike renewable natural resource land uses (e.g. fishing, farming, forestry), is a transient occupier of land while the metals and

minerals of economic interest are being extracted. At any given site, mining may have supported the economic welfare of the local community for a decade or more; at some celebrated sites (e.g. Avoca, Silvermines) mining activity spanned hundreds of years and employed thousands of workers and a rich industrial and cultural heritage is now linked to these sites.

However, the impacts of mining on the environment are long-term and may in some cases represent a risk to human health, animal health and the environment unless definitive remediation and rehabilitation and long-term management is undertaken on these sites. The impact of historic mine sites on the environment may be significant and includes:

- the destruction of the landscape including loss of alternative land uses e.g. agriculture, forestry, conservation, amenity etc;
- degradation of the visual environment;
- disturbance and pollution of watercourses;
- land subsidence and slope instability;
- generation and impact of acid mine drainage;
- metal leaching and heavy metal contamination of soils, water;
- waste storage and disposal;
- chemical pollution from ore processing;
- soil erosion and sedimentation of water courses; and
- dust generation and deposition.

The potential risk posed by the resulting contamination will be site specific and will be determined by linkages or connectivity between the sources of contamination and potential receptors such as children, adults, livestock and terrestrial and aquatic ecosystems.

On the positive side it should also be noted that old mining sites have created wealth and employment for local communities and can often be viewed as an important part of the cultural and industrial heritage of the surrounding area and community. These sites, or parts of these sites, represent an educational, cultural and heritage resource which can still benefit their local communities. These beneficial effects demonstrate that not all sites require intervention or active long-term management.

Acid mine drainage (AMD) or acid rock drainage (ARD) occurs when minerals, e.g., pyrite (FeS_2), containing sulphide and elemental iron are exposed to the weathering effects of air and water. This reaction (oxidation) is mediated and accelerated by certain sulphur-loving bacteria and results in the formation of sulphuric acid and the release of iron hydroxide. The acid leaches metals from exposed underground workings (this is normally referred to as AMD) or from waste rock piles or tailings on the surface (normally referred to as ARD). This process will continue for as long as the sulphide minerals remain exposed to air and water and until the sulphides are completely oxidised. This process can take hundreds or even thousands of years to complete. The environmental impact of AMD/ARD will depend on the sulphide content of the minerals, the host geology, the sensitivity of the receiving environment and the degree of neutralisation, dilution and /or natural attenuation. In addition to the generation of AMD/ARD, the leaching of metals from ore-bodies is particularly important in relation to toxicity problems and contamination of the wider

environment. Heavy metals can be toxic to humans and wildlife and can bio-accumulate and can be passed through the food chain.

Enhanced metal leaching is associated with acidic drainage due to high metal solubility and sulphide weathering rates under acidic conditions. For many rock types and environmental settings, metal leaching will only be significant where drainage pH drops below 5.5 to 6. However, neutral pH does not necessarily eliminate metal leaching. While the solubility of aluminium, iron, and copper is greatly reduced in neutral pH drainage, elements such as antimony, arsenic, cadmium, molybdenum, selenium and zinc remain relatively soluble and therefore can be found in significant concentrations in drainage water (Price and Errington, 1998). Factors which enhance metal leaching include rapid weathering of metal-containing minerals, drainage conditions that increase solubility and high vertical and/or horizontal water run-off rates through contaminated mine wastes.

Erosion and sedimentation occur when bare rock, soils or processing wastes from mining activities are eroded by water or have been deliberately discarded into watercourses. Wind erosion can also occur where finer particles on mine waste dumps and tailings can become airborne under dry weather conditions and are deposited on other parts of the mine site or onto adjoining lands. This erosion and sedimentation process can have serious environmental impacts on watercourses such as clogging up and siltation of river beds, including the destruction of aquatic life and habitats. There is also the potential for sediments washed out from these sites to cause toxicity problems in livestock where animals grazing adjacent to unfenced streams in these areas might get access to contaminated sediments and turbid water while drinking from the streams.

Chemicals used to separate target metals from host rock can also cause serious environmental pollution where they leach or escape into the environment as a result of accidental spillages. These chemicals, which can include cyanide, sulphuric acid and mercury, can be highly toxic to humans, livestock, wildlife and aquatic ecosystems.

3. EXISTING INFORMATION ON HISTORIC MINE SITES IN IRELAND

Ireland has a very long history of indigenous mineral workings and metal fabrication, dating as far back as the Bronze age (*ca*. 2000 BC). Mining in historic times was small scale and sporadic. The lack of processing techniques lead towards a tendency to mine coarse grained metallurgically clean ores that could be manually cobbed rather than the finer grained and more complex sulphides (Williams and McArdle, 1978). During the 1920's the development of mineral resources was given high priority and in 1940 an attempt was made to rationalise legislation concerning prospecting, mining and mineral ownership under the Minerals Development Act. The following twenty years was characterised by small operations of moderate success mainly focused on old mining areas such as Silvermines, Abbeytown and Benbulben. Tax incentives for mining were provided through the Finance Act of 1956. These incentives in conjunction with a favourable international investment climate, led to exploration, which discovered the Tynagh Zn-Pb deposit in East Galway. This discovery demonstrated that substantial base-metal deposits exist in the Lower Carboniferous limestones in Ireland and that they could be located with

modern exploration techniques. Several significant deposits such as Silvermines and Gortdrum were subsequently discovered and in 1970 the giant Navan zinc-lead deposit of world-class standard was discovered; the Galmoy and Lisheen base metal deposit discoveries followed in 1986 and 1990 respectively.

Unlike the modern present day mines in operation in Ireland (Navan, Galmoy and Lisheen), where strict environmental controls are in place and administered through the IPPC licensing system, most of the historic mines in Ireland were developed under less strict environmental controls. There is little specific legislation requiring the remediation and management of historic mine sites in Ireland other than specific clauses in mining leases granted by the State. For health and safety reasons, Section 32 of the Minerals Development Act, 1940 requires the fencing off of entrances and shafts, which were used during mining operations. However, the Local Authorities have responsibilities in relation to the management of historic mine sites under various Sections of the Planning Act 2002, the Derelict Sites Act 1990, Public Health Act 1878 and as a result of a recent European Court Judgement.

The Geological Survey of Ireland (GSI) is the national geoscience agency and is a line division of the Department of Communications, Marine and Natural Resources. In recent years GSI has undertaken a preliminary inventory of mine wastes at historic mine sites in Ireland. This study was undertaken as part of a European Commission Environment Directorate (DGXI) wider study to look at the management of mining, quarrying and ore-processing waste in the European Union. It would also appear likely that an inventory of historic mine sites may be required under the European Commission proposed Directive on the Management of Waste from the Extractive Industry (COM (2003) 319 final). Article 19 of the current draft provides for the exchange of technical and scientific information with a view to developing methodologies relating to the drawing up of inventories of closed waste facilities from extractive industries. The GSI's previous work was largely a 'desk' exercise where existing records were reviewed. This work did not involve a risk assessment or risk categorization of the sites.

The primary information held by the GSI of relevance to the project is stored in a databank known as the Mine Records. This databank is part of the National Archives and contains papers relating to Irish mine sites – some dating back to the seventeenth century. The documents are a mix of drawings, maps, reports and drill logs. The more recent documents relating to 20th century operations commonly contain 'Abandonment Plans'. Such plans illustrate the "as left" condition for the relevant mine. These documents will be invaluable in the proposed study.

The Exploration and Mining Division (EMD) is responsible for minerals policy formulation and implementation and for the administration of the regulatory aspects of the Minerals Developments Acts 1940 – 1999 which govern exploration for and development of all minerals except ordinary clay, stone, sand and gravel. As such the Division holds an extensive database in hard copy and in some instances digital format of records relating to mineral ownership, landownership, mine site, shaft and subsidence locations, State Mining Facility information, Mineral Acquisition orders and Exempted Minerals and resultant responsibilities, current safety and subsidence responsibilities in areas of abandoned mine workings, e.g., Allihies, Bunmahon and

several coal mines, Mine Heritage funding, e.g., Arigna, etc. All of this information can be made available to the project.

The EPA also funded a small project to identify and draw up an EPA register of historic mine sites in Ireland (Grennan, 1996). A methodology was developed which made a preliminary ranking of sites depending on their potential to pollute. A Pollution Index Number (PIN) was assigned to each site. Factors which contribute to the pollution index number are scale and size of operation, method of mining, elements/heavy metals present, processing chemicals used and potential to generate acid rock drainage and acid mine drainage. The PIN system, which ranges from PIN 1 to PIN 9, is a combination of arithmetic and exponential numbering. PIN 1 indicates the highest value with sites in this category having the greatest potential to cause pollution. Included in this category are all of the country's recently closed large metal mines and the major coalfields. PIN 2 sites are medium sized mines (i.e., > 100,000 tpa production and/or > 100 people employed) usually worked prior to 1960 and /or satellite deposits associated with larger mines. PIN 3 sites are more minor in extent and potential impact.

Based on existing information sources, a preliminary list of potential sites, which require further site investigation for more objective evaluation, has been prepared. This list provides the starting point for this proposed project and includes base metal mine sites and coalfields. Table 1 provides a summary of these sites and their assigned PIN index. The Table is modified from Grennan's work.

Table 1: Provisional list of priority historic mine sites in Ireland for inclusion in this study.

Mine name	Location	Commodities mined	PIN Index
Avoca*	Co. Wicklow	Cu, Au, Pb, Zn, Ag	1
Gortdrum	Co. Tipperary	Cu, Hg, Ag	1
Munster Coalfield	Cos. Cork and Limerick	Coal (anthracite)	1
Leinster Coalfield	Cos. Laois, Kilkenny and Carlow	Coal (anthracite)	1
Connacht Coalfield	Cos. Roscommon, Leitrim and Sligo	Coal (bituminous)	1
Slieve Ardagh Coalfield	Co. Tipperary	Coal (anthracite)	1
Silvermines*	Co. Tipperary	Pb, Zn, Ba, Cu, Ag	1
Tynagh*	Co. Galway	Pb,Zn,Cu,Ag,Ba	1
Allihies	Co. Cork	Cu (As, Mo, Pyrite)	2
Ballyshannon "2"	Co. Donegal	Pb (Zn, Ag)	2
Ballycorus	Co. Dublin	Pb, As	2
Castlecomer Brick	Co. Kilkenny	Fire-clay	2
Abbeytown	Co. Sligo	Pb, Zn	2
Glengowla	Co. Galway	Pb, Ag, Zn (Au, Cu, Ba, F)	3
Clements	Co. Galway	Pb, Ag (Fe, Zn, Cu)	3
Ternakill	Co. Galway	Ni, Fe, Cu, S, (Mo)	3

Keel	Co. Longford	Zn (Cd)	3
Kilnaleck	Co. Cavan	Silica sands	3
Victoria	Co. Tipperary	Slate	3
Glendalough	Co. Wicklow	Pb (Ag)	3

*In recent years some limited site characterisation work has been carried out by GSI, the EPA or by consultants on behalf of EMD at these sites.

4. OUTLINE WORK PROGRAMME

An outline work programme is set out below; the activities listed are indicative. The tasks have been divided into four phases spread over a period of 2 years and are schematically shown as a Gantt Chart (Figure 1).

- **Phase 1: Inception Report and Preparation of Work Programme**
- **Phase 2: Background Information, Preparation of Protocols and Planning of Investigations**
- **Phase 3: Site Investigations and Data Interpretation**
- **Phase 4: Risk Categorization and Final Report**

Phase 1: Inception Report and Preparation of Work Programme

A detailed work programme shall be drawn up by agreement between GSI, EPA and EMD with advice and guidance from relevant international experts. The advice and guidance of the international experts will be co-ordinated by the **Project Team**. Ongoing consultancies at Silvermines, Lisheen and Galmoy can be accessed via EMD. The work programme will set out in detail the various elements of the project. Information will be provided on the approach to be adopted to progress each component of the project.

The programme will also provide a mechanism for progress reporting and progress review. Progress Reports will be prepared by the Project Team to be submitted to the **Steering Group** at intervals of 3 months or at such other intervals that the Group may decide, one week in advance of project review meetings.

All aspects of project management including progress reporting, critical path analysis and financial management over the course of the project will also be provided for in the work programme.

Deliverable: Inception Report and Documented Work Programme
Estimated Timeframe: Within 1 month of project start

Phase 2: Background Information, Preparation of Protocols and Planning of Investigations

There will be a review of international best practice re the preparation of mine site inventories and characterization of wastes in order that the project deliverables meet both international (Mine Waste Directive and Environmental Liability Directive) and national (Ministerial / Legislative) responsibilities. The Silvermines remediation project under EMD is a reference source.

This phase will involve an evaluation of existing information on abandoned mine sites in Ireland with a view to compiling a list of relevant sites in Ireland (the Inventory) and identifying sites that require additional investigation. The preliminary works will also include an analysis of the impacts, both positive and negative, of abandoned mine sites on the environment and on human and animal health.

Following completion of preliminary works, the various protocols and procedures to be followed for conducting site investigations and risk categorization of sites based on the outcome of these investigations, will be prepared and agreed.

Task 2.1: Background Information and Preparation of Inventory

Existing information on historic mine sites, including that held by the GSI, EMD and the EPA, will be evaluated and an inventory of historic mine sites prepared. The inventory should be consistent, in so far as it can be, with that likely to be required by the proposed EU Extractive Industries Waste Directive. The inventory will be in digital format and will be prepared in a database and GIS format.

As EMD have locations of State Mining Facilities and an extensive number of mine shaft locations already in digital and GIS format the Division's expertise in database management is available to the Project to contribute to database and GIS design.

The task will also include international expert advice and a review of the literature to identify the main potential impacts arising from historic mine sites in an Irish context. All relevant elements of the environment will be considered. The result will be a concise report identifying those impacts, which will guide the rest of the work in the project.

Following preparation of the inventory and identification of main potential impacts, a list of sites requiring further investigation will be prepared.

Deliverable: Inventory of Historic Mine Sites, Report on Potential Impacts of Historic Mines and Priority List for Further Investigation.
Estimated timeframe: Within 5.5 months of commencement.

Task 2.2: Preparation of Protocols and Planning of Investigations

This task will involve reviewing existing sampling protocols which are used to carry out site investigations. These protocols will be assessed for applicability to this project. An existing protocol may be selected or may be amended and further developed where necessary to ensure that each site is investigated according to a detailed sampling programme. This will ensure that the information obtained from each site is reliable and the procedure is replicated at each site.

A work plan will be prepared for the site investigations covering all aspects of the investigations to be conducted such as sampling grids, estimated duration, timeframe, resources required, costs etc.

A methodology to assess the risk posed by these sites will also be prepared and agreed prior to commencement of site investigations. The collective experience of the GSI-EPA-EMD project team, combined with reference to the international experts plus reference to best international practice will be used to develop a risk assessment methodology. It would appear that risk assessment methodologies for historic mine sites are not well developed internationally. However, certain countries such as the USA and Canada are currently engaged with the development of such methodologies. Best international practice in relation to risk assessment will need to be established and, if considered necessary, a study trip to countries should be undertaken as part of the project.

Deliverable: Protocols for Site Investigations and Risk Assessment of Sites and Work-Plan for Investigations
Estimated Timeframe: within 6 months of commencement

Phase 3: Site Investigations and Data Interpretation

Task 3.1: Site Investigations and Characterisation

The sites selected from Task 2.1 will be surveyed. It is envisaged that the site surveys will be carried out by suitably qualified personnel from GSI and the EPA and should as a minimum include an environmental scientist, mine geologist, geochemist and geotechnical engineer. The protocols developed in Task 2.2 will be used to ensure reliability and replication at each site.

A range of representative samples will be taken from each mine site as appropriate, e.g., soils, surface water, stream sediment, mine wastes (including tailings) and each sample annotated and located accurately on a site plan. These samples will undergo further preparation at GSI and will be despatched to external laboratories for analysis for a wide range of chemical parameters including heavy metals. Fractions of samples will be archived at GSI for future reference.

Open pits, rock waste dumps, mine dumps etc. at the various sites will also be surveyed where appropriate in relation to subsidence risk and future slope stability by a geotechnical engineer.

The information obtained from historic records, on-site surveys and analytical results will be compiled into a GIS database, which will be used to archive the information and to produce appropriate maps for the final report.

Deliverable: Site Investigation Reports and GIS database.
Estimated Timeframe: Within 13 months of commencement.

Task 3.2 Data Interpretation

Quality control procedures will be used to ensure reliability of data being reported by external laboratories.

Data interpretation at each site will involve the entire Project Team. Data processing and visualisation will involve specialised geochemical software.

Deliverable: Geochemical maps for each site.
Estimated Timeframe: Within 17 months of commencement.

Phase 4: Risk Assessment and Final Report

An assessment will be undertaken by the Project Team, with assistance from the international experts, of the information available for each site following the site investigations. A summary of the results from the on-site investigations and sampling for each site will be prepared as part of the Final Report. Conclusions will be drawn for each site and appropriate recommendations will be made including, where appropriate, on the need for remediation and/or management required. The recommendations will be based on the conclusions drawn and the application of the risk assessment methodology prepared as part of Task 2.2.

A final report will be prepared which contains and summarises all the relevant information gathered during the course of the project. The report will be published jointly.

Deliverables: Risk Assessment, Recommendations and Final Report
Estimated Timeframe: Within 23 months of commencement.

5. DELIVERABLES

The key deliverables **from the project will be:**

- an ***Inventory*** of historic mine sites in Ireland, compiled in digital and GIS format;
- ***Protocols*** for conducting site characterisation of historic mine sites;
- ***Methodology for Risk Assessment*** of historic mine sites;

- ***Site Investigation and Characterisation Reports*** at each of the selected sites;
- compilation of all relevant information on each site in ***GIS format;***
- application of risk assessment methodology to the various sites;
- ***Recommendations*** for actions to be taken at each site;
- ***Final Report*** including a section on the potential impacts of historic mine sites on the environment, human and animal health.

6. PROJECT MANAGEMENT & IMPLEMENTATION

The project will be operated as a shared-cost project jointly managed by the EPA, GSI and EMD. A joint project management team (**Project Team**) will oversee the performance of the project in meeting its objectives and will involve staff from the EPA, GSI and EMD. The GSI will recruit temporary project staff and engage appropriate international experts to guide the work programme. The project team will report progress to a **Steering Group** which will have representatives from the EPA, GSI, EMD and other stakeholders as outlined below.

Currently GSI operates a number of such shared-cost projects with Local Authorities and the European Commission. In each case a specific Project Account is set up in Finance Division DCMNR. Monies from the Local Authority or the Commission are lodged to the Project Account at regular intervals on foot of agreed Deliverables. These monies are used to pay the salaries of temporary staff engaged whole-time on the project; all travel and subsistence costs of both permanent and temporary staff; all other external costs (e.g. consultants).

It is envisaged that the GSI and EMD contributed cost to the project will be current permanent and contract staff time, all ancillary support together with a limited cash contribution from DCMNR; whereas EPA will contribute a greater proportion of cash and a smaller proportion of permanent staff time.

It is envisaged that some elements of the work, particularly the laboratory analytical work, would be contracted out in accordance with public procurement procedures.

Steering Group
The Steering Group shall comprise **two** representatives from each of the EPA, GSI and EMD and **one** representative shall be invited from the following organizations or groups of organizations: Department of Environment, Heritage and Local Government, Department of Agriculture and Food, Department of Health/Health Services Executive, Health and Safety Authority, Teagasc, Central Fisheries Board. The Steering Group shall be chaired by one of the representatives from the EPA. Any organization may nominate a substitute delegate to attend any meeting in the event that its representative cannot attend.

The role of this Group is to consider historic mine sites and any issues arising from them. The Group will have the authority to commission projects of relevance to the Group. This proposal is one such project.

Project Team

The Project Team shall comprise any person engaged in the work of the project. Employees from the EPA, GSI and EMD working on the project are automatically members of the Project Team. From time to time consultants and contractors working on the project will also be considered part of the Project Team. Mr. Gerry Stanley (GSI) will lead the Team.