Client: Galmoy Mines Ltd

Second Interim Closure and Rehabilitation Plan

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GALMOY MINES LTD.

Galmoy Mine, Co Kilkenny

Second Interim Closure and Rehabilitation Plan – November 2005

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APPENDICES

1 INTRODUCTION

1.1 Galmoy mine

Galmoy Mine is an underground lead-zinc mine located in County Kilkenny, Ireland. The mine is owned and operated by Galmoy Mines Limited, (GML; "the Company"), formerly Arcon Mines Ltd. Construction of the mine commenced in May 1995 with the first ore being extracted in August 1996. The zinc/lead processing plant was commissioned for the treatment of ore in March of 1997 and the first concentrates were exported from the port of New Ross in April
1997.

During the period March 1997 to December 2004 the Galmoy Mine processed 4.412 million tonnes of zinc/lead ore producing some 763,000 tonnes of zinc concentrates. Galmoy Mines Limited currently employs approximately two hundred and fifty managerial, administrative, production and technical personnel.

1.2 Planning and permitting background

The first planning permission approved in 1994 was for the extraction and processing of zinc/lead ores associated with the CW and G orebodies as defined by exploration conducted by the Company up until 1988.

A second planning permission was approved in 2002 for the mining of additional resources found by the Company as a result of its ongoing exploration programme. The additional resources were contained within the orebodies known as CW South, G East, G West, and K.

A third planning permission was approved in 2004 for further development of the Galmoy Mine by the mining of a new orebody, known as the R zone, together with construction of an additional ventilation shaft. The R Zone contains at least 2 million tonnes of high grade zinc and lead ore and development of this additional resource will extend the mine life to 2010.

A planning application is being considered for a further orebody, K2, in the near future.

In October 2002 the Company obtained an Integrated Pollution Control Licence from the Environmental Protection Agency, under the recently implemented IPC legislation. This supersedes to some extent aspects of the planning permissions that relate to pollution control, and transfers responsibility for this aspect from Kilkenny County Council to the EPA.

Section 2 summarises the conditions of the relevant planning permissions and IPC licence that relate to the mine closure and decommissioning. In addition, the various international guidelines and standards relevant to this Mine Closure Plan are reviewed.

1.3 Previous mine closure plans for Galmoy

During 1993, a *Mine Closure and Rehabilitation Plan* was prepared by Wardell Armstrong prior to the granting of planning consent. This 'Initial Closure Plan' was prepared in accordance with current good practice in the industry. At that time, the technical document *Rehabilitation of Mines: Guidelines for Proponents,* published by the Ontario Ministry of Northern Development and Mines, was considered to provide the best guidance with regards to mine closure, although not always strictly relevant in the context of the Republic of Ireland.

The Initial Closure Plan was prepared in accordance of the requirements of the original planning permission for the mine. This planning permission was based on an initial mineable ore reserve of 6.2 million tonnes, which projected a 10-year mine life at an average processing rate of approximately 650,000 tonnes of ore per annum.

A mine closure and rehabilitation plan submitted at the time of a planning application can only be based on projected conditions and will require review and modification during the life of the mine. Legislation, conditions and techniques have changed since Galmoy Mine was first constructed and the Closure Plan therefore needs to be reassessed as mining and tailings disposal progresses.

As a consequence a revision of the Initial Closure Plan and the preparation of a first Interim Closure Plan was undertaken in 2003 and submitted to Kilkenny County Council and the EPA in 2004 (in Draft). Since the preparation of the Initial Closure Plan, the Mineral Industry Research Organisation (MIRO) has published Technical Review (No. 20), *A Technical Framework for Mine Closure Planning.* This document does not differ significantly from the *Ontario Guidelines* but provides a more relevant framework for Ireland and was therefore used as a basis for the first Interim document.

1.4 This Second Interim Mine Closure Plan

Following a review of the 2004 interim plan, EPA and KCC submitted detailed comments on the Draft plan to the Company. This included an Expert Review prepared by Cantab Consulting (Kent) Ltd, setting out a gap analysis, detailed request for further information and recommendations for modification of the Closure Plan.

In June 2005 Wardell Armstrong International Ltd (WAI) were commissioned by the Company to prepare a Second Interim Mine Closure Plan, to update and extend the 2004 plan in the light of the Expert Review and comments from EPA and KCC, along with changes in the mining operation, technical advances in mine restoration and experience gained at the mine itself. A meeting was held at Galmoy on 26th June 2005 with the Company, WAI and representatives from EPA, KCC, Laois County Council and the DCNMR, at which the scope and content of this second interim plan was agreed.

Since the 2004 plan was prepared the EPA have published their 'Draft for Consultation' *Guidance Documents and Assessment Tools on Environmental Liabilities Risk Assessment and Residuals Management Plans incorporating Financial Provision Assessment* (May 2005). This sets out the EPA's required format and scope for closure plans for licensed industrial operations, including waste disposal and mining activities.

This second interim plan has been prepared in accordance with this Guidance, which requires a different approach to that used in the previous plans. The plan is therefore structured as follows:

- Regulatory Requirements that are relevant to the plan;
- The Mining Site and Operations;
- Initial screening and operational risk assessment;

- Closure, Restoration, Aftercare and Management Plan (CRAMP) – known liabilities;
- Environmental Liabilities Risk Assessment (ELRA) – unknown liabilities;
- Financial provision.

Technical and supporting information is given in a number of Appendices.

1.5 Purpose and accuracy of the Mine Closure Plan

The purpose of a Mine Closure Plan prepared long before the actual closure time is twofold:

- To ensure that the mine design and operation anticipates closure requirements and thus minimises closure costs and potential long-term environmental liabilities. This includes progressive restoration of some areas, as they become available.
- To ensure that adequate financial provision is made for closure during the life of the mine, and in the event of early enforced closure.

As such, the plan is prepared in sufficient detail to demonstrate that what is proposed is feasible and in order to make sufficiently accurate cost estimates. Costs are estimated using calculated quantities and realistic commercial contracting rates for engineering and landscape works, and are considered to be reliable to within ±10%.

Immediately prior to the time of closure a more detailed closure and restoration plan will be prepared, with more detailed costings and work specifications. This will be based on the previous interim plans but will take account of circumstances and decisions of the responsible authorities at the time.

This plan is presented mainly on the basis of closure of the mine at the anticipated end of the mine's life, in the normal course of events. However, in the event that the mine is closed before this, due to economic or other circumstances that are not anticipated, the Plan will still be implemented along the same lines. There will be variations to deal with some facilities not being completed, such as partial filling of a cell of the TMF. Costs have been prepared for both anticipated closure and enforced early closure at various stages in the mine life.

The preparation of this Closure Plan has relied on various technical reports and documents prepared by others, referenced in the text or the Appendices as appropriate. Conclusions drawn and recommendations made are subject to the validity and completeness of these sources.

2 REGULATORY REQUIREMENTS

2.1 Mining Licence

Arcon Mines Ltd. were issued State Mining Licenses as follows:
No. 1 on 3rd February 1995;
No. 6 on 29th August 2002;
No. 8 on 21 January 2005;
No. 10 on 28th February 2005; and
No. 9 on 25th August 2005.

1995
The 22nd covenant of the fifth schedule covers Mine Closure and Rehabilitation. It instructs the licensee to establish a fund dedicated for the closure and rehabilitation of the mine. This is also covered by the planning permission issued by Kilkenny County Council.

The 24th covenant of the fifth schedule is Closure Provisions and instructs the licensee to comply with all the conditions of the planning permits required by any competent authority in connection with the closure and rehabilitation of the Mine.

2002 and 2005
These licenses have similar covenants regarding Mine Closure Provisions.

2.2 Planning permission conditions

The first planning permission was granted by Kilkenny County Council (KCC) in 1993. This was appealed and the Planning Board granted permission in 1994 for the extraction and processing of lead/zinc ores associated with the CW and G orebodies as defined by exploration conducted by the company up until 1988.

Further permissions were granted in 2002 and 2004 following the discovery of the CWS, GE and K orebodies and the R orebody respectively. The prospected mine life after the discovery of the R orebody is expected to run until 2010. The permission granted has been extended to the end of March 2019.

The conditions of each planning permission that are relevant to mine closure are summarised below.

2.2.1 Kilkenny County Council, 27th May 1993

The application by/on behalf of Arcon Mines Ltd was received on 2nd Dec 1992. The permission for a lead/zinc mine was granted subject to 63 conditions, on 27th May 1993.

The conditions relating to mine closure are No. 43 to 49. These are summarised briefly below:

Condition 43
This relates to the fund set aside prior to commencement of development, for mine closure and rehabilitation. This could be varied subject to the provisions of condition number 49.

Condition 44
This relates to revised mine closure fund with set allowances to be made (allowances a – l).

Condition 45
This relates to the requirement of a “Closure Monitoring Plan” for long term post closure monitoring.

Condition 46
This relates to the amendment of the Mine Closure and Rehabilitation Plan to include a trial rehabilitation area.

Condition 47
This relates to the requirement of a detailed and fully costed landscape management plan, covering maintenance aftercare and all other works necessary to achieve a “walk away” maintenance status.

Condition 48
This relates to the demolition of the electrical substation within the main plant site being incorporated into the “Mine Closure and Rehabilitation Plan”.

Condition 49
This relates to the submission of a report regarding the Mine Closure and Rehabilitation Plan to the planning authority.

2.2.2 An Bord Pleanala, 29th April 1994

An appeal was made to the Planning Board regarding the discharge of clean surplus groundwater and treated process effluent to the local river. The Planning Board directed the council to grant the license subject to 13 conditions. Condition 13 related to mine closure. The condition stated that treatment pond/settlement pond sludge are not to be deposited in the upper layer of the tailings impoundment.

2.2.3 An Bord Pleanala, 29th April 1994

An appeal was made by parties including Arcon Mines Ltd. against the planning permission decision made on 27th May 1993 by the Council of the County of Kilkenny. An order was released by the Planning Board to grant permission in accordance with a second schedule, subject to conditions.

Condition 43
Part (b) was removed from Condition 43, which relates to the fund set aside, prior to commencement of development, for mine closure and rehabilitation. Part (b) related to Condition 44. Condition 44 was a list of works contemplated which the fund should include, but not be limited to, provision for. This was replaced with an order for the fund to be no less than £4,500,000. The fund could be varied subject to the provisions of condition number 46.

Condition 44
Following the change made, condition 44 relates to the establishment of a trial rehabilitation area. These provisions were originally set in Condition 46 prior to the appeal.

Condition 45
This relates to the Landscape Management Plan, originally outlined in Condition 47 prior to the appeal.

Condition 46

This relates to the "Mine Closure and Rehabilitation Plan" which was originally outlined in Condition 49 prior to the appeal. Part (f) was changed slightly to outline the contributions made to Kilkenny County Council by the developer for costs incurred.

2.2.4 *Kilkenny County Council, 27th March 2002*

The application by/on behalf of Arcon Mines Ltd, (now Galmoy Mines Ltd), was received on 30th Sept 1999 and further information on 04th Dec 2001. The permission for extension of the lead/zinc mine was granted subject to 27 conditions, on 27th March 2002. At this point the mine was operating under IPC License 517.

The conditions directly related to mine closure are numbers 3 and 13. These conditions are summarised briefly below:

Condition 3
Part (a) relates to the review of the "Mine Closure and Rehabilitation Plan", under condition 46 of the parent permission (Ref. P 884/92) with regard to the existing subsidence and proposed extension.

Part (b) relates to the fund dedicated to providing the costs of Mine Closure and Rehabilitation, under condition 43 of the parent permission with regard to the existing subsidence and the proposed extension.

Condition 13
This relates to the provisions which should be made by the developer to ensure the mitigation of impacts to water supply sources which are adversely affected by all stages of the development and in the post-closure period.

2.2.5 *Kilkenny County Council, 23rd Dec 2003*

The application by/on behalf of Arcon Mines Ltd, (now Galmoy Mines Ltd), was received on 22nd May 2003 and further information on 03rd Nov 2003. The permission for further extension of the lead/zinc mine was granted subject to 19 conditions, on 23rd Dec 2003. The mine was operating under IPC License 517.

The conditions directly related to mine closure are numbers 3, 6, 9 and 11.

Condition 3
This has not changed since the last document except the provision for the new extension (R orebody) has been noted.

Condition 6
This relates to the grant of 'permission to extract' expiring on 31st March 2019.

Condition 9
This relates to the enforcement of the closure plan if operations cease for a specified period of time.

Condition 11
This relates to the provisions set out in condition 13 of the previous document.

2.2.6 *An Board Pleanala, 1st June 2004*

An appeal was made by Arcon Mines Ltd against the planning permission decision made on 23rd Dec 2003 . An Board Pleanala directed the council to remove a condition that was not relevant to mine closure.

2.3 IPC conditions

The Environmental Protection Agency issued Galmoy Mine with IPC License No. 517 in October 2002

2.3.1 Conditions

The License has 15 conditions. Condition 14 covers Site Closure, Decommissioning & Perpetual Aftercare. Condition 15 covers financial provisions. These two conditions are reproduced below. In addition, Condition 7 deals with disposal of hazardous waste, including tailings, which will also be relevant at closure.

Condition 14

14.1 Following termination, or planned cessation for a period greater than six months, of use or involvement of all or part of the site, the licensee shall decommission, render safe or remove for disposal/recovery, any soil, subsoils, buildings, plant or equipment, or any waste, materials or substances or other matter contained therein or thereon, that may result in environmental pollution.

14.1 Closure and Perpetual Aftercare plans:

14.1.1 The licensee shall within twelve months of date of grant of the licence, submit to the Agency for agreement, fully costed plans for the decommissioning or closure and perpetual aftercare of the site or art thereof.

14.1.2 The plans shall be reviewed annually and proposed amendments thereto notified to the Agency for agreement as part of the AER. No amendments may be implemented without the written agreement of the Agency.

14.2 The closure and perpetual aftercare plans shall include as a minimum, the following:

14.2.1 A scope statement for the plans.

14.2.2 The criteria which define the successful decommissioning of the activity or part thereof, which ensures minimum environmental impact.

14.2.3 A programme to achieve the stated criteria.

14.2.4 Where relevant, a test programme to demonstrate the successful implementation of the closure/decommissioning plan.

14.2.5 A programme for perpetual aftercare.

14.3 A final validation report to include a certificate of completion for the closure plan, for all or part of the site as necessary, shall be submitted to the Agency within three months of execution of the plan. The licensee shall carry out such tests, investigations or submit certification, as requested by the Agency, to confirm that there is no continuing risk to the environment.

Condition 15

15.1 Agency Charges

15.1.1 The licensee shall pay to the Agency an annual contribution of €20,334, or such sum as the Agency from time to time determines, towards the cost of monitoring the activity as the Agency considers necessary for the performance of its functions under the Environmental Protection Agency Act, 1992. The licensee shall in 2003 and subsequent years, not later than January 31 of each year, pay to the Agency this amount updated in accordance with changes in the Public Sector Average Earnings Indices from the date of the licence to the renewal date. The updated amount shall be notified to the licensee by the Agency. For 2002, the licensee shall pay a pro rata amount from the date of this licence to December 31 2002. This amount shall be paid to the Agency within one month of the date of grant of this licence.

15.2 Financial provision for Perpetual Aftercare

15.2.1 The licensee shall maintain a fund, or other form of approved security, that is adequate to assure the Agency that the licensee is at all times financially capable of complying with the closure and perpetual aftercare provisions of Condition 14. The type of fund and means of its release/recovery shall be agreed by the Agency prior to its establishment.

15.2.2 The closure and perpetual aftercare fund(s) shall be maintained in an amount always sufficient to underwrite the current closure and perpetual aftercare plan.

15.2.3 The licensee shall in parallel with Condition 14.2.2 revise the cost of closure and perpetual aftercare annually and any necessary adjustments to the fund must, within two weeks of the revision, be forwarded to the Agency for agreement. Any adjustment agreed by the Agency shall be effected within four weeks of said written agreement.

15.2.4 Unless otherwise agreed any revision to the closure and perpetual aftercare fund(s) shall be computed using the following formula:

$$RCAC = (ECAC \times WPI) + CiCC$$

Where:

RCAC = Revised closure/perpetual aftercare cost
ECAC = Existing closure/perpetual aftercare cost
WPI = Appropriate Wholesale Price Index [Capital Goods Building & Construction (i.e. Materials & Wages) Index], as published by the Central Statistics Office, for the year since last closure cost calculation/revision.
CiCC = Change in compliance costs as a result of change in site conditions, changes in law, regulations, Regulatory authority charges, or other significant changes.

15.3 Environmental Liabilities

15.3.1 The licensee shall arrange for the completion, by an independent and appropriately qualified consultant, of a comprehensive and fully costed Environmental Liabilities Risk Assessment for the whole site which will address liabilities from past and present activities. A report on this assessment to be submitted to the Agency for agreement within twelve months of date of grant of this licence.

15.3.2 Within eighteen months of the date of grant of this licence, the licensee shall make financial provision in a form acceptable to the Agency to cover any environmental liabilities incurred by the licensee. The amount of indemnity must always be capable of covering the liabilities identified in Condition 15.3.1.

15.3.3 The amount of indemnity, held under Condition 15.3.2 shall be reviewed and revised as necessary, but at least annually.

15.3.4 The licensee shall within two weeks of purchase, renewal or revision of the financial indemnity required under Condition 15.3.2, forward to the Agency written proof of such indemnity.

2.3.2 Schedules

The EPA also released schedules within IPC License 517. Three of these schedules apply to the aftercare and mine closure. These are shown below

Schedule 2(ii) Monitoring of Process Effluent

Emission Point Reference No.:	SW1
Location:	Sampling station prior to River Goul Outfall
Emission Point Reference No.:	PS8
Location:	Sampling station at discharge from Treated Effluent Pond

Parameter	Monitoring Frequency Note 1	Analysis Method/Technique
Flow	Continuous	On-line flow meter with recorder
Temperature	Continuous	On-line temperature probe with recorder
pH	Continuous	pH electrode/meter and recorder
Dissolved Oxygen	Continuous	DO Meter/Recorder
Conductivity	Continuous	Conductivity
Chemical Oxygen Demand	Daily	Standard Method
Suspended Solids	Daily	Gravimetric
Nitrite (NO_2)	Daily	Standard Method
Sulphate	Daily	Standard Method
Ammonia (as N)	Daily	Ion selective electrode
Lead	Daily	Atomic Absorption/ICP
Zinc	Daily	Atomic Absorption/ICP
Cyanide (when in use)	Daily	Standard Method
Nitrate (NO_3)	Weekly	Standard Method
O – Phosphorus (as P)	Weekly	Standard Method
Other Metals Note 2	Weekly	Atomic Absorption/ICP
Biochemical Oxygen Demand	Monthly	Standard Method
Mineral Oil	Monthly	Standard Method
Toxicity Note 3	Annually (24 hour flow proportional composite)	As per Condition 6.6, and thereafter to be agreed with the Agency

Note 1: All daily and weekly sampling to be on continuous flow proportionate composites. The existing time proportional sampling equipment on SW-1 and PS-8 should be replaced with flow proportional sampling equipment. Daily to be a 24 hour composite, and weekly to be a 7 day composite. Monthly samples by grab.

Note 2: Al, As, Hg, Cd, Fe, Cu, Mg, Ni, Mn, Co, Ba.

Note 3: The number of Toxic Units (Tu) = 100/x hour EC/LC_{50} in percentage vol/vol so that higher TU values reflect greater levels of toxicity. For test regimes where species death is not easily detected, immobilisation is considered equivalent to death.

Schedule 3(ii) Other wastes for Disposal/Recovery

Waste Materials	Further Treatment, Recovery/Recycling On-Site Note1	On-Site Reuse Note 2	Method of Disposal/Recovery
Waste Rock	On site crushing, screening and sizing	Construction fill	Authorised waste contractor
Tailings	None	Proportion is Backfilled	Tailings Management Facility
Bag filter contents	None	Returned to process	--
Gypsum	None	None	Backfill in Mine
Mill Liners	None	None	Authorised disposal contractor
Pump Liners	None	None	Authorised disposal contractor
Truck Washings	None	Returned to process	--
Filter Cloths	None	Bulkhead construction	Authorised disposal contractor
Demolition Waste from on-site works	Removal of biodegradables	Use of inert material as fill	Authorised disposal contractor
Pallets	None	None	Returned to supplier, or authorised disposal contractor
Explosive waste & Explosive packaging	None	None	Burned on-site (EU protocol)
Packaging Waste	None	None	Authorised disposal contractor
Steel drums	Washed	None	Authorised recovery contractor
Plastic drums	Washed	Floats in TMF	Appropriate recovery / Authorised waste contractor
Tyres	None	Ballast in TMF	Appropriate recovery / Authorised waste contractor
Scrap Metal	None	None	Authorised recovery contractor
Sludge from the drainage, mine water, reclaim and clear water ponds	None	None	TMF
Sludge from Sewage Treatment Plant	Dewatering	Landspread where possible	Agreed disposal contractor
Office & Canteen waste	None	None	Agreed disposal contractor
Pyrite Concentrate	None	None	To be agreed as the situation arises
Other Note 3			

Note 1: The licensee may treat, reuse, recycle or recover waste subject to the prior written agreement of the Agency.

Note 2: Other method to be agreed with the Agency.

Note 3: No other waste shall be disposed of/recovered off-site without prior notice to, and prior written agreement of the Agency.

Schedule 3(iii) Monitoring of Tailings Management Facility

Location	Parameter	Monitoring Frequency	Analysis Method/Technique
Piezometers in TMF Embankment (location as per Condition 9.3.1)	Water level	Weekly	Dip Meter
	pH, Conductivity	Weekly	Electrometric
	Sulphate	Weekly	Standard Methods
	Pb, Zn, As, Fe, Cu, Hg, Co, Mg, Mn, Cd, Ni, Cl,	Quarterly	Standard Methods
	Cyanide	Only analysed if measured (>0.05mg/l) in the process return water sample	Standard Methods
TMF Retaining Wall	Standard walk-over	Weekly	Visual

	condition & stability checks Embankment Settlement/ movement Annual safety inspection report	Quarterly Annually	Survey of fixed movement monitoring stations Agreed standard.
Underground Mining **(within 70m horizontal radius of TMF)**	Stope Stability Backfill Ground Control Pillar Assessment	Weekly " " "	Visual and by standard geotechnical/mine engineering instrumentation
TMF	Volume of tailings disposed Tonnage of tailings disposed Used Capacity Remaining Capacity	Continuous Monthly Annual Annual	Flow meter Dry Density Agreed method Agreed method
Tailings Chemistry (including carrying water)	Acid / Base Counting Pb, Zn, As, Fe, Cu, Hg, Co, Ca, Mg, Al Cyanide (total) pH, SO_4, SS, NO_2, NH_3	Bi-annually Monthly Weekly (when in use) Weekly	Agreed Method Atomic Absorption/ICP Standard Method Standard Method
Use of spigot distribution system	Period and volume/tonnage Efficiency of distribution	Continuous during use Daily	Record Log Visual
TMF Observation Boreholes (To be agreed as per Condition 9.3.1)	Water level pH, Conductivity Sulphate Fe, Pb, Zn, As, Fe, Cu, Hg, Co, Ca, Cd, Mg, Mn, Ni, Cl, PO_4, NO_2, NO_3, NH_4 Cyanide	Monthly Monthly Monthly Quarterly Only analysed if used in the process	Dip meter/gauge Electrometric Standard Methods Standard Methods Standard Method

Schedule 4(ii) Groundwater Monitoring

Emission Point Reference No's: Mine - Clean Water and dewatering Boreholes (inclusive)

Parameter	Monitoring Frequency	Analysis Method/Technique
pH	Monthly	pH electrode/meter
Temperature	Monthly	Standard Method
Conductivity	Monthly	Standard Method
Dissolved Oxygen	Monthly	Standard Method
Extraction rate (m^3/day)	Continuous	Meter with recorder
Water Level	Monthly	Dip meter
Pb, Zn, Fe, SO_4, Al, NH_3, NO_2	Monthly	Standard Methods
Mn, As, NO_3, Cl, Ortho-P, Mg, Hg, Ni, K, Na, Alkalinity, Hardness, SS	Quarterly	Standard Method

2.4 Guidance and International Practice

The following publications aim to give guidelines which the mine closure and rehabilitation plan is in accordance with. Current guidelines and best available techniques are enclosed within these publications:

- MIRO 1999. A Technical Framework for Mine Closure Planning. Mineral Industry Research Organisation. Technical Review Series No.20
- European Commission - Reference Document on Best Available Techniques for Management of Tailings and Waste Rock in Mining Activities. July 2004.

2.4.1 MIRO

Chapter 1 introduces the need for mine closure planning, the underlying philosophy of designing for closure and the fundamental aims of achieving site stability and safety in respect of the chosen after-use. These ideas are reflected in Chapter 2 where the relative perspectives and requirements of the mine owner/operators, regulators, local communities, European location and legislation, are discussed.

Chapter 3 introduces the sequence of events, the planning and management aspects and the financial input required for the development of a mine closure plan. This is essentially divided into two stages: Closure Planning and Closure Plan Implementation. Closure Planning deals with the process of developing the plan from a conceptual document through to a final closure plan, whilst Closure Plan Implementation deals with the practicalities such as decommissioning, post closure rehabilitation and monitoring, ultimately resulting in site release.

The technical, scientific and engineering principles which ultimately determine mine closure design and the details of the mine closure plan, are found in Chapter 4. It is essential to consider the issues discussed in this section in order to develop a comprehensive and competent closure plan. These concepts are applied in Chapter 5 where closure and rehabilitation activities are recommended for individual mine components. Each component in this section may be used as a stand-alone practical reference for individual mine closure projects.

Monitoring requirements and the design of a monitoring programme, to be developed in conjunction with closure planning and implementation, are outlined in Chapter 6. Finally, the financial implications and aspects of mine closure are dealt with in Chapter 7. Here, advice is given on cost analyses and the provision of financial assurance and warranty. A number of examples of actual closure are given in Chapter 8.

A series of Appendices provide checklists which can be used for various aspects of closure and conclude with a short account of the regulatory requirements in a number of European countries and countries in the rest of the World.

The guidance is not prescriptive, nor is it a compliance document. National, local and other relevant statutes and regulations must be consulted when planning and implementing closure. The design criteria and technologies suggested, or given as examples, are not intended to restrict the use of alternatives more appropriate for particular site circumstances.

2.4.2 European Commission Best Available Techniques

The following summaries aim to highlight the sections of this publication that are relevant to the mine closure aspect of the operation:

2.4.2.1 *Common Processes and Techniques*

Chapter 2, Common Processes and Techniques, aims to provide background information in the management of tailings and waste rock. Chapter 2.6 deals with the mine closure aspect of this and is entitled Closure, Rehabilitation and After-care of Facility.

2.4.2.2 Applied Processes and Techniques

Chapter 3, Applied Processes and Techniques, and in particular Chapter 3.1.2.3 Tailings Management, looks at the tailings management processes and techniques which have been applied to Base Metal (inc. Lead and Zinc) operations at different sites around the world. More specifically, Chapter 3.1.2.3.4, Closure and After care, looks at these cases in context of the post-closure aspect of the operations.

2.4.2.3 Techniques to Consider in the Determination of BAT

Chapter 4, Techniques to Consider in the Determination of BAT (Best Available Techniques), presents a number of techniques for the prevention or reduction of emission and techniques to prevent or mitigate accidents in accordance with Section 6.3 of Communication (COM(2000)664).

Chapter 4.2.4, Closure and After Care Phase, focuses on sites within the scope of tailings/waste rock management facilities. It is standard practice that successive reclamation activities that have been performed during the operational phase of the mine life are evaluated before the final closure of the site. The issues addressed in this section are included in previous phases, but are reconsidered against the ‘as built’ situation at the site and the closure plans adjusted accordingly.

Within 4.2.4, there are two sub chapters, which are 4.2.4.1, Long-term Closure Objectives and 4.2.4.2, Specific Closure Issues. The Long-term Closure Objectives section considers different classes of failure mechanisms to be accounted for in the design of long-term stable tailings and waste rock management facilities. Examples of these mechanisms are slope failures, extreme events such as earthquakes and slow actions such as erosion.

The Specific Closure Issues section looks at potential issues, which will be characteristic of a site such as heap stability and the potential problems and hazards associated with tailings ponds.

These sections go in to more depth than the previous Chapters and demonstrate detailed considerations to be made and guidelines to adhere to when dealing with the closure and after care aspect of an operation.

Chapter 4.3, Emission Prevention and Reduction, although not approaching the mine closure aspect directly, focuses on the methods of prevention of harmful emissions/releases such as ARD. This is relevant throughout the operational stage of the mine through to the closure and aftercare of the facilities, which can potentially cause harm to the environment such as the tailings facility. Different types of preventative, control and treatment measures are discussed in this section. Specifically, Chapter 4.3.1.5, Decision Making for closure of ARD Generating Sites, mentions various guidelines (e.g. MIRO 1999. A Technical Framework for Mine Closure Planning. Mineral Industry Research Organisation. Technical Review Series No.20.) for mine closure planning and presents a decision tree which is available for closure design of a potentially ARD generating tailings and waste rock deposit.

4.3.6, Progressive Restoration/Revegetation, shows the advantages of this process being employed throughout the operation. The closure plan stage of the operation will benefit from this in a number of ways, including cost and time minimisation and implementation of successful techniques discovered through the operational stage.

Seepage Management, including prevention, reduction and control, is discussed in Chapter 4.3.10. Seepage management is an ongoing commitment throughout the operational stage but will more than likely remain through the closure stage.

Chapter 4.3.11, Techniques to Reduce Emissions to Water has guidelines for the treatment of suspended solids and dissolved metals, acid waters, alkaline waters, permeable reactive barriers, xanthates, arsenic and cyanide emissions. Again, these are monitored closely during the operational stage and in the post-closure stage. Similarly, 4.3.12, Groundwater Monitoring and 4.3.13, After care, briefly touch on the groundwater quality and surface run-off from the TMF.

Chapter 4.7, Environmental Management Tools, describes this as '*the best environmental performance is usually achieved by the installation of the best technology and its operation in the most effective and efficient manner*.' It goes on to say that this is recognised by the IPPC Directive definition of 'techniques' as '*both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned*'. An Environmental Management System (EMS) is a tool which operators can use to address these decommissioning issues in a systematic, demonstrable way and this section deals with the stages and development of the EMS.

2.4.2.4 Best Available Techniques for the Management of Tailings and Waste rock in Mining Activities

Chapter 5, Best Available Techniques for the Management of Tailings and Waste rock in Mining Activities, overviews the sections discussed previously and summarises the best available techniques for each aspect, including Environmental management.

2.4.2.5 Emerging Techniques for the Management of Tailings and Waste rock in Mining Activities

Chapter 6, Emerging Techniques for the Management of Tailings and Waste rock in Mining Activities, explains some techniques which are in the experimental stage of development but have been proven to display enough potential to become BAT in the near future. An example of this would be Inhibiting Progress of ARD.

3 THE MINING SITE AND OPERATIONS

3.1 Location

The mine site surface facilities are located mainly within the Townland of Castletown on either side of the Johnstown/Rathdowney (R435) road. The mine decline, concentrator, service and ancillary facilities are to the east of this road, while the tailings disposal and explosives storage facilities are located to the west of this road. Figure 3.1 shows:

- The existing surface features including mine facilities;
- The extent of the CW and G orebodies as permitted under the original permission (1994);
- The extent of and area mined to date of the CW South, G East and K orebodies as permitted under the second permission (2002); and
- The extent of and area mined to date of the R Zone as permitted in 2004.

A number of minor surface features associated with the mine and its further development are located in the Townlands of Whiteswall, Garrylaun and Moneynamuck. The site of Galmoy Mine comprises approximately 216ha, with the surface developments taking up approximately 56ha within this area. The site consists largely of agricultural lands used principally for grazing with a small number of associated residential and farm buildings.

3.2 Geological Setting

The Galmoy ore deposits lie in a northeast striking belt of Lower Carboniferous carbonates, mainly limestone, which are the host rocks of the Tynagh, Silvermines, Tara and Lisheen mines. The form of the mineralisation is essentially a strata bound zinc/lead replacement, which is hosted by a grey rock matrix breccia at the base of the Waulsortian Limestone Formation, which is dolomitised in the mine area.

The zinc and lead mineralisation is present principally as the sulphides, sphalerite and galena in a number of textural varieties. Pyrite and dolomite are the main gangue minerals. The sphalerite occurs in three recognisable forms, the galena in two and pyrite in four.

The area is cut by numerous faults. Two main sets are apparent, trending ENE and NNW respectively. The most important is the G-Fault, which is a normal fault that bounds the G orebody to the south, with a down-throw in excess of 200m to the north-northwest, and a dip of 55^0 in the same direction. This fault is likely to have been the main conduit for the mineralising hydrothermal fluids. The regional dip of the Lower Carboniferous beds is about 10º southeast but, in the vicinity of the Galmoy deposits, the dip does not conform to this general pattern, the host rock and CW orebody dips 10º west-southwest and the G orebody 10º northwest.

3.3 Orebodies

The Galmoy Mine was initially designed for the development, extraction and processing of two zinc-lead deposits known as the CW and G orebodies for which planning permission was granted in 1994. A comprehensive diamond drilling and assaying programme was carried out to delineate the CW and G orebodies.

Subsequent exploration activities have delineated additional reserves in the CW S, G NE, G W, K, K2 and R orebodies.

The locations of the orebodies with reference to the mine infrastructure are shown on Figure 3.1 and further detail on the main orebodies is given below.

The CW orebody is approximately 400m by 700m in area, averaging 6m in thickness with variations from 3m to 18m. The orebody is located 70m below surface and dips 10º northwest. The most prominent feature in the CW orebody is the locally termed Main Fissure, which strikes northwest southeast through the middle of the orebody dipping 83º to the northeast. It is 2m to 5m wide and filled with a highly altered clay material.

The G orebody is approximately 400m by 300m in area, averaging 8m in thickness with variations from 3m to 22m. The orebody is located 90m below surface and dips gently to the northwest. The most prominent feature is the G Fault that strikes east-west on the southern boundary of the orebody dipping 55º to the north. The fault is normal and has a surface displacement in excess of 120m. It is circa 50m wide.

The K orebody is approximately 1,200m by 50m in area, averaging 5.4m in thickness with variations from 3.7m to 21m. The orebody is located circa 100m below surface and is undulating.

The G East orebody is approximately 300m by 160m in area, averaging 5.6m in thickness with variations from 3.7m to 27m. The orebody is located circa 80m below surface and dips gently to the north.

The CW South orebody is approximately 200m by 50m in area, averaging 4.8m in thickness with variations from 3.7m to 11.2m. The orebody is located circa 130m below surface and dips gently to the south.

The K2 orebody is approximately 350m by 35m in area, averaging 4.1m in thickness with variations from 3.7m to 5.0m. The orebody is located circa 130m below surface and undulates.

The G West orebody is approximately 200m by 100m in area, averaging 4.3m in thickness with variations from 3.7m to 6.5m. The orebody is located circa 40m below surface and dips gently to the north.

The R ore-body lies southeast of the CW ore-body, averaging 8.7m with variations from 3.7m to 20m The orebody is located between 120 m to 150 m below surface.

3.4 Scheduled Reserves and Resources

The mill has treated 4.6 million tonnes of ore through to the end of March 2005. The remaining reserves at the end of March 2005 (the latest calculation) are approximately 4.0 million tonnes. This is summarised in Table 3.1.

TABLE 3.1
Galmoy Mine Reserves and Resources as at March 2005

Ore zone	*Category*	*Tonnes*	*Zn%*	*Pb%*
CW	Reserve	224,000	10.1	0.6
CW South	Reserve	115,000	16.5	0.9
G	Reserve	710,000	10.1	2.1

G East	Reserve	292,000	9.6	3.0
G NE	Reserve	55,000	12.5	5.0
G West	Reserve	143,000	8.8	1.0
K Zone	Reserve	657,000	9.1	2.1
K2	Reserve	97,000	11.0	1.0
R Zone	Reserve	1,726,000	18.2	6.7
TOTAL		**4,019,000**	**13.6**	**4.0**

The anticipated Life of Mine Plan showing the year-on-year ore and concentrate production, tailings production, backfill, etc, is given in Appendix 7.

3.5 Mine Layout

Mining of the reserves is by underground methods extending from the existing underground infrastructure. The mine design is based on the remaining reserves taking into account the economics and rock mechanics parameters of the orebodies.

Access to the underground workings is provided by a 10° decline mined from surface. This decline is equipped with a conveyor for ore hoisting, a roadway for man and machine access and mine services such as pump columns, water columns, backfill distribution columns and electric and communications cables. From this decline an eastern decline accesses the CW orebody and a western decline accesses the G and K orebodies. A separate decline accesses the R Zone from the CW orebody. Ore extracted from the orebodies is hauled by diesel articulated trucks to a jaw crusher located at the western fringe of the CW orebody. From the crusher the ore gravitates to the conveyor system below, on which it is transported to the coarse ore stockpile building at surface.

Development of the new orebodies commenced during 2002, and continues until the final extremity of the K orebody is reached in 2007. Stoping of the CW South, G North East and K orebodies also commenced in 2002, with G in 2003, and R in 2004. From 2006, a production rate of 720,000 tonnes per annum is planned.

3.6 Mining Method

Room and pillar stoping with post backfill is the primary mining method. Typical dimensions are 10m wide rooms with 5m by 5m square pillars. The method is continuously evaluated and may, on the basis of additional geotechnical information and operating experience, be modified to improve operating safety, control of subsidence, economics, or minimising environmental impacts as appropriate. The use of drift and fill is being undertaken in some localised areas where high metal grades justify greater extraction ratios than the normal room and pillar design.

Mining of the remaining reserves will be undertaken using mechanised mining techniques. The process utilises electro-hydraulic drilling and pneumatically or pump loaded explosives for blasting. This is followed by the loading of the ore using diesel powered loading equipment into low profile articulated trucks for transportation to the underground jaw crusher. The mining equipment includes:

- Twin-boom electro-hydraulic drilling machines
- Explosives loading vehicles
- Load haul dump (LHD) units
- Mine haulage trucks

- Roof bolting machines, shotcreting vehicles and other production and service equipment.

Ventilation air is drawn down the main access decline by means of the ventilation fans at the base of the upcast ventilation shafts, located adjacent to the orebodies. Air is directed, as required, throughout the underground workings by a combination of auxiliary fans, ventilation bulkheads, doors and brattices.

3.7 Ground Stability and Support

The primary stability of the underground mine workings is provided by rockbolts and pillars, supplemented by backfill.

The mine uses a cemented high-density backfill made from thickened total mill tailings. Large areas of the CW and G orebodies have been backfilled and backfill is now also being placed in the K and R orebodies. At the end of 2004 872,000 dry tonnes had been placed in the mine.

Apart from the R Zone the orebodies at Galmoy have typical dips of 7° to 9°. It is estimated that approximately 85% of the excavated voids will have fill placed in them at the end of the mine life. The backfill will be placed to maximise the tight filling of the mined voids. By establishing backfill discharge points at the crests of the orebody, the area of tight fill can be maximized and it is estimated that 60% of the area to be filled will achieve tight fill. The remainder will have an estimated unconfined permanent pillar height of less than 1m.

A binder in the form of cement or a mixture of cement and ground granulated blast furnace slag is mixed with the tailings to allow mining against the cemented fill. Where no future mining is planned alongside the fill and only sufficient binder will be added to the tailings to prevent future liquefaction.

The present backfill plant has the design potential to place up to 550,000 dry tonnes of mill tailings per annum.

With regards to the R-zone orebody, the geotechnical logging of the diamond drill core recovered from the exploration program shows that the ground conditions in and around the ore-body can be expected to be good to very good. In all cases, in the ore zone and in the footwall and hangingwall, the conditions are markedly superior to the conditions encountered in the CW ore-body. In particular, the rock in the hangingwall above the ore is considered by the mine to be of particularly high quality.

In the R-zone orebody the thickness and grade of the ore will dictate which of four mining methods will be used to extract the ore, namely room-and-pillar, drift-and-fill, bench-and-fill and open stoping with fill.

The mining methods have been designed to minimise any surface subsidence as well as to maximise the value generated from the resource. Depending on the conditions in the ore-body, the mining methods will leave permanent ore pillars, or stopes filled with high-strength backfill, in addition to cemented tailings backfill placed tightly to the roof of the excavations. This combination of tightly filled excavations, permanent pillars and stopes filled with high-strength backfill will restrict the convergence of the rock above the ore-body and be effective in minimising surface subsidence.

The area overlying the R ore-body contains no infrastructure of any kind and any minor subsidence that may occur is expected to be imperceptible.
A review of the surface stability from underground mining is given in Appendix 2. This is based on extensive reports prepared by Golder Associates.

3.8 Mineral processing

The crushed ore is discharged from the underground conveyor belt into an enclosed stockpile on surface. This stockpile is capable of storing 6,000 tonnes live capacity of ore, sufficient to feed the concentrator for three days. A reclaim system, within a tunnel under the stockpile, equipped with vibrating feeders and a conveyor belt, feeds the ore, at a controlled rate, to the grinding mills in the concentrator building.

The concentration process is achieved in three stages: grinding, flotation and dewatering.

Grinding is carried out in a semi-autogenous grinding (SAG) Mill. The SAG mill is operated in closed circuit with a ball mill and four classifying cyclones. The final product from the grinding circuit is 100μm -120μm. A second ball mill regrinds the rougher concentrate prior to zinc cleaner flotation.

Flotation is carried out in naturally aspirated cells, the lead (galena), being separated first, followed by the zinc, (sphalerite). Reagents, including collector, zinc depressants and pH modifiers, are added to the ball mill feed. The overflow from the classifying cyclones discharges into the conditioning tank where additional reagents, including a galena collector and frother, are added and pumped to the flotation cells whereby a rougher and then cleaner concentrate are produced. The lead concentrate is then pumped to a thickener as the first stage of dewatering the lead concentrate.

The tailings from the lead flotation circuit are pumped to the zinc conditioning tank where further reagents, including a pH modifier, zinc activator, collector and frother are added. This conditioned pulp is then pumped to rougher, scavenger flotation cells where a preliminary separation of sphalerite takes place. The resultant tailings are pumped to the mine backfill plant or to the tailings pond. The concentrate from the rougher cells is pumped to the zinc regrind mill which is in closed circuit with a bank of classifying cyclones, from which the overflow is fed to a three stage cleaning flotation process. The tailings from these cells pass to scavenger cells.

The zinc concentrate may be fed to a leach circuit, consisting of 6 tanks of 400m^3, with the potential to use up to 1,000l/hr of sulphuric acid.

The leached zinc concentrate flows to the zinc thickener as the first stage of dewatering. The lead concentrate flows to a parallel lead thickener. The underflows from the lead and zinc thickeners are stored in tanks holding approximately twenty-four hours of production. From these tanks, the concentrates are pumped to two pressure filters, where the concentrate is dewatered.

Two concentrates are produced, a zinc concentrate consisting mainly of sphalerite with a metal content of approximately 53% Zn and a lead concentrate consisting mainly of galena with a metal content of approximately 50% Pb. The concentrator operates continuously, seven days a week, achieving an operational availability of 90%.

During the remaining life of the mine it is intended to increase the capacity of the concentrator from 650,000 tonnes per annum to 720,000 tonnes per annum.

Upgrading of the lead and zinc flotation circuits and the zinc filter press was completed in 2005.

3.9 Backfill Plant

The backfill plant consists of a thickener, binder addition system, mixing tank and distribution pump. These are all located adjacent to the mill building. The thickened tailings are pumped to a weigh hopper and from there to a pan mixer where the binder is added and mixed to form the backfill. The backfill is then discharged to a holding hopper, which feeds a positive displacement pump, delivering the backfill to the underground distribution line.

A binder in the form of cement (typically 4% but up to 10%) and/or ground granulated blast furnace slag is mixed with the tailings.

3.10 Tailings Management Facility

The remainder of the tailings, that is not delivered underground as backfill, is pumped to the adjacent tailings management facility (TMF).

The TMF is divided into two separate cells, known as Phases 1 and 2. Phase 1 had a capacity of 880,000m^3 and was filled in July 2000. It is currently undergoing rehabilitation. Phase 2, with a design capacity of 1,167,000m^3 is being currently used for disposal and at the end of December 2004 an approximate volume of 230,000m^3 remained available in Phase 2 of the facility.

The as yet unbuilt Phase 3 of the TMF has a design capacity of 777,000m^3. Construction of this cell is envisaged in 2006.

Process water from the TMF is pumped back to the concentrator for re-use or treatment prior to disposal.

A review of the construction and stability of the TMF is given in Appendix 3. This is based on detailed reports prepared by Golder Associates on behalf of Arcon Mines Ltd (now Galmoy Mines Ltd).

3.11 Water Management

A schematic of the mine's water management system is shown in Figure 3.2. The principal source of water is the mine dewatering system. Water is pumped from the mine to surface using two separate systems:

- Mine Clean Water;
- Mine Dirty Water.

Clean water entering the mine through fissures is intercepted and piped to a clean water sump from where it is pumped directly to a conditioning pond on the surface to prevent it from becoming contaminated by contact with the mine working areas.

Conditioning of this water involves aeration and temperature equilibration after which a portion of the water is used for augmenting the flows in local streams and the remainder is discharged to the River Goul in combination with the treated effluents.

Mine dirty water is pumped to surface for treatment and subsequent transfer to the effluent holding pond. The treated mine water is discharged to the River Goul in combination with the other effluents and the surplus conditioned groundwater.

The arrangement of the water treatment plant is shown diagrammatically in Figure 3.3. The plant was modified in 2003 and the overall capacity of the plant is of the order of 650m^3 per hour. The effluent emission limit values (ELVs) for the plant are as follows:

Zinc	300µg/l (but can achieve 100 µg/l)
Lead	50 µg/l
Suspended solids	25mg/l

The TMF is the principal water storage area. This is used as a source of supply for the concentrator, which is the largest water user on the mine. In addition three holding ponds are located at the northern end of the plant site, the largest of which is the groundwater (mine clean water) conditioning pond that has a capacity of 17,200m^3.

The second largest of these three ponds, the effluent holding pond, is used to store the treated mine water, treated process water and the treated domestic sewage prior to discharge and has a capacity of 8,500m^3.

The smallest of the three ponds, the storm water pond, is used to store run-off water from the plant site. It has a capacity of 1,800m^3 to facilitate settlement of suspended solids before overflowing into the effluent holding ponds.

All surface run-off from the mine plant site is drained into the plant site settlement pond that overflows into the effluent holding pond. Surface drainage from surrounding land is intercepted and drains away from the plant site into surface watercourses.

All domestic sewage arising on the site is piped to a treatment unit consisting of primary settlement, biological treatment using a horizontally mounted rotating disk unit and secondary settlement with sludge return. The treated effluent is pumped into the effluent holding pond on site.

3.12 Mine Services

Access to the mine site is by asphalt surfaced road from the R435 road which passes between the plant site and the TMF. A security building controls access to the mine site, which is surrounded by a chain-link security fence.

The mineral extraction and processing facilities are supported by various services, which are located across the mine site. A number of these services are accommodated in the administration and services building. This contains offices for management and administrative personnel, laboratories, underground plant maintenance workshops and stores facilities, together with washing, first aid and rescue facilities. Additional maintenance and storage facilities are provided in the former farm buildings to the south of the water treatment plant.

Electricity supply to the mine is via two dedicated 38kV overhead lines from the ESB grid. A main substation is located at the plant site to transform the voltage to 6.6kV. Power is distributed to surface and underground facilities via buried cables. Auxiliary substations provide any necessary further transforming and switching at the various plant locations. Installed standby diesel generation capacity is also provided for critical drives in the mine and process plant.

Marked diesel fuel for plant and mine equipment is stored on site, in two 48m^3 capacity purpose built tanks, installed within a protective bund. A separate tank containing diesel fuel for road use by the mine's haulage contractors is located adjacent to the concentrate loading area. Lubricants are stored in an area of the garage/workshop section of the services building. A waste oil storage tank is located adjacent to the maintenance workshops. Heating fuel for the administration building is stored in a tank immediately adjacent to the building.

Explosives and blasting accessories are stored in five licensed magazines located within protective mounding to the west of the TMF. A service building for security control is located close to the magazines.

3.13 Residues and environmental effects

From the very beginning the Galmoy Mine has been subject to rigorous EIA and design of environmental mitigation measures. Thus the known and unknown environmental liabilities have been anticipated and allowed for in the mine's design and operation.

Figure 3.4 shows the mine activities and highlights where emissions, discharges and solid wastes arise. The nature and extent of these are reported regularly by the mine in their Annual Environmental Review submitted to the EPA.

A number of appendices to this Plan give detailed information on aspects of the environmental effects that are pertinent, as follows:

1. Review of the groundwater rebound when mine pumping ceases.
2. Review of the surface stability from underground mining.
3. Stability of the TMF – review of the design and status of the facility in terms of its long term stability.
4. TMF behaviour and water balance – review of the available information on the hydrology and geochemistry of the tailings.
5. Mine site contamination – risk assessment and cleanup requirements based on recent sampling.
6. Review of the TMF restoration and prospects for long term land use.

These appendices form the technical backup for the development of this Plan and are referred to in various sections as appropriate.

3.14 Environmental management & monitoring

GML have a comprehensive environmental management programme for the Galmoy Mine, which is implemented by the Environmental Department under the management of a full time Chief Environmental Protection Officer. Regular monitoring of emissions, effluents, wastes and effects from the mining operations takes place, together with monitoring of receiving environmental media. Detailed Annual Environmental Reports are presented each year.

4 INITIAL SCREENING AND OPERATIONAL RISK ASSESSMENT

In accordance with the EPA's *Guidance Documents and Assessment Tools on Environmental Liabilities Risk Assessment and Residuals Management Plan incorporating Financial Provision Assessment (Draft May 2005)*, the specific CRAMP, ELRA and FP requirements for the closure plan requires that a risk assessment is carried out. This initial screening and risk assessment is based on the following key aspects:

- Complexity
- Environmental Sensitivity
- Pollution Record

Once the risk assessment has been undertaken a risk category can be assigned to the site. Although this process has been carried out it should be noted that the site is regarded as a 'Seveso facility', based on the storage of specific categories of chemicals and also the operation of a TMF, and is therefore automatically classified in the High Risk Category.

4.1 Complexity

The EPA have derived complexity bands based on classification from the Environmental Protection Operator and Pollution Risk Appraisal EPA OPRA Complexity Score). Based on the look up tables given within the ELRA, RMP & FP guidance document the site is classified as follows:

'The extraction and processing (including size reduction, grading and heating) of minerals within the meaning of the Mineral Developments Acts 1940 to 1999, where an activity involves – (a) a Metalliferous operation, or (b) any other operation where either the level of extracted or processed minerals is greater than 200,000 tonnes per annum or the total operational yield is greater than 1,000,000 tonnes, and storage of related mineral waste'.

The Band G5 (being the most complex site) is applied based on the above classification. This attributes a value of 5 to be used within the Operational Risk Assessment.

4.2 Environmental sensitivity

The following environmental sensitivity assessment has been undertaken with the following receptors considered:

- Human Beings
- Groundwater
- Surface Water
- Air Quality
- Protected Ecological Sites
- Sensitive Agricultural Receptors

Table 4.1
Environmental Sensitivity Sub Matrix
Scores attributed to Galmoy are underlined

Environmental Attribute	***Environmental Attribute Score***
Human Occupation	
<50m	5
50m-250m	<u>**3**</u>
250m-1000m	1
>1km	0
Groundwater Protection [2,3]	
Regionally Important Aquifer	<u>**2**</u>
Locally Important Aquifer	1
Poor Aquifer	0
Vulnerability Rating – Extreme	<u>**3**</u>
Vulnerability Rating – High	2
Vulnerability Rating – Moderate	1
Vulnerability Rating - Low	0
Sensitivity of Receiving Waters[4]	
Class A	<u>**3**</u>
Class B	2
Class C	1
Class D	0
Designated Coastal and Estuarine Waters[5]	2
Potentially Eutrophic Coastal & Estuarine Waters[6]	1
Air Quality & Topography	
Complex Terrain[7]	2
Intermediate Terrain[8]	<u>**1**</u>
Simple Terrain[9]	0
Protected Ecological Sites[10]	
Within or directly bordering protected site	2
<1km to protected site	<u>**1**</u>
>1km to protected site	0
Sensitive Agricultural Receptors[11]	
Fruit, vegetable or dairy farming<50m from site boundary	<u>**2**</u>
Fruit, vegetable or dairy framing 50m-150m from site boundary	1
Fruit, vegetable or dairy farming>150m from suite boundary	0
Environmental Attribute Score	**15**

1. Measured from the boundary of the site to public or private occupied building or public open space.
2. Groundwater Classification according to DoELG, EPA, GSI Groundwater Protection Schemes (1999)
3. Aquifer Classification score to be added to groundwater vulnerability score.
4. Site located within catchment of EPA Surface Water Classification (1996) or adjacent to transitional water body.
5. Designated as a sensitive areas UWWT Regulations (2001)
6. EPA (2002) Water Quality in Ireland (1998-2000)
7. Generally elevated terrain such as a mountain the side of a valley, where receptors are at elevations above the stack tip elevation. US EPA (20000) Meteorological Monitoring Guidance for Regulatory Modelling Applications.
8. Intermediate terrain where the elevations of receptors lie between the stack tip elevation and the plume rise elevation.
9. Relatively flat terrain where receptor elevations are between stack base and stack tip elevation.
10. Distance form site boundary to protected areas designated as pNHA (Irish wildlife acts 1976, 2000),cSAC (Habitats Directive 1992) and/or SPA (Birds Directive 1979)
11. Distances derived on UK DEFRA (2003), Local Air Quality Management – Technical Guidance LAQM TG (3).
12. Total score equal to addition of Environmental Attribute Scores

On the basis of the Environmental Sensitivity Classification table in the EPA Guidance (given below as Table 4.2) it can be seen that the Environmental Attribute Score awarded for the site is High (15), giving an Environmental Sensitivity Classification value of 3.

Table 4.2 Environmental Sensitivity Classification	
TOTAL Environmental Attribute Score	***Environmental Sensitivity Classification***
Low <7	1
Moderate 7-12	2
High >12	3

4.3 Risk category

The EPA draft guidance document classifies the pollution record score based on the compliance of a facility and/or the presence of contamination arising from the activities. Based on this assessment the Galmoy mine facility has been classified as having Significant ground contamination and awarded a Pollution Record score of 3.

The basis of this assessment is twofold:

a) the contamination of the soil identified during the limited site investigation (see Appendix 5);
b) the presence of the TMF and tailings.

Both of these factors indicate that there is the *potential* for groundwater to be contaminated and thus require a score of 3. There is no indication that score is justified on the basis of pollution incidents or compliance record at the mine.

4.4 Overall assignment of risk category

On the basis of the Complexity Rating, Environmental Sensitivity rating and Pollution record scoring a total score can be calculated for the Galmoy Mine facility and the site specific risk category assigned. This will allow the appropriate Closure, Restoration and Aftercare Management Plan procedure to be adopted. Table 4.3 below details the Operational Risk Assessment and Risk Category assigned to the Galmoy Mine facility.

Risk categories given by the EPA are:

<5 Low
5 – 9 Medium
>9 High

Table 4.3 Galmoy Mine Facility Operational Risk Assessment		
Complexity		***Score***
Licensed Activity Class	Look up table	
1.3 '*The extraction and processing (including size reduction, grading and heating) of minerals within the meaning of the Mineral Developments Acts 1940 to 1999, where an activity involves – (a) a Metalliferous operation, or (b) any other operation where either the level of extracted or processed minerals is greater than 200,000 tonnes per annum or the total operational yield is greater than 1,000,000 tonnes, and storage of related mineral waste'.*	G5 (Highest)	5
Environmental Sensitivity	***Sub Matrix Score***	
Human Occupation Located approximately 50m-250m from the site	3	
Groundwater Protection - Overlying Regionally Important Aquifer - Groundwater Vulnerability Extreme	2 3	
Sensitivity of Receiving Waters - A default classification of Class A has been assigned	3	
Air Quality and Topography - Intermediate Terrain	1	
Protected Ecological Sites - >1km to protected site	1	
Sensitive Agricultural Receptors - Dairy/sheep farming within <50m from site boundary	2	
Total – Environmental Sensitivity	15 (High)	3
Pollution Record		
- Significant ground and potential groundwater contamination		3
Overall Risk Score (Hazard Potential * Environmental Sensitivity * Pollution Record)	***5 * 3 * 3 =***	***45***
Risk Category		***High***

This analysis places Galmoy Mine in the High risk category. This concurs with the default category of HIGH designated to the site as a SEVESO facility. Therefore the Closure, Aftercare Management Plan (CRAMP) for the known liabilities (Section 4) will follow the process as outlined within Section 3 of the EPA draft guidance.

5 CLOSURE, RESTORATION AND AFTERCARE MANAGEMENT PLAN (CRAMP)

5.1 Approach and principles of the CRAMP

5.1.1 Basic approach

This Interim CRAMP has been prepared to describe the arrangements for active decommissioning of the mine, rehabilitating the land and protecting the natural resources of the locality against contamination in the post-closure period. The CRAMP deals with known liabilities, that can be defined and costed in accordance with normal mine closure procedures. There is some provision for uncertainties and worst case assumptions, but no allowance for unknown liabilities, which are covered in the ELRA later.

As in the previous Plans the approach is based on:

- Ensuring the *physical stability* of all man-made structures that remain after mine closure and of land around and above mine workings;
- Ensuring the *chemical stability* of the site and mine workings, particularly mobilisation and dispersal of pollutants into the environment including surface and groundwater;
- Restoring an environment that promotes the *biological stability* of the site;
- Optimising the opportunities for *land use* following closure and ensuring the long-term compatibility of the rehabilitated site with the surrounding area.

The purpose of an active closure, restoration and aftercare management plan is to ensure that, after the mining operation is finished, the site does not impose a hazard to public health and safety as a result of physical or chemical deterioration. As a temporary use of the land, it is also important to ensure that the mine does not impose any permanent constraints on the beneficial use of the immediate and nearby land, water resources and landscape quality.

The Galmoy mine can conveniently be considered in four parts:

1. Underground workings and mine entries, which underlie the whole area;
2. The mine site surface facilities, located on the east side of the R435 road, and including a number of outlying structures (evasees on ventilation raises, magazine);
3. The TMF, located on the west side of the R435 road, with associated infrastructure (though the magazine is dealt with as part of the mine site);
4. Off-site facilities – mainly the water supply to local residents and the town of Rathdowney.

The intention is that most of the mine site and surface facilities will be demolished such that the ground can be rehabilitated to its original condition or to a similar standard. Underground workings will be decommissioned and will remain in a safe, sealed condition. However, the tailings management facility (TMF) will remain *in-situ*, creating a permanent change to the original landform and soil conditions at the mine site, with long term implications for land use and land and water quality. As such, there will be different environmental objectives and approaches to decommissioning for each area. The mine site and surface facilities are therefore considered separately from the TMF in this Plan.

5.1.2 Scoping and closure scenarios

The basic objective for the restoration or rehabilitation of any mineral operation is to achieve an after use for the site that is sustainable in the long term. Three categories of closure were adopted in the 1992 for the Initial Closure Plan for Galmoy Mine. Similar principles have been used within the MIRO Technical Review. The three categories are as follows:

- *Active Care,* requiring regular operations, monitoring and maintenance of the site that is not typical of normal land management practices (e.g. water treatment).

- *Passive Care,* where regular and active intervention is not required but there is a limited need for monitoring and infrequent maintenance to non-critical structures, in order to maintain a watching brief on the long term stability and environmental liabilities.

- A *Walk Away* condition where no additional monitoring or maintenance is required after the rehabilitation has been carried out.

The site maintenance, aftercare and management for these three categories refers to the activities arising specifically from the use of the land as part of a mining operation. Many forms of productive and amenity land use require management and maintenance, normally associated with that use. The aim is to rehabilitate the land to a use that is beneficial, whereby the resources required to maintain it are consistent with the benefits from the land. Such benefits can be either economic, such as crop production, or intangible, such as amenity value.

The IPC licence for Galmoy requires that the closure plan and financial provision allows for perpetual aftercare. This implies that the site will never be considered to have achieved a walk away condition, in terms of environmental risks and liabilities, even if it has achieved this from a land use point of view. In this context, perpetual is taken to mean of the order of 30 years for practical purposes.

Specific objectives

The intention is that the majority of the Galmoy Mine site, that is the areas occupied by all the surface facilities and ancillary areas, but excluding the TMF, will be decommissioned and rehabilitated to a condition as close as possible to a greenfield site. The original land use will not necessarily be restored and, indeed, some parts of the mine infrastructure may be retained for use; but there will be no constraints on future land use due to residual contamination or structures. Materials will be treated and/or disposed of in an appropriate manner such as:

- equipment or uncontaminated materials with a resale or scrap value will be cleaned and sold;
- uncontaminated or decontaminated rubble will be deposited underground in the mine or incorporated in surface landscaping;
- contaminated materials which will not prejudice long term rehabilitation (such as soils and sludges) will be deposited in the TMF; this will be subject to obtaining an IPC licence from the EPA.
- materials that are unsuitable for placing in the TMF, such as waste oils, or are surplus to requirements at the end of the demolition work will be disposed of as per Condition 7 (schedule vi) of the current IPC licence.

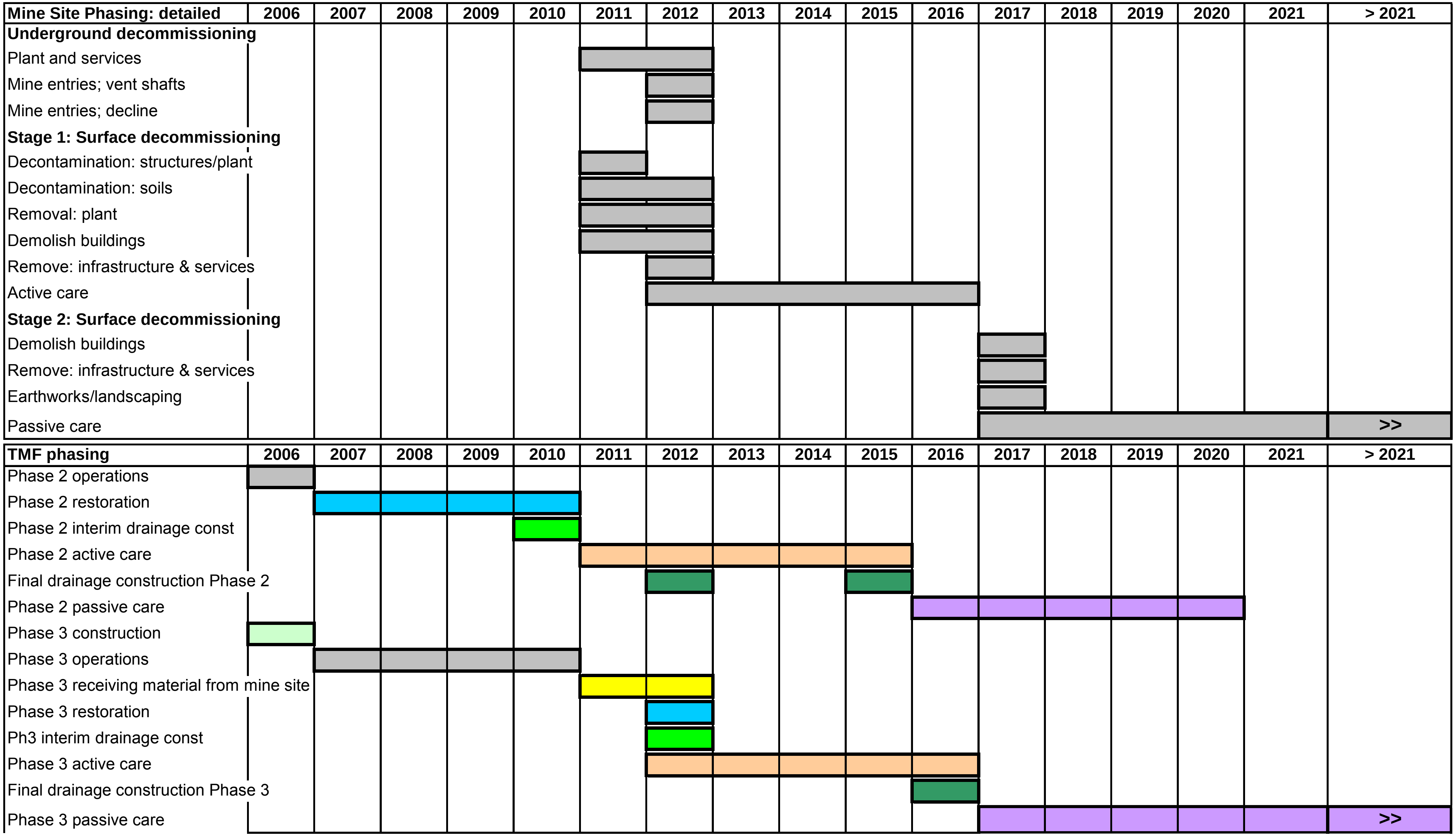
In the long term, the only significant route for migration of residual contamination away from the site will be *via* surface water and groundwater. The intention is to achieve water quality in both media that does not affect downstream water use or biological quality. Drainage arrangements will be such that discharges from the site will be sufficient to maintain the pre-mining water quality in the receiving surface waters and groundwater or, if there are slight chemical changes, that these are not significant in human or environmental terms.

Rehabilitation stages
Progressive rehabilitation is possible for the TMF as a result of its phased design (rehabilitation work has already taken place on Phase 1 of the impoundment). However, for the operational mine site there is little scope, although initial site landscaping has been designed to minimise the visual impact of the mine's operation. As much as possible of this landscaping will be incorporated into the final rehabilitation scheme.

The decommissioning and rehabilitation of the mine involves a number of discrete stages, as follows:

- Progressive rehabilitation of the TMF during the mine operation, including trial plots and development scale areas.
- Stage 1 decommissioning of the mine and plant site and rehabilitation of the remaining areas of the TMF to their respective final specifications. Major structures will be removed at this stage and the site landscaped, followed by a period of *active care* including monitoring of environmental parameters for 5 years (subject to review).
- Stage 2 decommissioning, including removal of minor plant remaining on site, will take place on completion of the *active care* period.
- In the long term, perpetual aftercare will involve normal land management as far as possible, with a greater degree of passive care for the TMF.

The programme up to 2021 (including 5 years of passive care) is illustrated on the chart below. Clearly passive care will continue well beyond this time (for practical purposes up to 2048).



Note: this is an indicative chart; the programme will be reviewed at each stage. Perpetual aftercare continues beyond the period shown.

5.2 Underground decommissioning

5.2.1 Decommissioning objectives

The underground decommissioning operation will comprise the following main aspects:

- ensuring long-term mine stability by backfilling stopes
- decommissioning of plant and services
- sealing of mine entries.

To allow for the full and safe implementation of the Closure Plan, the dewatering and mine ventilation systems will be maintained in operation. Full dewatering of the mine will be required until backfilling operations have been completed, and all underground plant has been removed or decommissioned. Pumping from the mine will then cease. However, the ability to pump from the existing dewatering wells will remain, allowing a controlled recharge to the strata and gradual flooding of the mine. Dewatering will be reduced to the level needed to provide sufficient water for the tailings impoundment reinstatement and decommissioning works. Ventilation of the mine will be maintained until such time as the decline and ventilation raises have been de-equipped and sealed.

A review of the groundwater regime and its behaviour after mining ceases is given in Appendix 1.

5.2.2 Plant and services

The mine production operations make use of various mobile and fixed plant underground. About 20 items of mobile plant are used underground, including drill rigs, explosives loading vehicles, load-haul-dump (LHD) units, haulage trucks and ancillary plant. Fixed plant comprises rock breakers, jaw crushers, conveyor belts, ventilation fans and pumps. In addition, services supplied underground will include pipe ranges for water and backfill material and the electrical reticulation system which includes six sub-stations and the associated supply and distribution cabling.

All of the underground mobile plant will be removed to the surface upon closure for scrap or resale. All abandoned fixed plant that remains underground will be drained of oils and cleaned with detergents to remove any hydrocarbon residues and prevent pollution of the groundwater. Where ducts and pipe ranges in the declines and shafts obstruct sealing operations, they will be removed.

All containers of fuels, oils and greases will be removed to the surface. All rubber-based materials, such as conveyor belting, will be removed and transported to the surface for disposal.

5.2.3 Mine entries

5.2.3.1 Requirements for decommissioning

Details of the mine entries are as follows:

- The access decline, 6.0m wide by 4.5m high, descends at a gradient of 18% from the portal excavation to the orebodies. This provides the main access to the underground workings for men and materials as well as containing the ore conveyor. The water supply column, mine water pumping and backfill pipe ranges together with electrical supply cables are installed within the decline. The decline is supported variously by lattice girders, rockbolts and shotcrete. The portal excavation is approximately 77m long, 34m wide and 12m deep and is supported by shotcrete within the rock strata.

- At present, five ventilation shafts serve the mine, CW orebody (CW West and East shafts), on the G orebody (G North East and South shafts) and R orebodies. A further ventilation shaft is planned for the K orebody. The shafts are vertical and 3m to 3.5m in diameter. Each shaft has a ventilation fan located at its base and, at surface, a 90° steel column or elbow that acts as an evasee. The shafts are supported and lined from surface to rockhead and are equipped with ladders and landings for emergency egress.

Following closure of the mine, the presence of the mine entries could create potential hazards, which include:

- danger to the public through accidental entry;
- subsidence or ground collapse and consequent danger to the public; and
- pollution of the groundwater due to unauthorised dumping of toxic materials.

In order to pre-empt any of the above possibilities, the mine entries will be sealed and stabilised. The works will be designed and carried out in accordance with industry-standard guidelines and as described in the following paragraphs.

5.2.3.2 Decline

The sealing of the access decline will be undertaken once all decommissioning operations requiring access to underground have been completed and pumping has ceased. The decline will be sealed off and filled from the surface over a length of approximately 230m from the portal. The rock cover over the infilled decline will be c. 40m, which will be sufficient to prevent the occurrence of crownhole collapses at the surface.

The conveyor structure and services will be removed from the length of decline to be filled and transported to the surface for disposal as scrap. An auxiliary ventilation circuit will be installed from the surface to ventilate the working area. Details of the filling arrangement are shown on Figure 5.1. A concrete plug will be placed at the bottom of the length of decline and the decline progressively filled with clean debris arising from the demolition of the surface buildings. About 6,000m^3 of material will be required to fill the 230m length of decline. Sufficient clean debris will arise from the surface demolition to achieve this.

Once the decline has been filled, a concrete wall will be placed just inside the portal. The portal will then be infilled with approximately 10,000m^3 of subsoil material currently stockpiled around the mine site area and the ground reinstated as described in Section 6.2 below.

5.2.3.3 Ventilation shafts

Work will commence on sealing the ventilation shafts once underground decommissioning operations are complete and there is no requirement for ventilation of the workings. All six shafts will be treated at the end of the mine life. Prior to sealing the shafts, the ladders, landings and surface steelwork will be removed. All steelwork will be removed, cleaned if necessary and sold for scrap. The security fencing will remain during the sealing operations to prevent unauthorised access but will be removed subsequent to final reinstatement.

The shafts will then be sealed by the construction of a reinforced concrete cap, founded at rockhead as shown on Figure 5.2. Once the concrete has cured, the excavation will be backfilled, compacted and reinstated.

Where the depth to rockhead makes it impractical to found a rockhead cap (i.e. for the CW East shaft), the shaft will be filled with clean granular material and a concrete plug placed adjacent to the bottom of the shaft (as shown on Figure 5.3) in order to retain the fill. Approximately 900m^3 of material will be required to fill the shaft and sufficient clean granular material will be available on site to achieve this. The cap will then be founded on the overlying superficial deposits.

5.2.4 Mine stability

Since the commencement of the production operations, the Company have utilised the specialist services of Golder Associates Ltd ('Golders') to assist with the assessment of ground stability and design of underground support measures at the mine. In this period Golders have prepared a number of reports into these issues. A review of these reports and the current and potential future stability of the mine workings, with reference to long term effects on the surface, is given in Appendix 2.

To date the majority of underground working has taken place in the CW, GNE and G orebodies. The stability of the hangingwall in the rooms and of the pillars has generally been good, as was expected from the favourable rock quality predicted.

As a result of a collapse in the CW orebody in January 2002, various operational procedures have been implemented, detailed in the "*Underground Failure Prevention Plan*" (see Appendix 2).

These measures are primarily changes to operational procedures and are designed at utilising information on the strata conditions to design the ground support method e.g. increasing pillar dimensions or the use of drift-and-fill mining.

The most relevant of the above to the closure situation is the programme of backfilling of the extraction areas. The Company has prepared a backfill programme going forward with the objective of placing up to 85% of the tailings produced as backfill underground. The estimated annual tailings placement required in order to meet this target and satisfy Condition 7.3 of the IPC Licence are given in Appendix 7.

The mine has been designed to ensure long-term stability, and therefore there are no proposals with respect to restricting land use associated with movements occurring due to mining either during or after the closure period.

5.2.5 Early closure

In the event that the mine closes before the underground mining has reached the anticipated extent, decommissioning will follow the same approach and will involve the same activities.

Backfilling of underground voids, with tailings recovered from the TMF, will continue beyond closure to ensure that long term underground stability is achieved.

5.3 Mine site surface

5.3.1 Decommissioning and restoration objectives

It may be possible to find long term uses for buildings such as the services building, which are capable of conversion to other purposes. However, the majority of the surface buildings, plant and infrastructure will be decommissioned in two stages as shown on Figure 5.4.

The first stage will take place on completion of mining operations and include the removal of such major structures as the stockpile building, concentrator and services building. Following a period of *active care* of the site, estimated at 5 years, the remainder of the plant, principally those items associated with the rehabilitation of the tailings impoundment, will be removed. This will comprise the water treatment works, sewage works, pumping station and the well water conditioning and effluent holding ponds. The site will then be finally landscaped.

The pre-existing farm buildings that have been converted for use as engineering workshops and stores will be retained.

<u>Afteruse options</u>

The intention for the mine facilities site is that the land will be rehabilitated to a condition as close as possible to a greenfield site. This means that there will be no constraints on future land use due to residual effects of the mining operation. At the completion of mine closure and rehabilitation, a *walk away* option for the mine site will be possible.

The original land use will not necessarily be restored, though this must potentially be the most viable long term use. It is feasible that some of the infrastructure and buildings installed for the mine project could find a beneficial use after the mine has closed. However, it is not possible to make predictions at this time about what uses and opportunities might be appropriate in a decade or so. Proposals made now are therefore based on making the best use of the land which would, in any event, be feasible and beneficial in the context of present land use.

The options for use of land in this area (excluding hard uses) can be summarised as:

- Agricultural
  - cultivated crops
  - permanent pasture
  - rough grazing

- Forestry
  - softwood trees
  - mixed or broadleaf plantation

- Amenity
  - recreation and sports
  - wildlife (grassland, woodland, wetland).

With the exception of the existing residential property and associated land, it is proposed to establish a mixture of uses, namely agricultural pasture and amenity woodland. This will be consistent with the potential productivity of the land and with the surrounding land uses. The site will be capable of being profitably incorporated into an adjacent farm unit, as a means of ensuring its long-term management. Whilst the land will have been disturbed, with consequent disruption of the soils, techniques and resources, as described in this plan, will be used as necessary to return the land to a productive state.

5.3.2 Decontamination

5.3.2.1 Structures and plant

Prior to the demolition and/or removal of any building, service or item of plant, a careful examination will be made to establish its level of contamination with any of the following materials or residues:

- fuels, oils and greases;
- mineral concentrates;
- process reagents and chemicals; and
- partially treated effluent including sewage sludge and process water.

In general, all contaminants will be removed, drained or flushed from all plant, tanks and pipelines. All residues containing fuels, oils and other hydrocarbon contamination will be removed off-site and re-cycled or disposed of in an appropriately licensed waste management facility. All other residues will be disposed of within the tailings management facility.

All buildings, structures, plant and surfaces will be hosed down or flushed out with high pressure freshwater. The washwater will be intercepted in the site drainage system and depending upon its level of contamination, either pumped directly to the tailings impoundment or via the settlement holding ponds. This will provide the opportunity to dispose of the resultant sludge to the TMF, subject to Condition 7 (schedule 3(ii)) of the IPC licence. Any material containing lead or zinc will be milled to extract the metals.

During and after demolition, further high-pressure washing will be undertaken as necessary to ensure that all materials are clean. In such a situation, and in spite of rigorous cleaning, a very minor degree of contamination will inevitably remain but this will not preclude the use of materials as general fill or salvageable scrap.

5.3.2.2 Ground area and soils

When the plant site has been entirely cleared and contoured, the whole area will be systematically surveyed for surface soil contamination by sampling and laboratory analysis in accordance with EPA procedures and guidelines. Checks will be made for lead, zinc, cadmium, arsenic and hydrocarbons. Particular attention will be paid to soils beneath the reagent stores, fuel and lubricant storage areas, maintenance areas, concentrator, covered stockpile and coarse ore storage area, where isolated areas with higher levels of contamination may occur. Supplementary samples will be collected at these locations and a wider range of determinands analysed for, specific to the potential contaminants that may be present.

A risk assessment process will be used to determine acceptable threshold concentrations within the soils to determine the safe levels of contamination for the proposed re-use of the site, in accordance with EPA or relevant UK guidelines such as CLEAR. Any soils containing levels of contaminants in excess of the threshold concentrations would be removed to the TMF or disposed of at an appropriate facility off-site.

In 2005 an interim contamination assessment of the mine site was carried out, as a basis for this CRAMP. As advised by EPA this assessment was undertaken in accordance with the UK CLEA guidelines, involving a risk assessment approach to determine safe clean-up levels for heavy metals and hydrocarbons. This is reported in full in Appendix 5 and was used as the basis for costing of the plan and financial provisions.

5.3.3 Removal of plant

All plant and machinery, either mobile or an integral part of any surface building, will be decontaminated, as described in Section 5.3.2 and, together with all other plant brought from the underground workings, will be sold off site as either salvageable equipment or scrap.

An assessment has been made of the plant and, in general, the quantities of plant to be removed from the mine site are similar to those considered in the initial (1992) mine closure plan (see Appendix 8 for details).

5.3.4 Demolition of buildings

5.3.4.1 Requirements for demolition

All demolition will be carried out in accordance with current industry standards and good practice as described in British Standard BS6187:2000 *Code of Practice for Demolition*. Before any demolition is started a detailed survey and examination of the structure and its curtilage will be made together with all available plans of the original design and subsequent modifications. All services connecting to the structure will be cut off or diverted before work commences.

Once each structure is completely demolished above and below ground, the resulting debris will be divided into the following three categories:

- Structural steelwork, metal cladding, conveyors, stairs, handrails and other miscellaneous steel items will be taken off site and sold as scrap.

- Reinforced concrete, masonry, gravel and crushed stone will be reduced to acceptable sizes, where necessary, to be used as bulk fill materials for the access decline and ventilation raises. An approximate volume of 6,000m^3 will be required for the decline and another 5,000m^3 for the ventilation shafts. There will be an adequate amount of bulk fill material from the first stage demolition work to provide this fill material.

- Any excess material will be spread *in-situ* as part of the landscaping or, if contaminated in any way, taken to the TMF for disposal as per schedule 3(ii) of the current IPC licence.

5.3.4.2 Stage 1 : Buildings

The following buildings will comprise the first stage of the demolition work. Any particular changes from the details included in the original mine closure plan are noted.

a) Coarse Ore Stockpile Building - a 12-sided, conical shaped, steel truss framed, engineered structure with a reinforced concrete ring beam with spread footings and insulated metal cladding forming the sides. The floor of the structure is a reinforced concrete slab with a concrete lined tunnel directly below. The as-built size of the building is smaller than that previously considered. The surface conveyor system, including approximately 200m of conveyor and cladding, from the access decline and leading to the concentrator, will be demolished with this building.

b) Concentrator/Mill Building – a steel framed, engineered structure of similar construction as the administration/services building. This contains all the milling, flotation and filtration plant in addition to the concentrate storage/ loading area and compressors.

c) Outside tanks and structures – comprising lead and zinc thickeners, leaching circuits, pyrite plant and structures such as the concentrate truck wash sump will be removed at this stage.

d) Backfill plant – comprising the thickener (c.30m concrete tank), cement silos and associated plant not included within the original closure plan. This may be necessary for an extended period for backfilling of the mine in the event of premature closure but it is intended for this to be included within the Stage 1 demolition works.

e) Magazines – five concrete buildings, which will be broken up and used as fill. Earth bunds surrounding the magazines will be spread and the area graded.

f) Reagent store and mill maintenance workshops – steel framed, aluminium clad structures adjacent to the old farm buildings, not previously included.

5.3.4.3 Stage 2: Buildings

The remaining buildings, having continued their specific operation for the active care period of approximately five years, will form Stage 2 of the demolition work. In the event of any future land use changes for the site, it is possible that some of these buildings may remain on site. The buildings are as follows:

a) Administration/Services Building - a double storey, steel framed, engineered structure with reinforced concrete foundations and base slab and insulated metal cladding forming the walls and roof. Interior floors are of reinforced concrete and steel construction while internal partitions are of concrete block or gypsum board. The northern end of the building is a maintenance workshop for the underground mobile plant. 2 No. above-ground, bunded diesel tanks are located opposite the building, each of 48m^3 each. Several smaller tanks containing road diesel, engine and hydraulic oil are also located around the building. A waste oil storage tank is located adjacent to the maintenance workshop for the storage of used engine oils and products removed from the oil/water separator.

b) Water Treatment Plant - located adjacent to the concentrator building, comprising tanks, clarifier, 2 No. lamella separator units and associated pumps and pipework constructed on reinforced concrete foundations. The design of this system has been revised since the original closure plan.

c) Sewage Treatment Plant - comprising a settlement and biological treatment unit.

d) Water distribution pumphouse – comprises a small metal clad building and adjacent freshwater storage tank.

e) Gatehouse and Weighbridge - a single storey, steel framed structure with reinforced concrete foundations and insulated metal cladding forming the walls and roof. In the interests of security and as a general multi-purpose building, this will remain until all decommissioning activities have ceased.

The main electrical sub-station will not be demolished. This comprises a single storey metal clad building with reinforced concrete floor slabs containing switchgear, control and metering equipment. Overhead line terminal poles, transformers and other associated equipment is located outside the building but within a fenced compound. It will remain indefinitely in a securely fenced compound to provide a power supply, in the event of any future possible land use changes in the vicinity. The ESB will be requested to takeover the control and maintenance of the compound and its equipment after the Stage 2 demolition is complete and electrical power is no longer required on the site.

In addition the former farm buildings that are used as storage and maintenance workshops shall be retained for the duration of the Stage 2 works and then will be returned to the future landowner for re-use.

5.3.5 Removal of infrastructure/services

5.3.5.1 Requirements for removal

The extent of the demolition of the infrastructure and services and related minor structures will be as follows:

a) All access roads not required for post-mining use, and surfaced areas, including the crushed stone hardstanding areas over the site will be ripped to formation level and all crushed stone used as mass fill in either the ventilation shafts or access decline.

b) All services and their associated structures and chambers in the plant area will be demolished and completely removed and the resultant trenches backfilled. This will also apply to the tailings water, freshwater and reclaim water pipelines to and from the tailings management facility.

c) The 150mm dia. augmentation flow to the Erkina river system and the main 450mm dia. water discharge pumping main to the River Goul, which lie mainly outside the mine site area, will be left *in-situ* apart from two sections located on property owned by GML (where the depth of cover over the pipeline is reduced). The associated concrete and brickwork structures and chambers will be broken down to a depth of at least 1200mm below existing ground level. Their bases will be punctured to allow the free draining of the surrounding ground, then filled to above top of pipe level with the resulting crushed concrete and brickwork, or crushed stone, and backfilled. Any exposed ends of pipework will be plugged with a concrete seal.

All sections of the infrastructure and services to the mine will follow the procedures for decontamination described in Section 5.3.2 before decommissioning and subsequent demolition commences.

All services connecting to buildings to be demolished will be cut off or diverted before demolition commences. During the first stage of demolition this will leave many redundant services. However, only those services which can be isolated and removed without damaging other services required for the *active care* period will be removed at Stage 1. Most services run close together and will be more easily removable *en masse* during Stage 2 demolition.

Those internal access roads and hardstanding areas that are not required for any post-mining use will only be ripped up and removed at Stage 1 demolition if they provide no apparent use to movement and access around the site between the buildings and plant still operating during the *active care* period. However, this will not prejudice the need to provide a quantity of crushed stone from the hard standing areas for mass fill in the ventilation raises and access decline which occurs during the Stage 1 demolition.

The existing dewatering system comprises a number of underground sumps and pumps that pump mine water to the surface treatment plant and ponds as described in Section 5.2. This underground system will be decommissioned as described in Section 5.2.

5.3.5.2 Stage 1: Infrastructure removal

The following items of infrastructure and services will be decommissioned, demolished and removed as required in Stage 1 demolition:

a) The septic tank at the magazine area will be emptied, removed and disposed of by a licensed waste disposal contractor.

b) The car parking area outside the main site entrance and redundant access roads and crushed stone hardstanding areas will be ripped to formation levels and the material used for bulk fill in the ventilation raises and access decline, except for bituminous materials which will be disposed of at a licensed waste facility off site.

c) Electrical power, fire water and potable water distribution lines and sanitary waste lines to redundant buildings will be removed where physically possible and either broken up for fill or disposed of as scrap.

d) Redundant electrical power distribution lines within the plant site will be completely removed (excepting those required during the active care period, eg. for water treatment plant) unless they can be re-used to supply new developments.

e) Security fencing will be removed from the magazine area and the redundant pumping stations and taken off site for scrap.

f) Any fuel or other tanks not required for the active care period will be removed. These will include the heating oil, waste oil and haulage contractor's diesel tanks. Before the removal of any tank, it will be emptied of fuel, cleaned and rendered inert by filling with water. When the tank is ready for removal off site, the water will be removed but any opening will be resealed immediately after emptying. Similar precautions will be taken with the associated pipework and equipment. Any bunding or other spillage precautions will be kept in place during this operation so that no fuel or oil is allowed to enter any drainage system or watercourse. Any materials suspected to be contaminated with hydrocarbons will be removed from the site to a licensed waste facility.

5.3.5.3 Stage 2: Infrastructure removal

The following items of infrastructure and services will be decommissioned, demolished and removed to tip off-site as required in Stage 2 demolition:

a) The main fuelling depot will be used to fuel demolition plant and equipment used in both first and second stages of demolition. The facility comprises 2 No. $75m^3$ diesel tanks and dispensing arrangements contained in a concrete bunded area. A concrete spill pad is located adjacent to the tanks. The tanks will be decommissioned and removed in a similar manner to those in Stage 1. The concrete bunding and spill pad will be demolished for fill, and any material suspected as being contaminated will be disposed of in accordance with schedule 3(ii) of the current IPC licence.

b) The remaining access roads, except for that from the realigned R435 road which will continue to provide access to the former farm buildings, and the remaining hardstanding areas will be ripped to formation levels and removed

c) Decommissioning of the remote well dewatering system will commence once groundwater monitoring has established that an acceptable hydrogeological regime has established and that there are no additional water supply requirements. The pumping stations will be decommissioned, all plant removed and the reinforced concrete and brickwork structures completely demolished and removed to the plant site for use as fill.

d) The tailings, mine water, freshwater and reclaim water pipelines to and from the TMF will be completely removed.

e) The freshwater, fire water and potable water distribution pipelines, the associated freshwater and potable water tanks and the concrete and brickwork water distribution pump house will be completely removed.

f) The sewage collection and treated effluent pipelines will be completely removed from site.

g) The settlement holding ponds and well water conditioning ponds will be demolished by first removing from site the HDPE liner, the geotextile protection blanket and the gravel formation layer and then grading out the pond walls over the area of the pond.

h) Associated with the 450mm dia. Goul water discharge line, all concrete and brickwork scour and air valve chambers on the pipe will be demolished and removed to the plant site for use as fill except for the section of pipeline traversing the plant site which will be totally removed. The reinforced concrete outfall diffuser structure at the River Goul will also be broken down and the 450mm diameter inlet will be plugged with concrete. The exposed riverbank will be reinstated and protected against erosion. The 150mm dia. augmentation water discharge line will also be removed, together with the monitoring and decanting chambers and pumphouse, in a similar way to the 450mm dia. water discharge line.

i) The stormwater drainage will be completely removed except for a section of pipework which will be retained in order to drain the road accessing the existing farm buildings. A small length of drain will be constructed to discharge the collected stormwater from the last manhole to existing adjacent open drains.

j) The electrical power distribution lines within the plant site and the overhead power lines to the outlying dewatering pump stations will be completely removed unless they can be re-used to supply new developments. The power supply to the pump stations forming the replacement water supply scheme will remain.

k) All telephone and communications systems will be removed from site unless a long-term use can be found.

l) The site lighting, retained for site security during the active care period, will be removed from site.

The security fencing to the remaining pump stations, the settlement holding ponds and the remainder of the plant site will be removed from site only when all demolition work has been completed and the site has been graded prior to final landscaping.

5.3.6 Materials and Residues

5.3.6.1 Legislation

At the time of mine closure there will be wastes and unused materials and residues requiring appropriate disposal. The disposal of wastes from the operational mine is controlled by the Integrated Pollution Control Licence, in particular Condition 7, *Waste Management*. This covers both disposal on, and off-site and includes Schedules 3(i), *Hazardous wastes for Disposal/Recovery* and Schedule 3(ii), *Other Wastes for Disposal/Recovery.* These schedules specify the disposal methods for various waste materials.

Wherever possible these disposal methods will also be used after the mine has closed. However, there will be a number of instances where the disposal route will not be available or appropriate, and alternative methods will be required. There may also be particular wastes or redundant and unused materials at mine closure that are not listed within the Schedules.

5.3.6.2 Process chemicals and reagents

A number of chemicals and reagents are present on site that are used for mineral processing or water treatment. They are stored on site, up to the following maximum quantities:

TABLE 5.1
Process Chemicals and Reagents

Sulphuric Acid	100 tonnes
Hydrated Lime	60 tonnes
Sodium Carbonate	60 tonnes
Copper Sulphate	42 tonnes
Zinc Sulphate	25 tonnes
Potassium Amyl Xanthate	15 tonnes
Hydrogen Peroxide	25 tonnes
Aryl Phosphorodithioate	18 tonnes
Alkyl Thionocarbamate	18 tonnes
Sodium Isopropyl Xanthate	54 tonnes
Methyl Isobutyl Carbinol	5.5 tonnes
Anionic Polyacrylamide	1.0 tonne
Cationic Acrylamide	1.0 tonne
Danaflot	8 tonnes

All uncontaminated and unused reagents and chemicals will be returned to the supplier in accordance with the terms of the supply contract.

5.3.6.3 Laboratory Reagents

In addition to the process chemicals listed above, small quantities of reagents are stored on site for the purposes of laboratory analysis. The list of these reagents, with the maximum quantities stored, is as follows:

TABLE 5.2 Laboratory Reagents	
Nitric Acid	12.5 litres
Hydrochloric Acid	132.5 litres
Mg AAS Standard Solution	2 litres
Buffer Solution pH4	5 litres
Buffer Solution pH7	35 litres
Buffer Solution pH10	35 litres
Acetone	12.5 litres
Fe AAS Standard Solution	2.5 litres
Zn AAS Standard Solution	2 litres

These reagents will be returned to the suppliers or removed by a licensed waste management contractor. Where possible acids will be neutralised with lime and disposed of in the water treatment plant.

5.3.6.4 Nuclear Sources

There are a total of eleven separate nuclear sources on the site. Details of the sources are provided in Table 5. 3 below:

TABLE 5.3
Nuclear Sources

Location	Radionuclide	Radioactive Content	Type of Radiation Emitted
Concentrator			
Amdel	Curium 244	3.7 G.Bq.	Gamma
Final Tails Line – pump discharge	Caesium 137	1850 M.Bq	Beta
Primary Cyclone Feed Line	Caesium 137	1850 M.Bq	Beta
Regrind Cyclone Feed Line	Caesium 137	740 M.Bq	Beta
Lead Thickener Underflow	Caesium 137	370 M.Bq	Beta
Zinc Thickener Underflow	Caesium 137	370 M.Bq	Beta
Leach Circuit Feed	Caesium 137	3.7 G.Bq.	
Backfill density gauge No 1	Caesium 137	1.850 G.Bq	
Backfill density gauge No 2	Caesium 137	1.850 G.Bq	
X-ray machine - Courier			
Environmental			
Soil Moisture & Density	Caesium 137 Americium-Beryllium	370 M.Bq 1.85 G.Bq	Beta Neutron- Gamma

The ten sources within the concentrator are used for slurry analysis and density measurement. These will be removed by trained and accredited contractors, and returned to their original suppliers, in the United Kingdom and Australia. All operations will be carried out in accordance with the relevant national and international regulations relating to the transportation of nuclear sources.

The other source is within a soil moisture and density gauge, used to determine the level of compaction afforded to the earthworks during construction of the TMF. These are now redundant and will be returned to the manufacturer or other licensed user at the earliest opportunity for refurbishment and re-use elsewhere.

5.3.6.5 Fuels and oils

Fuels, oils and lubricants present on site in bulk tanks, drums, within plant and as waste. Maximum quantities stored on site are as shown in Table 5.4 below.

TABLE 5.4
Fuels and Oils

Diesel (site)	2 x 48,000 litres tanks and Mobile Plant tanks
Diesel (road)	2,000 litres tank (mine) 32,000 litres tank (haulage contractor)
Heating Oil	12,000 litres tank
Hydraulic Oil	12,000 litres tank
Engine Oil	3,000 litres tank
Other Lubricants/greases	Drums in store
Waste Oils	3,000 litres tank Plant and equipment

Unused diesel fuel in equipment will be drained down and added to that unused in store. Unused fuel, oil and hydraulic fluids of compatible grades, stored around the mine, will be collected and bulked with the main stock in the existing licensed, labelled and protected storage area. Disposal will be by sale off-site, either by return to the supplier or to a licensed contractor. Used lubricating oils and hydraulic fluids will be drained down from all plant and equipment and collected in the waste oil storage tank. Oils separated at the water treatment plant will also be collected in the waste oil storage tank. Care will be exercised to locate all sources of waste oils and to ensure that there will be compatibility of compounds in bulking. Disposal of waste oils will be by contract to a licensed waste oils recycling facility.

5.3.6.6 Residual ore stocks

All remaining ore at the surface will be milled and processed. All zinc or lead mineral concentrates remaining at the concentrate loadout area will be sold into the market in the same way as during production. Sludges from the treatment works will be deposited in the TMF.

5.3.6.7 Operational equipment wastes

The site will be scrutinised for materials likely to be contaminated or requiring special measures for disposal. These will include such items as:

- accelerator, plasticiser and stabiliser agents for shotcrete
- steel fibres for shotcrete
- resin capsules for rockbolt installation
- fire extinguishers
- conveyor belting
- containers or packaging which either are contaminated or require controlled disposal procedures
- used tyres
- cables, motors, transformers and switchgear

- HDPE linings from settlement tanks
- hoses, filters, etc. from workshops.

There is an existing disposal procedure for waste lead-acid batteries, hydraulic hose pipes, timber, metal and fluorescent lighting tubes.

Disposal contracts will take account of the need for the purchaser to properly dispose of any composite materials rejected after removal of those materials of value. Materials will be washed down as necessary and stored with other compatible materials prior to disposal.

To accommodate EC policy many of these materials can be recycled and this will be done by selling them for scrap where this is legal, safe and practicable. Materials to be recycled or sold for scrap will include batteries, steel from the buildings and non-ferrous metals from cables, motors, transformers and switchgear. Fire extinguishers will be returned to the supplier. Packaging, timber, tyres, conveyor belting and other industrial wastes, that cannot be sold, will be disposed of to an off site licensed facility.

5.3.6.8 Cement

Large quantities of cement and ground granulated blast furnace slag are used on the mine for shotcrete and as an pozzolanic agent within the underground backfill. The cement is stored in two silos (50t and 60t capacities) and the ground granulated slag is stored in an 80t silo. All remaining stocks will be utilised during the Stage 1 closure operations or removed from site for re-use.

5.3.6.9 Explosives

Explosives and associated items used at the mine are:

- Emulsion explosive
- Electric and non-electric type detonators.

The emulsion explosives are either in bulk form or as cartridges packed in 25kg cartons. Detonators are packaged in air tight bags or cartons. Explosives are stored in the surface magazines and are taken underground on a periodic basis as required by production operations.

All explosives and accessories will be disposed of according to the relevant explosives and security regulations to prevent unauthorised access. All cartons of explosives will be returned to the supplier.

Opened or damaged cartons of emulsion explosive and detonators will be destroyed underground by controlled detonation. This will be carried out by authorised personnel, under the direction of the Mine Manager.

Surplus bulk emulsion explosive will be returned to the supplier.

5.3.6.10 Polychlorinated Biphenyls (PCBs)

An audit of the electrical equipment on the mine site, including a 1300kVa transformer for the emergency standby generator, has shown that none contain PCBs. No particular precautions are therefore required at closure with regards to PCBs.

5.3.7 Landform and landscape

5.3.7.1 Earthworks

At the end of the Stage 1 decommissioning, when all major structures and materials have been removed and dealt with and the mine entries treated, the ground surface will be contoured to an appropriate landform. Stockpiled soils including subsoil will be re-spread. It is not possible to be definitive at this time about the actual landform, but the slopes will be graded to shallow profiles appropriate for shedding surface water. It is not intended to import any fill to the site and all re-grading will be with existing materials. Areas that have become compacted at the surface as a result of the mine development will be ripped in order to provide an appropriate substrate for rehabilitation.

Although some minor structures will remain until Stage 2, and there will be some local temporary grading until they are removed, the area occupied by the main buildings and much of the open space between will be graded during the Stage 1 works.

5.3.7.2 Drainage

Once the landform has been fully graded and contoured and the topsoil has settled, the final surface water drainage will be installed in Stage 2. A system of surface ditches will be constructed along field boundaries, designed such that there will be no ponding or un-drained areas. As shown on figure 5.5, these ditches will discharge to a main collector ditch along the eastern site boundary that will discharge to the existing watercourse to the north.

Areas of heavy soil with poor internal drainage will be locally drained as necessary with a piped field drain system, comprising perforated pipes with permeable backfill, discharging to a field boundary ditch. Any such drainage system will be designed in accordance with normal agricultural drainage practices.

5.3.7.3 Revegetation

Landscape

The proposed landscape layout and vegetation cover is shown on Figure 5.6. It comprises a mixture of woodland and permanent pasture, incorporating the planted screening bunds as field boundaries. New field boundaries will be established in order to create an appropriate field pattern for the agricultural use and for the land drainage pattern. The existing residential property and associated outbuildings and parkland will be retained.

This layout is provisional, and will continue to be reviewed periodically, especially at the time of mine closure. The actual layout could easily incorporate retention of selected buildings or other hard uses, within the landscape structure already established.

Ground preparation and amelioration

The re-graded surface will be cultivated with a wing-tined ripper to a minimum of 500mm depth to alleviate any surface compaction resulting from the earthworks operation, and large stones brought to the surface will be removed. The surface will be scarified immediately prior to placement of topsoil or other soil forming materials. Topsoil from stockpiles will be loose spread on the surface using dumper and hydraulic excavator, with no machinery access permitted over the soiled surface. Soil depths will depend on the material available in stockpile, but will be between 100mm and 250mm. Greater depths will not be necessary.

After the soil is spread, samples will be taken for analysis of pH, lime requirement and plant nutrients. Ameliorants such as lime and fertiliser will be spread at rates subject to the results of the soil analysis, before final surface preparation, so they are incorporated into the soil.

The topsoiled surface will be prepared by disc or spring-tine cultivator, with at least two passes working at right angles. All stones and other obstructions will be removed, and existing weed growth removed by herbicide treatment.

Vegetation establishment
After an initial two year regime of `green cropping' and cultivating, in order to restore soil structure, the final agricultural pasture will be established using conventional seeding techniques, applying a normal agricultural grass-ley mixture. The precise mixture will be determined at the time of rehabilitation, and subject to the potential productivity of the soils at the time they are replaced.

Woodland trees will be planted immediately using conventional forestry techniques. The species mix over the site will be appropriate to the soil conditions of the area as determined by soil pH testing. Groundcover vegetation will not be sown, in order to avoid competition with the trees. Weed growth around and within the plantation areas will be suppressed using herbicides.

Aftercare
Replaced topsoil will have been in stockpile for about 12 years and, whilst it will retain most of its fertility, its structure and microbial activity will have been lost. The soil will therefore require a period of aftercare and careful management in order to restore a fully functional and productive soil-plant system. A five year period of aftercare from the time the soil is spread is usually sufficient for restoring soil productivity in such circumstances and a detailed aftercare programme will be prepared at the time of the final landscape design. The requirements for pasture and woodland are outlined below.

- *Pasture*

As a first step the replaced soils will be sown with a `green crop' such as mustard or clover, which will be cultivated in at the beginning of the second year. A second green crop will then be sown immediately. At the beginning of the third growing season this will be cultivated again and the permanent pasture mixture sown.

During the third growing season, pasture areas will be cut once, in order to stimulate the sward tillering. In subsequent years, either cutting twice per year or light summer grazing will be the appropriate management. Top-dressings of fertiliser will be applied, at rates to be determined by soil analysis.

Care will be required in order to ensure that the fragile soils are not damaged by livestock foot traffic and that temporary drainage is carried out to remove any standing water.

- *Woodland*

Tree plantations will require pruning of dead wood, and replacement of failed trees. The ground surface around each tree will be kept free of weed growth with winter-applied granular residual herbicides. Fertiliser applications will be made according to soil and foliar analysis. In the last year of the five year aftercare period, thinning of the trees to prevent overcrowding will be required.

5.3.8 Early closure

In the event of early closure, it is considered that the mine site surface can be decommissioned and restored in line with the above plan with minimal variations. The same approach can be adopted for the structures, buildings and facilities and similar costs will be incurred.

Backfilling will continue after closure, thus the demolition of the backfill thickener and associated plant will be delayed by about 1 year.

5.4 Tailings Management Facility

5.4.1 Tailings Disposal Requirements

Galmoy is currently predicted to generate a total of 6.7 million tonnes of tailings over the full operational life (based on a total mineable reserve of 8.7 million tonnes). Approximately 3.5 million tonnes of tailings will be used underground as backfill. Consequently, the remaining 3.2 million tonnes require disposal in the surface tailings management facility (TMF). Given the calculated tailings density of 1.5t/m^3, the impoundment is required to have a storage volume of some 2.16 million m^3.

The historical and anticipated tailings production is illustrated in Figure 5.7. In 2000 a tailings backfill plant was commissioned and an increasing proportion of tailings will be disposed of underground (see Appendix 7). This has enabled the Company to retain the total tailings requiring surface disposal within the original design of the TMF, even though the amount of ore mined has increased considerably.

The planned production from current permitted reserves, allowing for tailings backfill (see Appendix 7) still requires tailings storage in the TMF in excess of the capacity remaining in Phase 2. On the basis of this and on the potential for further reserves being permitted the Company has decided to proceed with the construction of Phase 3 in 2006.

However, this plan is based on the production from the permitted reserves only, so at the current end of mine life in 2010 Phase 3 will only be partially filled.

5.4.2 Design Principles

The basis for the design of the tailings facility is described in detail in the design report prepared by Golder Associates (1992) and is reviewed in Appendix 3. The design was originally based on a single impoundment subdivided into three adjoining cells, referred to as Cell 1, Cell 2 and Cell 3. The design was subsequently amended slightly and currently comprises two phases covering a total area of 314,900m^2 and providing a total storage volume of over 2.8 million m^3 (see Figure 5.8).

Phase 1, which has a storage volume of 880,000m^3 was constructed in 1996. Tailings deposition commenced in 1996 and the phase was filled by July 2000. Phase 2, which has a storage volume of 1.167 million m^3 was constructed in 2000, is currently receiving tailings and is approximately 80% full. Phase 3 of the TMF is due to start construction in 2006, giving a further 777,000m^3 capacity. Each phase has a separate cycle of construction, operation and rehabilitation with only one cell being operational at any one time.

The detailed design phase that preceded the construction of Phases 1 and 2 and will apply to Phase 3 is reviewed in Appendix 3.

5.4.3 Construction, stability and behaviour of the TMF

The construction and long term stability of the TMF have been extensively studied by Golder Associates on behalf of Arcon (now GML) and the available information is reviewed and summarised in Appendix 3. Essentially the TMF has been designed and constructed to very exacting standards consistent with BAT and international practice. Its long-term integrity is thus not considered to be a threat.

The geochemical and hydrological behaviour of the tailings and TMF as a whole are reviewed in Appendix 4. The tailings solids are considered to be benign, with metal contents elevated above normal soils but not a threat to long term land use, and with a very low risk of acid generation.

5.4.4 Afteruse options

5.4.4.1 Comparison of options

The Initial and first Interim Mine Closure Plans reviewed the various afteruse options for TMFs and the constraints that affect the choice. A summary of the options is given in Table 5.5 below.

TABLE 5.5
Vegetation rehabilitation options for tailings impoundments

Option	Advantages	Disadvantages
Covering with an inert soil-forming material and seeding with grass or planting with shrubs.	❍ proven technology ❍ potentially more robust and productive ❍ readily adopted into a farming unit ❍ no short-term problems with soil toxicity ❍ no need for special tolerant vegetation ❍ minimise exposure of tailings and water infiltration	• soil forming material may be difficult to obtain locally • possibility of upward migration of toxic elements and salts • relatively high costs • surface has to be consolidated and stable before access
Direct seeding of tailings with tolerant grasses, using fertilisers and/or organic matter to ameliorate the surface.	❍ relatively well proven technology ❍ low cost ❍ can be established very quickly on tailings surface before machinery has safe access	• low productivity afteruse, perhaps some limited grazing, also wildlife value • tolerant varieties of grasses required • may require manual maintenance • will probably require initial trial work to confirm the most suitable vegetation and amelioration • allows water infiltration into the tailings surface • risk of wind erosion if sward is removed
Establishment of scrub and woodland by direct planting into tailings surface, using fertilisers and/or organic matter to ameliorate the surface.	❍ proven as a viable option ❍ low cost ❍ little long term management requirement ❍ possibility of some cropping, eg. by coppicing ❍ can be established on to unconsolidated tailings surface, eg. using willow cuttings ❍ greater evapotranspiration during growing season ❍ tolerant of high water table and seasonal waterlogging ❍ high wildlife value	• requires site specific trials to confirm practical techniques • deeper root penetration than grass, thus greater volume of tailings exposed to oxidation • greater water infiltration and surface storage, less shedding of water • more inclined to restrict surface drains with root growth
Maintenance of a wet tailings surface with a combination of fen, marsh and wet-scrub habitats	❍ proven as a viable option ❍ fairly low cost ❍ little long term maintenance ❍ no risk of dust generation ❍ no infiltration and seepage of water, all excess water is shed clean from the surface ❍ pyrite oxidation inhibited by anaerobic conditions ❍ very high wildlife value	• site specific development work required • requires water table control within narrow limits • dependent on very low permeability containment system remaining intact • perceived structural risk from saturated tailings, however this is minimal if the tailings are consolidated • greater long term monitoring requirement
Maintenance of open water over the tailings surface, in a similar way to a reservoir	❍ low cost ❍ little long term maintenance ❍ no risk of dust generation ❍ no infiltration and seepage of water, all excess	• dependent on very low permeability containment system remaining intact • perceived structural risk from saturated tailings, however this is minimal if the tailings are

	water is shed clean from the surface ❍ pyrite oxidation inhibited by anaerobic conditions	consolidated • greater long term monitoring requirement • water depth shallow and even over whole surface; could be a hazard • design to reservoir standards required

The preferred option at the time of the Initial plan was for low level amenity use with some light grazing to maintain the grass swards. This was based on conservative assumptions about risks to grazing animals and limited availability of soil forming materials.

5.4.4.2 Experience gained at Galmoy

Since the commencement of the mining the Company has carried out a series of revegetation trials, followed by progressive restoration of the Phase 1 cell after its completion in 2001. Extensive use has been made of soil forming materials available as waste (spent grains) from the brewing industry. Appendix 4 considers the long term geochemical and hydrological behaviour of the TMF. Appendix 6 is a review of the trials and Phase 1 restoration, in terms of the use of soil forming materials, risks from metal contamination and acid production, and potential use of the restored surface for grazing.

This review concludes that the TMF can be restored very satisfactorily with soil forming materials available at minimal costs. Areas restored in this way are capable of sustaining an agricultural use for grazing, though some limitations on grazing intensity and seasonal use will apply.

The availability of suitable soil forming materials cannot be guaranteed for all stages of the TMF restoration. Thus the option of direct revegetation of the tailings surface, with appropriate amelioration with fertilisers (including organic manures) remains a viable alternative. This option is one that is often adopted at mines where soil forming materials are scarce and the tailings are sufficiently benign to allow vegetation growth directly. The Company is proposing to initiate further trial work in 2006 to investigate this option and determine the optimum amelioration required.

5.4.4.3 Preferred restoration option

Whilst it is important to present definite afteruse proposals of proven viability, it is difficult, and may even be inappropriate, to be definitive about the most effective way of achieving these in the future. Opportunities not apparent now may present themselves in the future and land use priorities in the region may change. Also, the programme of further rehabilitation trials could identify greater opportunities to enhance and diversify the eventual rehabilitation goals. However, it is still necessary to demonstrate at this stage a clear afteruse and rehabilitation strategies, putting forward a preferred option that is achievable.

On the basis of the options examined previously and the experience gained to date, a low intensity agricultural use is proposed, involving grazing of permanent pasture. Whilst limited revenue would accrue from this use, the long-term aftercare and maintenance requirements in perpetuity are not onerous and this use would not pose a threat to the environment in the long term. The development of such uses on abandoned tailings impoundments has been achieved in other locations and so can be considered proven.

The TMF would therefore be returned to open grassland, which could be established by covering of the tailings surface with soil forming materials/organic fertilisers as achieved in Phase 1. The grassland could be maintained by periodic grazing and hay production.

In the event that soil-forming materials are not available at realistic costs, for any part of the TMF, a similar grassland vegetation cover can be achieved by direct revegetation of the tailings surface, using organic and inorganic ameliorants. The resulting surface can still be grazed but probably at a lower intensity.

It is not considered prudent to propose a more productive agricultural use at this stage, because the resources required to achieve and maintain it could be very high. It is unlikely that such a use would be cost-effective, given the initial input required.

5.4.5 Decommissioning and restoration works

Decommissioning and rehabilitation of the TMF is a progressive operation. Phase 1 of the facility is full and is undergoing progressive restoration as described in Appendix 6.

At mine closure, however, final rehabilitation of the impoundment will be required. This will be carried out in two phases: the initial Stage 1 decommissioning followed by a period of active care and the final Stage 2 rehabilitation. These stages are considered under a number of main headings as follows:

- Structural alterations
- Land use and landscape
- Drainage
- Surface preparation and amelioration
- Vegetation establishment and aftercare.

5.4.5.1 Structural alterations

In order to maintain the integrity of the TMF, especially its containment role, the facility must be retained in a stable and unaltered condition compliant with the original design criteria and objectives. This means that there is little scope for significant regrading of the impoundment walls or removal of the internal cell walls. The proposal is therefore to rehabilitate the impoundment walls and surface in their operational configuration, with limited structural alterations as follows:

- Addition of inert or soil forming material to the inner cell walls, between the crest and the tailings surface, will give a smoother transition between the impoundment wall and the tailings, and will cover/protect the section of liner above the tailings surface, enabling vegetation to be established.
- Modification of the decant and outfall structures to drain the surface of the impoundment. Drainage arrangements are discussed further below.

For the purposes of this second interim Plan the mine operations cease in 2010 and the tailings level in Phase 3 at this stage will only be about 2 metres depth and the level will be far lower than that of the first two phases. In addition, it is expected that Phase 3 will be used to contain material from the stage 1 decommissioning of the mine site with elevated levels of heavy metals. This contaminated material from the mine site will be placed on the tailings in Phase 3 to form a solid surface. Phase 3 will then be capped with material from the upper part of the outer cell walls. The outer cell walls of Phase 3 will be cut down to an appropriate level (assumed to be 2m above the final surface to allow for flood storage) and the material generated will be utilised to construct a free draining surface area on top of the cap.

5.4.5.2 Drainage

Drainage requirements

In the long term the drainage arrangements within and around the TMF have to provide for the safe discharge of water from three sources:

1. Seepage water from the internal drainage within the cells, which is discharged at different points and may contain elevated concentrations of some trace elements and salts. The internal drainage arrangements are described in Golder (1992) and summarised in Appendix 3.
2. Tailings surface water, which will be discharged from the impoundment at one point and which will be relatively clean (see Appendix 4).
3. Clean surface water from the outer impoundment walls and surrounding catchment, intercepted in a perimeter drain.

The operational site drainage arrangements are described in Golder (1992) and summarised in Appendix 4. This Appendix also considers the long term water balance and drainage follows for different conditions on the impoundment. There are differences between the drainage flows envisaged in the Initial 1992 closure plan and those now predicted, arising from:

- The flows have been recalculated using rainfall data from an on-site rain gauge (rather than the data from Met Eirann for Kilkenny used in the 1992 Initial Mine Closure Plan).
- The estimated seepage through the base of the geomembrane has been increased from $0.1m^3/hr$ to $4.0m^3/hr$ (based on the Phase 1 & 2 cell area of 23ha combined) to accommodate a more conservative assessment of long-term defects in liner integrity.

During operation of the mine, all clean surface water from the whole catchment area is being discharged direct to an existing open watercourse. Tailings supernatant effluent is being returned to the plant and excess water is being treated and discharged to the River Goul.

On decommissioning, this treatment facility will not be available, so all waters emanating from the TMF will have to be capable of discharge to the existing watercourses, along with the clean external catchment water. The post closure drainage arrangements will therefore have to ensure that potentially contaminated waters are of adequate quality for discharge after dilution with clean waters.

1. **Interim** drainage arrangements established during Stage 1 of the Closure Plan and continuing for the *active care* period, when potentially contaminated water can be retained for monitoring and, if necessary, treatment; and

2. **Long term** drainage arrangements established during Stage 2 of the Closure Plan, followed by the *passive care* period, which require no intervention, and during which natural dilution will ensure adequate water quality.

Flood provision

The likelihood of flood events is considered in Golder (1992), which concludes that the rise in water on the surface of the TMF during a 1 in 100 year 24 hour peak rainfall event, including failure of the decant, will be less than 200mm on any cell. The risk of overtopping of the cell walls is therefore very remote. However, the risk of long-term extreme rainfall events requires that provision be made in the rehabilitated impoundment for a spillway to prevent uncontrolled overtopping of the impoundment wall. Details are given in Golder (1992).

It is intended that the final capacity of the all three cells will accommodate the maximum flood storage requirement, with Phase 3 providing the balance not accommodated within Phases 1 and 2. A spillway will be constructed between Phase 2 and 3. Phases 1 and 2 are already be connected to allow drainage to flow from one to the other.

Interim (Stage 1) drainage arrangements
The proposed interim arrangements are shown on Figure 5.9. Internal and surface water from the TMF will be collected in the main sumps on Phase 2 and Phase 3 and will be pumped to the conditioning ponds at the mine site for dilution with clean site drainage, augmented with pumped groundwater if necessary. Water treatment will continue, if necessary, before discharge of water to the existing watercourse (River Goul) via the existing pumping main. Figure 5.9 also shows the flow sheet for the interim drainage arrangements with estimated flows for differing conditions.

Monitoring of water quality during this Stage 1 active care period will determine the stage at which the water quality will have stabilised at a level suitable for discharge. It is not anticipated that this will be longer than 5 years.

Long term drainage arrangements
The proposed final arrangements to be established in Stage 2 are shown on Figure 5.10. Downstream of the outfall from the TMF it is proposed to construct a new attenuation pond, into which would drain the entire tailings impoundment surface and internal water, and the clean surface water. The pond will have a capacity of 40,000 - 60,000 m³, in order to achieve a degree of conditioning of the water from the impoundment prior to discharge. Calculations of the water balance between the original and revised TMF layouts shows that no revisions to the design of the attenuation pond are required.

During the summer period, when the majority of the flow into the pond will come from the internal drainage, dilution will only be within the volume of the pond. It is estimated that, at the end of a dry month, the discharge from the pond will still achieve a dilution of between 5 and 10 times that of the internal discharge from the impoundment. Figure 5.10 shows the flowsheet for the final drainage arrangements, with estimated flows for dry, average and wet conditions.

The rise in water level on any cell during a 1 in 100 year storm event will be less than 200mm, and for very extreme events (twice the 1 in 1000 year event) spillways will be incorporated into the impoundment's construction (Appendix 4 and Golder, 1992 (a)).

Drainage details
The internal drainage of the impoundment will remain in the as-constructed arrangement, except that the sump chambers will be removed during Stage 2. The main collector pipes will discharge directly into the open channels at the base of the outer impoundment walls, and thence to a main collector point. If it becomes necessary to control and terminate the flow of internal drainage, or if it becomes blocked, then the main collector pipe will be grouted upstream of the liner, in order to seal it.

The final surface tailings on each cell would be shaped as a shallow valley and aligned towards the outfall points as shown on Figure 5.10. Water would be decanted down a cascade into a stilling basin and then into the attenuation pond. As Phase 3 will be at a lower level than Phases 1 and 2 it will have an independent outflow arrangement, similar in principal to that described for Phase 2. The discharge will flow north around the TMF to join the Phase 2 outflow.

An additional spillway for flood flows will link Phase 2 with Phase 3. The size of the spillway will be dependant on the flood storage capacity remaining in the Phase 2 cell. Water from the Phase 1 cell would spill into Phase 2 cell as currently operated.

The attenuation pond will be lined with natural clay materials obtained on site, if these are available, or with bentonite (approximately 4%, mixed to 300mm depth) if not. Sealing of the base of the pond will achieve a permeability of 10^{-9}m/sec.

The profile of the pond is such that marginal and deep-water vegetation will establish and the biological activity within the pond should provide some additional conditioning of discharge water. This will not be a primary function of the pond, but will be an added benefit.

The perimeter interceptor channel around the base of the impoundment will be cleared and regraded if necessary, along with the ditches from the remainder of the catchment area.

5.4.5.3 Surface preparation and amelioration

During construction of the TMF, topsoil was stripped from the area and has been stockpiled for re-use during rehabilitation operations. Although the quality of the soils will deteriorate during storage, they will still have considerable soil-forming value within the context of the preferred rehabilitation option.

The availability of spent brewery grains have led to the use of this material in the progressive restoration of Phase 1 of the TMF, as described in Appendix 6. Subject to the continued availability of this or similar material it is proposed that this soil forming material will be utilised for the restoration of Phases 2 and 3.

The topsoil and/or other soil forming materials that are available will be spread over the tailings surface using the techniques used previously for Phase 1 and described in Appendix 6. A depth of soil forming material between 150mm and 500mm would ideally be placed over the tailings; however, the volume of available soil materials will determine the extent of the area covered.

In the event that soil forming material is not available, direct revegetation of the surface will require amelioration in order to sustain good grass growth. Subject to the consolidation of the tailings surface, ameliorants and soils will be spread with conventional agricultural machinery, fitted with low ground pressure tyres, or with other adapted machinery. If access is limited, some materials can be applied in a water slurry, sprayed on from the impoundment walls (as for hydroseeding). Surface consolidation could be enhanced, if necessary, by establishing a temporary grass sward, which will help to remove surface moisture and will provide root reinforcement of the tailings surface.

During the final stages of the drainage of each phase, the surface water will be progressively removed and 'beaches' will form. The tailings slimes have a fine particle size, with natural cohesion that will reduce the potential dust generation. Nevertheless, in order to prevent the risk of dust blow from these beaches, the surface will be progressively treated with a crusting agent and, if surface consolidation is required, a temporary grass sward.

5.4.5.4 Vegetation establishment

Seeding of the outer impoundment walls was undertaken just after construction using a low maintenance amenity mixture, and a diverse sward has been generated. In some areas natural colonisation has led to the development of gorse stands.

Seeding of the tailings surface areas will be undertaken using hydroseeding, conventional broadcast or hand seeding, depending on the accessibility of the slopes and tailings surface to light machinery. The tailings surface will be seeded with a similar mixture, but including metal and/or salt tolerant cultivars. The revegetation trials undertaken to date (as described in Appendix 6) have shown that the following three species are the most appropriate based on coverage, root penetration and low uptake of heavy metals:

Festuca rubra	cv Merlin
Agrostis tenuis	cv Heriot
Agrostis castellana	cv Highland

It is possible that, at the time of decommissioning for Phase 2, a wider selection of species may be available and further trial work will enable a full range of suitable species to be determined.

Whilst there are elevated levels of some phytotoxic elements present in the tailings, these should not be at a sufficient level to cause major problems (see Appendices 4 and 6). The use of metal tolerant cultivars will provide a level of insurance and confidence in the ability of the sward to thrive in the long term. However, the principle of establishing vegetation directly and indirectly on tailings impoundment surfaces is well established, and the techniques are proven and confirmed by the results of initial trials.

Appropriate organic and inorganic fertilisers will be applied as part of the seeding process. Again, trial work and soil analysis will determine the optimum amounts that need to be applied.

Figure 5.11 shows the partially completed and restored TMF, during progressive restoration (during 2005). Figure 5.12 shows the final landscape of the TMF after restoration is complete.

5.4.5.5 Aftercare

Aftercare in the short term will comprise periodic fertiliser additions, in order to establish a self-sustaining soil-plant system that will require minimal maintenance in the longer term. Light grazing will be permitted for short periods from the third year onwards, during the summer months. Cutting once per year, to remove a hay crop, will help to promote a dense sward.

Areas of gorse or other natural scrub development will be cut and treated to remove the growth and maintain a grass sward over the tailings surface and the embankment side slopes.

5.4.6 Early closure

In the event of early unplanned closure it is likely that the current tailings disposal cell will be below its design capacity. The decommissioning and restoration undertaken will depend on how full the cell is, as follows:

Status of cell:	*Decommissioning and restoration:*
Cell walls constructed and tailings deposited to <0.5m depth.	Removal of tailings into existing cell (or to new smaller cell); removal of cell walls and lining.
Tailings deposited to >3m of cell wall crest.	Top of cell wall removed and used for cover over tailings; containment liner re-fixed at crest wall.
Tailings deposited <3m of cell wall crest.	Cell decommissioned as per normal closure process, with additional fill placed below inner crest.

5.5 Replacement water supply

During the planning stages for Galmoy mine studies anticipated a potential loss of local water supplies from wells due to lowering of the groundwater levels resulting from mine dewatering. In order to mitigate this two wells were drilled for a replacement water supply scheme, which is currently operated by the Company, providing potable water to the township of Rathdowney and areas adjacent to the mine. This system will be transferred to the ownership of the Local Authorities, who will then become responsible for the operation of the wells, reservoir and distribution network. It is intended for this transfer to take place prior to the closure of the mine, subject to the agreement of all parties.

5.6 Aftercare Management Plan

5.6.1 Orebodies

In the short term the operational subsidence monitoring will continue biannually, using the existing monitoring points. In the longer term passive care stage the frequency of monitoring will reduce progressively to every 5 years, using the same monitoring points.

5.6.2 Mine facilities site

As discussed previously the intention for this area is to return it as closely as possible to a greenfield site condition. Thus the long term aftercare management will include periodic (5 year) inspections of the site to confirm ground conditions, continued sustainable land use and the absence of contamination. The condition of the sealed mine entries will also be examined. Any remedial works required will be initiated and inspected.

The frequency of inspections will be kept under review and if any remedial works are required then the frequency will be increased as considered appropriate.

5.6.3 Tailings Management Facility

It is expected that the TMF will require a greater level of monitoring and aftercare than the mine site, in order to ensure its continued stability. The frequency of periodic inspections and monitoring following Stage 2 decommissioning will be annually, for at least 5 years but perhaps longer until the monitoring indicates that a steady state within the required criteria is reached. Thereafter the frequency of inspections will decrease, initially to every 2 years and eventually to 5 years.

Apart from the frequency, inspections and monitoring of the TMF and groundwater beneath it will be carried out in accordance with Condition 7.6.13 and Schedule 3(iii) of the IPC Licence.

The intention is that, as part of the passive care approach to the long-term management of the TMF, the maintenance requirements for the vegetation should be minimal. The Stage 1 active care aftercare period will bring the land up to an appropriate level of productivity, after which the selected land use will require very little, if any, intervention and the vegetation will continue to develop and thrive even if it is not tended. The only operations that will be required are:

- Maintenance of fences, access roads, outfall and spillway structures, on an inspection and repair basis.
- Clearing of the perimeter interception channel and other ditches in the catchment. Maintaining the channels to the attenuation pond.
- Addition of fertilisers, if deficiencies develop. This should only be necessary if grass areas are grazed, and even then experience suggests that this is unlikely under an extensive, as opposed to an intensive, grazing regime.
- If grass areas are to be retained, and not allowed to progress to scrub, then occasional light spring and summer grazing, or cutting once per year, will be required. Stock densities should be kept low, and large animals (horses and cattle) should be excluded from the impoundment surface.

The reinstated pasture areas adjacent to the impoundment can be managed in the same way as any similar agricultural land, and will be self-supporting.

The land area as a whole, containing the rehabilitated TMF, new woodland and restored pasture, will form a mixed-use land unit, which, if managed for a variety of amenity and productive purposes, should be self-financing. Management of the area could be let, with a licensee having the benefit of the products in exchange for maintaining the non-productive areas.

5.6.4 Long Term Monitoring

5.6.4.1 Monitoring strategy

Whilst the mine is in operation, aspects of the surrounding environment are monitored on a regular basis. The intention is to continue with this monitoring during Stage 1 of decommissioning *(active care)*, with a gradual transition to the long term *passive care* monitoring regime proposed in this Interim Closure Plan. For many aspects this will mean phasing out the monitoring altogether, where no residual impacts are anticipated. In the long term, the residual impacts and thus the monitoring requirements should be very low.

<u>Standards for environmental quality</u>
Monitoring results will be compared with the appropriate environmental quality standards, as a basis for establishing performance of the decommissioning work overall, including rehabilitation. These standards may vary in the medium and long term future, and for some factors there are unlikely to be appropriate standards. For the present purposes, the following standards are proposed:

Soils and vegetation:	No increase on average levels pertaining at the time of mine closure (bearing in mind sampling variation, distance, soil type and time of year).
Surface waters:	As set out in the IPC licence, and subject to Quality of Fresh Waters for the Support of Fish Life - Salmonid subdivision (EC Directive 78/659/EEC), also Surface

	Water abstraction (75/440/EEC), A31/MAC value.
Groundwater:	Groundwater Directive (80/68/EEC) – *subject to implementation of the new Groundwater Directive to be made pursuant to Article 17 of the Water Framework Directive 2000/60/EC.* Also – proposed Interim Guideline Values for the Protection of Groundwater in Ireland (EPA 2003)
Air quality :	Deposition of metals at a rate no more than pre-mining background levels (bearing in mind natural variation and ambient conditions).

5.6.4.2 Soils and vegetation

Current soil and plant tissue analysis show no contamination of soils and vegetation outside the mine perimeter. Ambient air and dust sampling are well below emission limit values. One final soil sampling programme, as originally undertaken, will be conducted in the last year of the mine life to confirm that no contamination has taken place.

On the TMF walls and surface, bulk groundcover vegetation samples will be collected randomly twice yearly (summer and winter), and soils once per year, and analysed for total Pb, Zn, Cd and As.

For the longer term, beyond 5 years, there is no significant potential contaminant dispersal mechanism into the surrounding land and monitoring is not considered necessary. This is especially the case if sampling during the 5 year active care period indicates a stable environmental condition. Once the impoundment surface soil/vegetation has stabilised, there should be little long term change in movements of metals requiring monitoring.

The composition of the vegetation, particularly tree/shrub planting, on the impoundment and surrounding planted woodland areas will also require occasional inspection for management purposes. This will entail assessment of species composition and plant density, general health and vigour. Monitoring will be discontinued in the long term *passive care* stage, assuming that a stable situation has been attained.

5.6.4.3 Surface waters

Following the active care period and decommissioning of the water treatment plant, discharges to the R. Goul will cease and therefore the catchments will not be affected as far as water quality is concerned. Therefore, water quality monitoring in the R. Goul is not necessary. However, water flows in upper tributaries will be monitored during Stage 1 re-establishment of the groundwater levels, in order to ascertain when augmentation pumping is no longer necessary.

Surface water from the mine site and tailings impoundment will discharge into the R. Glasha, a tributary of the R. Erkina. The proposed arrangements for monitoring water quality in this catchment are as follows:

<u>Mine site</u>
Surface water from the graded and rehabilitated site will drain into a small tributary of the Glasha. All contaminated material from the site will have been removed, so no contamination of this tributary is anticipated. However, for the active care period the tributary will be sampled 6 times each year (2 each for low, intermediate and high flow conditions) and the waters analysed for dissolved and suspended metals (Pb, Zn, Cd and

As), TSS, BOD, conductivity and pH. This sampling should confirm that no contamination is leaving the site by this route. In that event, no sampling is envisaged beyond the active care period. If contamination is detected, then further investigations will determine the cause so that remedial action can be taken.

Tailings Management Facility
Surface and internal water from the impoundment and drainage from the surrounding land will discharge into the R. Glasha. During the active care period the impoundment waters will be collected and cycled to temporary arrangements at the mine site before discharge to the R. Goul (interim drainage arrangements, described in Section 5.4.5). For the long term, all waters will discharge to the watercourse. In both the long and short term each component of the flows will require separate sampling, along with the combined flow downstream. The flow components sampled will include, as appropriate: surface and internal flows from the cells, combined impoundment discharges, surrounding land drainage and final discharge to the watercourse. Flow rates will be estimated and samples will be analysed for the following parameters: TSS, dissolved and suspended metals (Ca, Mg, Fe, Pb, Zn, Cd and As), CN, conductivity, pH, alkalinity, sulphate, COD and BOD.

During the active care period, monitoring will be similar to, but at lower frequency than, the operational monitoring of the TMF as set out in schedule 3(iii) of the IPC licence. Samples will be collected on six occasions each year, 2 for each low, intermediate and high flow conditions. No sampling is intended in the long term unless an unstable or above baseline situation for any of the measured parameters persists in the main watercourses to the end of the *active care* period. In this event, sampling will continue on the same basis as during the active care period for a further 5 years or until such time as a stable and compliant situation is attained.

During the Stage 1 *active care* period, sampling requirements for the discharges being stored in the retained mine process ponds will depend on the water treatment or dilution requirements, which cannot be determined until all Phase 1 monitoring data are available.

Water levels within the TMF cells and walls will be monitored as part of the operational requirements. The piezometers will be retained and dipped at the times that other sampling is undertaken.

5.6.4.4 Groundwaters

Groundwater quality monitoring in the area of the mine workings will only be relevant once mine dewatering ceases. Long term monitoring wells will therefore be established using existing water monitoring boreholes, supplemented by private wells adjacent to the mine site at the beginning of decommissioning, to monitor the overall groundwater flowing from the mine. Monitoring of the groundwater is currently being carried out by the Company, as part of the solute model, which will establish the present baseline.

During the 5 year *active care* period, samples would be collected on a 3-monthly basis (ie. 4 per year) from each well. In the longer term, sampling would decline to 2 per year and then once every 2 years. Longer sampling intervals may be adequate in the very long term. Samples would be analysed for dissolved and suspended metals (Ca, Mg, Fe, Pb, Zn, Cd & As), CN, conductivity, pH, sulphate, COD and BOD.

5.6.4.5 Air quality

During the active care period, the operational monitoring of dust deposition will be maintained at the same locations as the mine operational monitoring, analysing for deposited dust, Pb, Zn, Cd and As. In the long term, monitoring will not be required.

5.6.4.6 Ground movements

Ground movement monitoring is undertaken during the operational period of the mine. Following closure, the monitoring scheme will be continued during Stage 1 to cover the period of groundwater recovery (see Appendix 1) and a minimum of six months thereafter. This monitoring will enable any ground movements that arise to be identified. Subject to accessibility, the monitoring will incorporate regular inspections and levelling of established surface semi-permanent monitoring points spread over the mine area, on a six monthly basis.

In the long term (beyond the presently anticipated 5 year period) there will be no requirement for monitoring of ground movements.

5.6.4.7 Stability of the Tailings Management Facility

Following decommissioning, the continuing function of the impoundment will be assessed generally in accordance with Schedule 3(iii) of the IPC licence, though with a reducing frequency over time. In addition, monitoring will include inspection of the following:

- The downstream impoundment walls, for evidence of erosion, seepages, slope instability and potentially disruptive elements such as large trees.
- The internal drainage - for continuing flows and evidence of ochre precipitation.
- The water table within the tailings and within the impoundment cell walls, *via* piezometer tubes installed during the operational phase.
- The surface drainage and outfall structures and perimeter drainage channels, for structural integrity and freedom from blockage.
- Integrity of the vegetation cover, its general health, vigour, ground cover and species composition.

Any action required arising from this inspection will be implemented immediately. These inspections will be carried out monthly for the Stage 1 *active care* period. Following this, for the next five years inspections would be twice per year.

5.7 Implementation

5.7.1 Criteria for successful closure and reclamation

In addition to maintaining the environmental quality standards given in Section 5.6.3 above, the long term criteria for successful closure and reclamation can be proposed as follows:

a) For the mine site – re-integration of the site into the landscape and local land use, with minimal or no constraints.
b) For the TMF – whilst perpetual aftercare will always be required for a facility such as this, the surface and embankments of the TMF should remain stable and should support a light grazing agricultural regime with economic returns consistent with other land in similar use.

c) For water quality – discharges should be such that there is no derogation of water quality class in the receiving waters, nor any constraint on their future use (other than constraints imposed by other un-related facilities or discharges).

5.7.2 Update & review of CRAMP

The closure plan will be reviewed annually as per Condition 14.2 of the IPC Licence. The plan will be updated following the annual review should change be required due to either of the following circumstances:

- on any major change or extension to the mine plan, permitted activities or operational processes;
- within 5 years of the publication and acceptance by the EPA of a previous interim plan.

In this way the mine closure and restoration plan will keep abreast of changes to the mining operation, new techniques and opportunities, and changing priorities for afteruse of the site.

5.7.3 Implementation of the plan

One year prior to the planned closure of the mine (including deemed closure under the terms of the mining license, planning consent and/or IPC license) the Company will commence the formation of a Mine Closure Team, to implement, oversee and monitor the closure activities. This team will consist of a Manager (preferably an Environmental Engineer) and a Project Engineer. Ideally this team will consist of existing suitably qualified personnel from the Company who are familiar with the mining, milling and related operations at Galmoy. They will be supported by professional and specialist consultants engaged as required for specific investigation, design and supervision tasks. From the Company staff a small team of maintenance staff, samplers and laboratory staff will also be kept following closure to maintain equipment and carry out the ongoing monitoring programme during the active closure phase.

This team will implement a detailed site investigation and audit of the mine area to fully measure and define all the assets, potential liabilities and current state of the site. This will lead to the preparation of a fully detailed closure and restoration plan, based on but extending the detail of the previous interim plan. This plan will be agreed with the EPA, KCC and DCNMR.

Decommissioning and restoration works will be split into a series of defined packages, each of which will be implemented and administered as a works contract. For each package, detailed plans, specifications and cost estimates will be prepared, in accordance with normal construction practice.

The Mine Closure Team will draw down funds from the accumulated Mine Closure Fund, together with any residual assets sales and income accruing to the Company (although these have been assumed as zero in this interim plan) to carry out the closure and restoration plan.

It is envisaged that the full team will remain in place until the completion of the stage 2 closure and restoration works. At this time the team will be reduced to one full-time officer who will be responsible for the aftercare and passive care period, for five years. Thereafter, continued monitoring and passive care works will be undertaken by contract as required, with annual site audit reports and maintenance schedules.

As each stage of the closure plan is completed the Mine Closure Team will submit a validation report to the EPA within three months as required under Condition 14.4.

5.7.4 Monitoring

Long term environmental monitoring, described in Section 5.6.3 above, is an integral part of the perpetual aftercare.

Monitoring of the implementation of the CRAMP will be undertaken by the joint closure team, who will be accountable to KCC, LCC and EPA.

6 ENVIRONMENTAL LIABILITIES AND RISK ASSESSMENT

6.1 Scope of ELRA

The site specific ELRA covers all un-known but identifiable environmental risks or potential liabilities associated with the decommissioning, closure and aftercare of the Tailings Management Facility, Underground Mine Area and Surface Mine Site, in line with the EPA draft Guidance. The aim of the site specific ELRA are as follows:

- Identify and quantify the environmental liabilities at the Galmoy Mine, particularly unknown but possible events occurring during the decommissioning, closure and aftercare phases.
- Calculate the financial requirements to cover the identified unknown but possible events.
- Encourage the continuous environmental improvement of the Galmoy Mine through the management of potential environmental risks.

The site specific ELRA will review the unknown environmental risks to the following potential risk receptors. In general terms, a receptor is something that could be adversely affected by a hazard, such as an adverse effect or contaminant. In this context an environmental receptor covers all those aspects of the environment which may be affected by the processes undertaken at the mine site, which includes:

- surface Waters;
- ground Waters;
- air;
- ground or soil;
- human health; and
- animal and plant life.

Animal and plant life has been added to the list quoted within the EPA draft guidance as the proposed restored land use is agricultural/pasture. Therefore one of the receptors of unknown environmental risk would be the animals and plants ultimately residing at the site.

For any risk there are three essential elements, a failure mode, a receptor and a pathway. Each of these elements can exist independently, but they create a risk only where they are linked together.

6.2 Risk Classification and Identification

A risk is a combination of the probability, or frequency, of occurrence of a defined hazard or failure mode and the magnitude of the consequences of the occurrence. A risk classification and identification exercise has been carried out for the purposes of this ELRA via the following means:

- consultation of documents relating to the Galmoy Mine, particularly those aspects covered in Appendices 1 to 6;
- awalkover survey
- brainstorming exercises.

Due to the phased approach of decommissioning, closure and aftercare of the site the Risk Assessment have been carried out separately for the Tailings Management Facility (TMF), the Surface Mine Site and the Underground Mined Area.

Each known risk has been evaluated and assigned a value of likelihood of occurrence severity and cost for remediation. In accordance with the EPA Guidance Document a limit of 30 years has been assigned as a time limit for environmental liability in line with Article 10 of the '*Council Directive 1999/31/EC of 26 April 1999 on the Landfill of Waste'.*

Each risk is then assigned a risk score which along with the severity rating and occurrence rating allows the risk register to be established for the TMF, the Surface Mine Site and the Underground Mined Area.

The final task is the establishment of the Risk Matrix which allows the straightforward display of the risks in relation to occurrence and severity for the TMF, Surface Mine Site and the Underground Mined Area.

6.3 Risk Classification Tables

The risk classification tables as shown below are required in order to evaluate and prioritise the risks compared with each other. The tables allow site specific liabilities to be associated with risk classifications, and for a range of perceived remediation costs to be estimated.

Table 6.1
Unknown Risk Classification - Occurrence

Rating	**Occurrence**		
	Category	**Description**	**Likelihood of Occurrence (%)**
1	Very low	Very low chance (0-5%) of hazard occurring in 30 yr period*	0-5
2	Low	Low chance (5-10%) of hazard occurring in 30 yr period	5-10
3	Medium	Medium chance (10-20%) of hazard occurring in 30 yr period	10-20
4	High	High chance (20-50%) of hazard occurring in 30 yr period	20-50
5	Very high	Greater than 50% chance of hazard occurring in 30 yr period	>50

The assessment of the environmental liabilities has been limited to a 30-year period in accordance with Article 10 of the *Council Directive 1999/31/EC of 26 April 1999 on the Landfill of Waste.*

Table 6.2
Unknown Risk Classification - Severity

	Category	Description	Cost of remediation (€'000's)
1	Trivial	No damage or negligible change to the environment	€ 0-10
2	Minor	Minor impact/localised or nuisance	€ 10-50
3	Moderate	Moderate damage to environment	€ 50-100
4	Major	Severe damage to local environment	€ 100-1000
5	Massive	Massive damage to a large area, irreversible in medium term	€ 1000-10,000

6.4 Risk Identification

The risks associated with the TMF, Surface Mine Site and Underground Mined Area have been assessed in terms of severity and likelihood of occurrence to establish an overall risk score for each potential risk during the decommissioning, closure and aftercare phases. The forms are based on the sample form within the EPA guidance document. Separate forms have been undertaken for each part of the mine site.

The risks identified are those considered to be unplanned, possible, plausible events which may occur during the decommissioning and aftercare phases and which are not covered in the CRAMP (Section 4). The risks associated with the TMF are outlined in Table 6.3. The risks associated with the Surface Mine Site and the Underground Mine Area are outlined within Table 6.4 and 6.5 respectively.

Table 6.3
Tailings Management Facility (TMF)
Risk Assessment Form

Risk No.	*Phase*	*Potential Hazard*	*Description of Hazard*	*Environmental Effect*	*Severity Rating*	*Basis of Severity*	*Occurrence Rating*	*Basis of Occurrence*	*Risk Score (Severity x Occurrence)*
1	Decommissioning, Closure, Post Closure. Long Term Risk as TMF is to remain	Breach of Liner -TMF	Gradual Leakage	Groundwater contamination, Contamination of overlying soils	3	Cost of abstracting and cleaning groundwater in the vicinity of the TMF. Excavating insitu waste, contaminated ground repairing liner.	2	All work undertaken within TMF by experienced staff, instruction, avoidance of sharp objects	6
2	Decommissioning, Closure, Post Closure. Long Term Risk as TMF is to remain	Breach of liner -TMF	Sudden localized breach	Groundwater Contamination, Contamination of overlying soils	3	Cost of abstracting and cleaning groundwater in the vicinity of the TMF. Excavating insitu waste, contaminated ground, repairing liner.	1	All work undertaken within TMF by experienced staff, instruction, avoidance of sharp objects	3
3	Decommissioning, Closure, Post Closure. Long Term Risk as TMF is to remain.	Embankment Failure - TMF	Slope instability due to pore pressure build up	Groundwater contamination, Contamination of overlying soils.	4	Cost of abstracting and cleaning groundwater in the vicinity of the TMF. Excavating insitu waste, contaminated ground, repairing liner.	1	Monitoring of rising ground water levels.	4

Table 6.3
Tailings Management Facility (TMF)
Risk Assessment Form

Risk No.	***Phase***	***Potential Hazard***	***Description of Hazard***	***Environmental Effect***	***Severity Rating***	***Basis of Severity***	***Occurrence Rating***	***Basis of Occurrence***	***Risk Score (Severity x Occurrence)***
4	Decommissioning, Closure and Post Closure. Long Term Risk as TMF is to remain	Embankment Failure - TMF	Destabilising effect of trees.	Groundwater contamination, Contamination of overlying soils.	4	Cost of abstracting and cleaning groundwater in the vicinity of the TMF. Excavating insitu waste, contaminated ground, repairing liner.	1	Monitoring of vegetation cover on embankments.	4
5	Decommissioning, Closure and Post Closure. Long Term risk as TMF is to remain.	Embankment Failure - TMF	Interference by man such as excavation of embankment toe	Groundwater contamination, Contamination of overlying soils.	4	Cost of abstracting and cleaning groundwater in the vicinity of the TMF. Excavating insitu waste, contaminated ground, repairing liner.	1	Fencing of facility.	4
6	Decommissioning, Closure and Post Closure. Long Term risk as TMF is to remain.	Embankment Failure - TMF	Seismic Event	Groundwater contamination, Contamination of overlying soils.	5	Cost of abstracting and cleaning groundwater in the vicinity of the TMF. Excavating insitu waste, contaminated ground, repairing embankment.	1		5
7	Decommissioning, Closure and Post Closure. Long Term risk as TMF is to remain.	Embankment Failure - TMF	Long term erosion or attrition due to loss of vegetation cover.	Groundwater contamination, Contamination of overlying soils.	4	Cost of abstracting and cleaning groundwater in the vicinity of the TMF. Excavating insitu waste, contaminated ground, repairing embankment.	1	Monitoring of vegetation cover on embankments	4

Table 6.3
Tailings Management Facility (TMF)
Risk Assessment Form

Risk No.	***Phase***	***Potential Hazard***	***Description of Hazard***	***Environmental Effect***	***Severity Rating***	***Basis of Severity***	***Occurrence Rating***	***Basis of Occurrence***	***Risk Score (Severity x Occurrence)***
8	Decommissioning, Closure and Post Closure. Long Term risk as TMF is to remain.	Flooding and Overtopping of Cell	High rainfall conditions combined with failure of surface drainage system, leading to erosion and possibly failure of embankment.	Groundwater contamination, Contamination of overlying soils.	4	Cost of abstracting and cleaning groundwater in the vicinity of the TMF. Excavating insitu waste, contaminated ground, repairing embankment.	1	Monitoring of groundwater levels and rainfall. Assessment of likely occurrence of flood events	4
9	Decommissioning, Closure and Post Closure. Risk will reduce over time.	Continued Geochemical Activity within Cells - TMF	Long term mobilization of heavy metals from tailings solids, possibly linked to continued acid generation.	Groundwater contamination, Contamination of overlying soils.	4	Cost of abstracting and cleaning groundwater in the vicinity of the TMF. Excavating and disposal of dispersed tailings and contaminated ground.	1	Active aftercare	4
10	Decommissioning, Closure and Post Closure. Long Term risk as TMF is to remain.	Surface drainage-TMF	Rainwater ponding on surface leading to vegetation failure	Exposure of tailings to wind erosion and increased seepage rates affecting groundwater quality.	2	Cost of altering TMF surface levels to provide adequate slope for run off.	1	Risk of this should be identified through active aftercare	2

Table 6.3 Tailings Management Facility (TMF) Risk Assessment Form									
Risk No.	***Phase***	***Potential Hazard***	***Description of Hazard***	***Environmental Effect***	***Severity Rating***	***Basis of Severity***	***Occurrence Rating***	***Basis of Occurrence***	***Risk Score (Severity x Occurrence)***
11	Decommissioning, closure, phase 2 Demolition. Medium term risk as water treatment plant will be demolished as part of the phase 2 demolition works	Water treatment Plant - TMF	Failure of water treatment system	Groundwater and surface water contamination	3	Cost of abstracting and cleaning groundwater in the vicinity of the TMF.	2	Monitoring of groundwater levels and rainfall. Assessment of likely occurrence of flood events	6

Table 6.4
Mine Facility Surface
Risk Assessment Form

Risk No.	*Phase*	*Potential Hazard*	*Description of Hazard*	*Environmental Effect*	*Severity Rating*	*Basis of Severity*	*Occurrence Rating*	*Basis of Occurrence*	*Risk Score (Severity x Occurrence)*
1	Decommissioning, Closure. Short term risk as thorough contamination investigation will be carried out upon completion of phase 1 demolition and again on completion of phase 2 demolition	Residual Soil Contamination	Contaminated soil not removed during decommissioning work	Contamination of overlying soils, Groundwater contamination, Risk of harm to human, flora or fauna.	3	Cost of investigating, sampling and removing contaminated ground to licensed waste disposal facility as TMF will not be operational. Cost of abstracting and cleaning groundwater in the vicinity of the ground contamination.	2	Thorough site investigation in accordance with CLR/CLEA guidance to be undertaken post decommissioning of surface mine site	6
2	Post Closure. Long Term Risk as buildings will remain on site	Unstable Buildings	Retained buildings deteriorate to such a point to become hazardous to site users.	Risk to health/injury to humans and animals	2	Cost of demolition and disposal of buildings. Cost of medical or veterinary bills. Compensation for public or farmer.	1	Remaining building constructed of? Overall use of site assessed to be low	2
3	Decommissioning, Potentially Post Closure	Fly Tipping	Fly tipping of potentially hazardous material on surface site	Contamination of overlying soils, groundwater. Potential harm to humans, flora and fauna	2	Cost of removing fly tipped material to licensed waste disposal facility, Clean up of groundwater if necessary.	2	Site boundaries to remain secure. Onus for security of site post aftercare on landowner	4

Table 6.4
Mine Facility Surface
Risk Assessment Form

Risk No.	***Phase***	***Potential Hazard***	***Description of Hazard***	***Environmental Effect***	***Severity Rating***	***Basis of Severity***	***Occurrence Rating***	***Basis of Occurrence***	***Risk Score (Severity x Occurrence)***
4	Decommissioning – Phase 1 and Phase 2 demolition Short term risk	Contamination of buildings prior to demolition	Potentially contaminating material not removed from buildings prior to demolition	Potential airborne contamination during demolition process. Transfer of contaminated material underground if used for infill	3	Cost of abstracting and cleaning groundwater if contaminating material placed underground.	2	Works to be supervised by independent mine manager and deputy. Any material to be placed underground to be tested for potential contaminants.	6
5	Post Closure Long Term Risk	Explosive	Explosives not decommissioned adequately – remaining on site	Risk to health/injury to humans and animals	2	Cost of medical or vetinary bills. Compensation for public or farmer.	1	Works to be supervised by independent mine manager and deputy.	2
6	Decommissioning Short Term Risk as hazard would only constrain demolition works.	Ecological Colonisation site.	Colonisation of the site by a protected species'. Bats within buildings earmarked for demolition	May prohibit certain works taking place e.g. demolition	2	Cost of providing suitable surveys, translocation of species by appropriate persons	2	Ecological walkover survey to be undertaken prior to decommissioning	4

Table 6.5 Underground Mine Area Risk Assessment Form									
Risk No.	***Phase***	***Potential Hazard***	***Description of Hazard***	***Environmental Effect***	***Severity Rating***	***Basis of Severity***	***Occurrence Rating***	***Basis of Occurrence***	***Risk Score (Severity x Occurrence)***
1	Post Closure Long Term Risk	Groundwater Rebound	Plume of contaminatio n from underground workings within groundwater as a result of rebound	Groundwater contamination,	4	Cost of abstracting and cleaning groundwater. Removal of contaminating source material may be necessary.	2	Recharge is monitored during decommissioni ng	8
2	Decommissioning Short Term Risk of occurrence during demolition and infill phase of closure works	Fixed plant not cleaned adequately	Hydrocarbon, grease residues not cleaned off plant	Groundwater contamination,	3	Cost of abstracting and cleaning groundwater.	2	Works to be supervised by independent mine manager and deputy	6
3	Decommissioning Short Term Risk of occurrence during demolition and infill phase of closure works	Mobile plant not removed to surface	Contaminatio n via plant material. Potential for void space where plant remains	Groundwater contamination, Localised instability	2	Cost of abstracting and cleaning groundwater.	1	Works to be supervised by independent mine manager and deputy	2
4	Decommissioning – Phase 1 and 2 demolition and infill works. Short term risk	Serious injury or medical emergency	Accident as a result of the infilling works	Risk to health injury of Human	2	Cost of medical bills. compensation	2	Use of competent contractor to undertake works. Comply with Health and Safety standards.	4

Table 6.5
Underground Mine Area
Risk Assessment Form

Risk No.	***Phase***	***Potential Hazard***	***Description of Hazard***	***Environmental Effect***	***Severity Rating***	***Basis of Severity***	***Occurrence Rating***	***Basis of Occurrence***	***Risk Score (Severity x Occurrence)***
5	Decommissioning – Short term risk of occurrence during Phase 1 and 2 demolition and infill works.	Blockage of drainage pipes	Drainage pipes passing through the concrete plug, ventilation rises etc become blocked	Decline becomes flooded during infill works.	2	Cost of pumping water or unblocking pipeworks in order to allow infilling works to continue	2	Works to be supervised by independent mine manager and deputy	4
6	Decommissioning – Short term risk of occurrence during phase 1 and phase 2 infill works	Contaminated material	Material used for infill is found to be contaminated	Contamination of groundwater	4	Cost of abstracting and cleaning groundwater.	1	Demolition arisings and other infill material will be fully tested prior to placement.	4

The risk scores can be depicted within a risk matrix, based on the EPA draft guidance, allowing the risks to be easily displayed and prioritised. The severity and occurrence ratings for each identified risk assigned in Tables 6.3, 6.4 and 6.5 are shown in the tables below with severity on the x-axis and occurrence on the y-axis. Again a risk matrix has been provided separately for the TMF, Surface Mine Facility and Underground Mine Area as Tables 6.6, 6.7 and 6.8 respectively.

The risks have been colour coded in the matrix to provide a broad indication of the critical nature of each risk. The colour code is as follows:

- Red – These are considered to be major risks requiring priority attention.
- Amber / Yellow – These are moderate risks requiring action, but are not as critical as a red coded impact.
- Green (light and dark green) – These are lowest-level minor risks and indicate a need for continuing awareness and monitoring on a regular basis. Whilst they are currently low or minor impacts, some have the potential to increase to moderate or even major impacts and must therefore be regularly monitored and if cost effective mitigation can be carried out to reduce the risk even further this should be pursued.

Table 6.6
Tailings Management Facility
Risk Matrix

Occurrence	V. High	5					
	High	4					
	Medium	3					
	Low	2			**1, 11**		
	V. Low	1		10	2	**3**, 4, **5**, **7**, 8, 9	**6**
			V. Low	Low	Medium	High	V. high
			1	2	3	4	5
	Severity						

The majority of the ‘unknown’ risks associated with the TMF at Galmoy Mine fall in the green category within the risk matrix depicting a low level risk requiring awareness and monitoring. The matrix has shown that there are no ‘unknown’ risks in the red zone for the TMF which would require priority attention.

Table 6.7
Mine Site Facility Surface
Risk Matrix

Occurrence	V. High	5					
	High	4					
	Medium	3					
	Low	2		**3, 6**	**1, 4**		
	V. Low	1		**2, 5,**			
			V. Low	Low	Medium	High	V. high
			1	2	3	4	5
	Severity						

The risks associated with the Surface Mine Facility fall in the light green or green category within the risk matrix depicting a low level risk requiring awareness and monitoring. The matrix has shown that there are no risks in the red zone for the Surface Mine Facility which would require priority attention.

Table 6.8
Underground Mine Area
Risk Matrix

Occurrence	V. High	5					
	High	4					
	Medium	3					
	Low	2		**4, 5**	**2**	**1**	
	V. Low	1		**3**		**6**	
			V. Low	Low	Medium	High	V. high
			1	2	3	4	5
	Severity						

The risks associated with the Underground Mine area fall within the light green or green category within the risk matrix depicting a low level risk requiring awareness and monitoring. The matrix has shown that there are no risks in the red zone for the Underground Mine Area which would require priority attention.

6.5 Identification and Assessment of Risk Mitigation Actions

The assigned risk ratings can be reassessed by implanting risk mitigation measures. These can then be fed back into the risk matrix to illustrate the reduction in potential risk as a result of implementing risk mitigation measures.

Currently the risks identified for all areas of the Galmoy Mine Site lie within green - light green areas and as a result do not require priority attention.

The risk assessment process should be considered as a working document and it may be thought prudent at a later date for the risk mitigation measures process for ‘unknown’ risks to be undertaken.

In addition as this assessment is concerned with closure no risk owners have yet been assigned. Therefore no risk management programme has been carried out. However, a risk management programme for ‘unknown’ liabilities will have to be carried out nearer to the time of mine closure and risk owners should be assigned a this time.

Since risk management requires a fluid assessment of potential failure modes and processes, which may give rise to potential risks, this document should be considered a fluid document, and a risk assessment undertaken on an annual basis in order to assist this process.

6.6 Quantification of Unknown Environmental Liabilities

For ‘unknown’ liabilities associated with the decommissioning and closure of the Galmoy Mine it is necessary to provide an estimated financial model in order that suitable funds can be set aside.

The ‘unknown’ environmental liabilities are associated with the environmental risks which may or may not occur. These risks are associated with decommissioning and closure of the TMF, Surface Mine Facility and Underground Mine area at Galmoy

The best case scenario is that none of the risks occur and therefore at the end of the assessment period of 30 years, the additional costs incurred by Galmoy Ltd due to the environmental risks are nil. The worst case scenario is that a significant number of the identified risks materialise, incurring significant costs for Galmoy Mines Ltd.

In order to identify an indicative level of environmental liability associate with the environmental risks for the purposes of the decommissioning and closure of the TMF, Surface Mine Facility and Underground Mine Area a cost model has been used. This cost model generates the expected cumulative cost of the risks. The modelling has been undertaken using the median probability and severity of occurrence of each risk identified through the risk assessment process.

A cost model based on the simplified form within the EPA draft guidance is provided for the TMF (Tables 6.9 and 6.10), Surface Mine Facility (Tables 6.11 and 6.12) and Underground Mine Area (Tables 6.13 and 6.14).

Table 6.9
Tailings Management Facility (TMF)
Most Likely Scenario Financial Model

Risk No.	Occurrence rating	Likelihood of occurrence range	Severity rating	Cost Range	Median Probability %	Median severity (€)	Most likely scenario (€)
1	2	5-10%	3	€50,000-100,000	7.5	80,000	6000
2	1	0-5%	3	€50,000-100,000	2.5	80,000	2000
3	1	0-5%	4	€100,000-1,000,000	2.5	550,000	13,750
4	1	0 - 5%	4	€100,000-1,000,000	2.5	550,000	13,750
5	1	0-5%	4	€100,000-1,000,000	2.5	550,000	13,750
6	1	0 - 5%	5	€1,000,000-10,000,000	2.5	5,500,000	137,500
7	1	0-5%	4	€100,000-1,000,000	2.5	550,000	13,750
8	1	0 - 5%	4	€100,000-1,000,000	2.5	550,000	13,750
9	1	0 - 5%	4	€100,000-1,000,000	2.5	550,000	13.750
10	1	0 - 5%	2	€ 10,000-50,000	2.5	30,000	750
11	2	5-10%	3	€50,000-100,000	7.5	80,000	6000
TOTAL						**€ 9,070,000**	**€ 234,750**

Table 6.10
Tailings Management Facility (TMF)
Summary of Potential 'Unknown' Environmental Liabilities Associated with Closure

Description	Estimate of 'Unknown' Environmental Liabilities	Assumptions
Highest Cost Scenario	€9,070,000	Assumes all risks occur at their maximum costs
Lowest Cost Scenario	€0	Assumes none of the risks occur
Most Likely Scenario	€234,750	Based on median probability and severity for each risk.

Table 6.11
Surface Mine Facility
Most Likely Scenario Financial Model

Risk	Occurrence rating	Likelihood of occurrence range	Severity rating	Cost Range	Median Probability %	Median severity (€)	Most likely scenario (€)
1	2	5-10%	3	€50,000-100,000	7.5	80,000	6000
2	1	0-5%	2	€10,000-50,000	2.5	30,000	750
3	2	5-10%	2	€10,000-50,000	7.5	30,000	2250
4	2	5-10%	3	€50,000-100,000	7.5	80,000	6000
5	1	0-5%	2	€10,000-50,000	2.5	30,000	750
6	2	5-10%	2	€10,000-50,000	7.5	30,000	2250
TOTAL						**€ 280,000**	**€ 18,000**

Table 6.12 Surface Mine Facility Summary of Potential 'Unknown' Environmental Liabilities Associated with Closure		
Description	***Estimate of 'Unknown' Environmental Liabilities***	***Assumptions***
Highest Cost Scenario	€280,000	Assumes all risks occur at their maximum costs
Lowest Cost Scenario	€0	Assumes none of the risks occur
Most Likely Scenario	€18,000	Based on median probability and severity for each risk.

Table 6.13 Underground Mine Area Most Likely Scenario Financial Model							
Risk	***Occurrence rating***	***Likelihood of occurrence range***	***Severity rating***	***Cost Range***	***Median Probability %***	***Median severity (€)***	***Most likely scenario (€)***
1	2	5-10%	4	€100,000 - 1,000,000	7.5	550,000	41,250
2	2	5-10%	3	€50,000 - 100,000	7.5	55,000	4,125
3	1	0-5%	3	€50,000 - 100,000	2.5	55,000	1375
4	2	5-10%	2	€10,000 - 50,000	7.5	30,000	2250
5	2	5-10%	2	€10,000 - 50,000	7.5	30,000	2250
6	1	0-5%	4	€100,000 - 1,000,000	2.5	550,000	13,750
TOTAL						**€ 1,270,000**	**€ 65,000**

Table 6.14 Underground Mine Area Summary of Potential 'Unknown' Environmental Liabilities Associated with Closure		
Description	***Estimate of 'Unknown' Environmental Liabilities***	***Assumptions***
Highest Cost Scenario	€1,270,000	Assumes all risks occur at their maximum costs
Lowest Cost Scenario	€0	Assumes none of the risks occur
Most Likely Scenario	€65,000	Based on median probability and severity for each risk.

6.7 Review of Risk Assessment

The risk management of the closure process is an ongoing process. This assessment provides a baseline assessment of the major 'unknown' risks associated with the decommissioning and closure of the Galmoy Mine Facility. The mine processes and conditions on the closure of the mine will change and therefore this assessment should be reviewed periodically to ensure that the risks are identified and managed.

This risk assessment should therefore be considered to be a live document. It is recommended that the Mine operators and their consultants review the risk management for the decommissioning and closure on a regular basis and update the risk assessment accordingly (see Section 5.7.2).

6.8 Prevention and mitigation of risks, risk management

The thorough planning and design process that the Galmoy Mine has gone through should ensure that all potential environmental impacts and risks have been identified and minimised as far as is reasonable.

The design, CQA and operational management of the mine site, underground workings and particularly the TMF are discussed in Appendices 2, 3, 4 and 5. This includes extensive measures to minimise the risks identified. Monitoring and long term management measures to minimise risks after closure are described in Section 5.

7 FINANCIAL PROVISION

7.1 Known liability costs (CRAMP)

The closure of the mine may be brought about by either of two circumstances:

- Normal planned closure of the mine at the end of its useful working life, as currently permitted.

- Enforced early closure of the mine, for whatever reason, at any time during its working life. In this report, residual costs have been assessed for closure at the end of any of the remaining six years of operation, up to 2010.

7.1.1 Planned closure works

The works involved in closing and rehabilitating the Galmoy Mine have been broadly divided into two areas; the main plant site and the tailings management facility (TMF).

Two discrete stages are involved in decommissioning and rehabilitation:

Stage 1, planned to commence in 2011 after closure of the mine in 2010, comprises decommissioning, demolition and removal of buildings over most of the plant site and an active care period of five years.

Stage 2, planned for 2016, comprises the demolition of the remaining buildings, except for the main electrical sub-station. A five-year period of *passive care*, mainly for the TMF, is planned.

The cost estimates take account of the following activities, as described in detail in Section 5 of this plan (CRAMP).

- **Mine Operation**
  - Progressive rehabilitation and aftercare of the cell walls and tailings surface of Phases 1and 2 of the TMF.

- **Stage 1 decommissioning**
  - Decommissioning of mining operations, filling and capping of mine entries, (i.e. access decline and ventilation raises).
  - Decommissioning decontamination, demolition and removal of buildings, infrastructure and services not required for the active care period. All stone, concrete and brickwork resulting from this work will be used as mass filling material.
  - Subsequent to the results of a site specific site investigation, the removal of a quantity of contaminated material from the mine site to Phase 3 of the TMF and the replacement of this material with inert material from the excavation of the attenuation pond and the mine site soil stockpiles.
  - Capping Phase 3 of the TMF and the rehabilitation of Phase 3 utilising surplus outer cell wall material, stockpiled soils and/or other organic/soil forming materials.
  - The five year active care (aftercare) period comprises the operation and maintenance of well dewatering pump stations to supply groundwater for the

dilution of reclaim water and for processes and requirements on the main site; monitoring the quality of various bodies of water and their suitability for discharge into existing watercourses; operation, maintenance and security of the plant site buildings and equipment such as the water and sewage treatment plants; and all power costs to the above items where required.

- **Stage 2 decommissioning**

    - ♦ Decommissioning, decontamination, demolition and removal of the remaining buildings, infrastructure and services on the main site and as required elsewhere. All stone, concrete and brickwork resulting from this work will be disposed of off site.
    - ♦ Recontouring, spreading of cover materials and ameliorants and landscaping of the main plant site.
    - ♦ Lining of the attenuation pond and construction of drainage ditches and new outfalls etc. at the TMF.

- **Post closure**
    - ♦ The IPC licence requires that passive care continues in perpetuity, including maintenance and monitoring of the TMF and those parts of the mine site rehabilitated in Stage 2. For practical purposes this is taken to mean 30 years.

7.1.2 Planned closure costs

The estimates are based on normal engineering methods in accordance with current good industry practice. The figures quoted represent the expected realistic costs of these methods, taking the following into consideration:

- When there are alternative methods of working, the **worst case** has generally been assumed.
- Realistic rates and prices have been determined as far as possible in all cases.
- Quantities have been estimated from the best available information, as provided in other technical reports and from information derived from site plans/drawings provided by Galmoy Mines Ltd.
- The base date for all cost estimates is the third quarter, 2005 in Euros (€).

The estimates of cost for most of the works have been based on figures commissioned from local Quantity Surveyors, the Nolan Ryan Partnership (Kilkenny). These figures are based on the use of outside contractors, contracted for all decommissioning, demolition and landscaping, including specialist contractors for certain decommissioning activities, where required, such as the removal of hazardous materials from the site. For many discrete operations, such as the demolition and removal of a particular building, an all-inclusive lump sum cost was provided. The costs for underground works, such as the filling of the remaining stopes were based on figures supplied by Galmoy Mines Ltd.

The following additional allowances on construction costs have been made:
- 5% contingency
- 4% preliminary and general items
- 1% insurances
- 6% engineering and construction management fees.

Costs associated with the monitoring and long term management of the tailings impoundment were subject to an allowance for contingencies only, as these works are outside of the main works periods.

On completion of the planned mining operation, due to the difficulty in establishing a salvage value, no allowance has been made for resale or scrap value.

Throughout the operation of the mine the tailings management facility will be progressively rehabilitated as the phases are completed. Although the cost of this is effectively a part of operating the mine, in the consideration of planned closure it is regarded as a closure and rehabilitation cost. In the event of early closure, the progressive rehabilitation already undertaken has not been included in the closure costs.

Appendix 8 gives a detailed breakdown of the costs of decommissioning and demolition of the mine site during Stages 1 and 2, and the annual costs of rehabilitation of the TMF over the period of progressive rehabilitation up to mine closure in 2010 and the active and passive care periods up to 2021. There will be an annual recurring cost beyond this, in perpetuity.

In addition to the direct costs detailed above, a provisional allowance has been made for an initial administration cost. This is to cover the setting up of the long term entity to administer the closure and retain the residual assets and liabilities. The provisional cost allowed is considered appropriate to cover legal and accountancy fees, staffing, management fees, a technical and environmental audit of the site and preparation of the final Mine Closure and Rehabilitation Plan.

A summary of the estimated costs for normal planned closure and rehabilitation are summarised in Tables 7.1 and 7.2 below:

Table 7.1 Summary of Planned Closure Costs by Item	
Item	***At Q3 2005 costs***
Administration	**250,000**
Mine site and underground	
Phase 1 Decommissioning and Demolition	
Underground	782,058
Surface	856,764
Phase 1 Landscaping	592,350
Active Care	185,000
Phase 2 Demolition	595,299
Removal of Services	290,538
Phase 2 Landscaping	165,000
Passive care (to 2021)	25,000
Sub-total	3,492,007
Contingencies, Preliminaries, Insurances	356,751
Sub-total	3,848,759
Engineering Construction Management	227,776
Total	**4,076,534**
Tailings Management Facility	
Restoration, landscaping, revegetation, etc	733,021
Active care: Interim Drainage and water treatment	646,587
Final Drainage, attenuation pond, outfalls.	435,140
Passive care, monitoring, etc (to 2021)	302,235
Sub-total	2,116,983
Contingencies, Preliminaries, Insurances	201,886
Sub-total	2,318,869
Engineering Construction Management	120,091
Total	**2,438,960**
Grand Total (to 2021)	**6,765,494**
Annual cost thereafter	56,000

Table 7.2

Summary of Planned Closure Costs by Year

Expenditure in year	*At Q3 2005 costs*			
	Mine site & underground	*TMF*	*Total*	*Cumulative*
2010	0	31,566	31,566	31,566
2011	Administration		250,000	281,566
2011	957,968	164,872	1,122,840	1,404,406
2012	1,708,731	994,121	2,702,852	4,107,258
2013	58,249	105,584	163,833	4,271,091
2014	58,250	105,584	163,834	4,434,925
2015	19,279	572,754	592,033	5,026,958
2016	19,279	193,358	212,637	5,239,595
2017	1,233,778	50,756	1,284,534	6,524,129
2018	5,250	59,427	64,677	6,588,806
2019	5,250	50,756	56,006	6,644,812
2020	5,250	59,427	64,677	6,709,489
2021	5,250	50,756	56,006	6,765,495
Total	4,076,534	2,438,960	6,765,495	
Annual thereafter			56,000	

7.2 Enforced Early Closure

7.2.1 Early closure works

This section considers the possibility of enforced closure during mine operations, with decommissioning and rehabilitation carried out by a residual body.

7.2.1.1 Mine site

Early closure of the mine and the plant site would take place in the same way as the normal planned closure. The decommissioning strategy would remain unchanged. Therefore, with the exception of minor extras such as the disposal of a full reagent inventory, many of the principal costs of the works will be the same.

Despite the likelihood that early closure would endow the plant and equipment with an enhanced resale value, for the purposes of this Plan no value has been ascribed for the plant and equipment.

7.2.1.2 Tailings Management Facility

The TMF will be developed throughout the life of the mine. The first phase has been filled and is currently being rehabilitated, whilst the second phase is being filled progressively so that each year the condition of the impoundment will be different.

As a result the cost of early, enforced closure in any year will be unique. The options for rehabilitation are discussed in Section 5. The rehabilitation and afteruse strategy for the impoundment will be the same regardless of the time at which it takes place. Interim and final drainage arrangements will be as described in the *Closure Plan*, modified as appropriate for the closure conditions.

The condition of the impoundment has been considered for each year of mine operation and the works for the rehabilitation assessed accordingly. Since Phase 3 will be the operational cell from 2006; there will be three typical conditions, which are described below with the proposed rehabilitation works:

- Cell partially filled (more that 3m freeboard) – embankment height reduced, liner re-anchored and area rehabilitated.
- Cell almost full (less that 3m freeboard) – a wedge of fill placed inside the embankment to cover the exposed liner and the area rehabilitated.
- Cell full - normal rehabilitation.

The choice between these options will be based on cost and availability of fill material, as well as the proportion of the cell filled with tailings.

7.2.2 Early closure costs

Full detailed costs for early closure are given in Appendix 8. Table 7.3 gives a summary of the estimated expenditure for mine closure in any year. The expenditure estimates exclude the costs of progressive rehabilitation of the tailings impoundment expended in previous years. The costs of closure in a particular year will be expended over a period in a similar way to that described above.

Table 7.3

Summary of Early Closure Costs by Year

Closure in Year	***Costs incurred if closure in the year — Includes 5 years passive care***				
	Administration	***Mine Site and Underground***	***Stope Backfill***	***TMF***	***Total***
2006	250,000	4,076,534	884,128	1,937,094	7,147,756
2007	250,000	4,076,534	884,128	2,831,604	8,042,266
2008	250,000	4,076,534	877,698	2,831,604	8,035,836
2009	250,000	4,076,534	286,136	2,614,948	7,227,618
2010	250,000	4,076,534	0	2,438,960	6,765,494

Depending on the year of closure, early closure costs (i.e. total expenditure) vary between €8m and €6.8m. The highest cost would occur in 2007, as the operational cell in the TMF is at a relatively early stage of development with a freeboard greater than 3m, which would result in additional costs associated with remedial works to lower the height of the embankment.

In the early years there are additional costs associated with the backfilling of the underground stopes with cemented tailings to ensure long term stability. As the programme of backfill placement proceeds towards 2007, the backlog of areas to be backfilled are reduced with a consequent decrease in associated costs.

7.2.3 Risk assessment on costs

As indicated the cost estimates for the CRAMP have been developed by Nolan Ryan, Quantity Surveyors, in accordance with standard estimating practice and using contractor commercial rates wherever possible. Nolan Ryan have estimated that the cost estimates, excluding provisional sums and contingencies, are reliable to ±10%. This is within the expected range of reliability for this stage, ie. for budgeting, authorisation or control purposes (more reliable than costs estimated for feasibility, less than for pre-bidding or tendering), and corresponds to Class 3 of the Association for the Advancement of Cost Engineering *Cost Estimate Classification System 1997*. As indicated above, a contingency of 5% has been added to the estimated costs.

7.3 Unknown liability costs (ELRA)

The unknown liability costs associated with closure and post-closure periods have been estimated according to the procedure in the EPA *Guidance Documents and Assessment Tools on Environmental Liabilities Risk Assessment and Residuals Management Plans incorporating Financial Provision Assessment (Draft May 2005)*. This is set out in Section 6 of this plan.

It is not possible to cost every possible risk scenario and variation in detail, so broad ‘order of cost’ ranges have been used as the basis for the Severity Rating given in Table 6.2. Table 7.4 below gives a summary of these; note that the lowest cost scenarios are zero (€0).

Table 7.4
Summary of Unknown Liability Costs

	Most likely scenario	Highest cost scenario
Underground workings	€65,000	€1,270,000
Mine site surface	€18,000	€280,000
Tailings Management Facility	€234,750	€7,070,000
Total	€317,750	€10,620,000

7.4 Financial instruments

A mine closure fund is already in place and funded by the Company. This will cover the potential liabilities for the CRAMP, described above. Details of the nature and extent of the financial provisions are not considered further here and will be subject to separate discussions between the Company, KCC, DCNMR and EPA as appropriate.

7.5 Legal agreements and vehicles

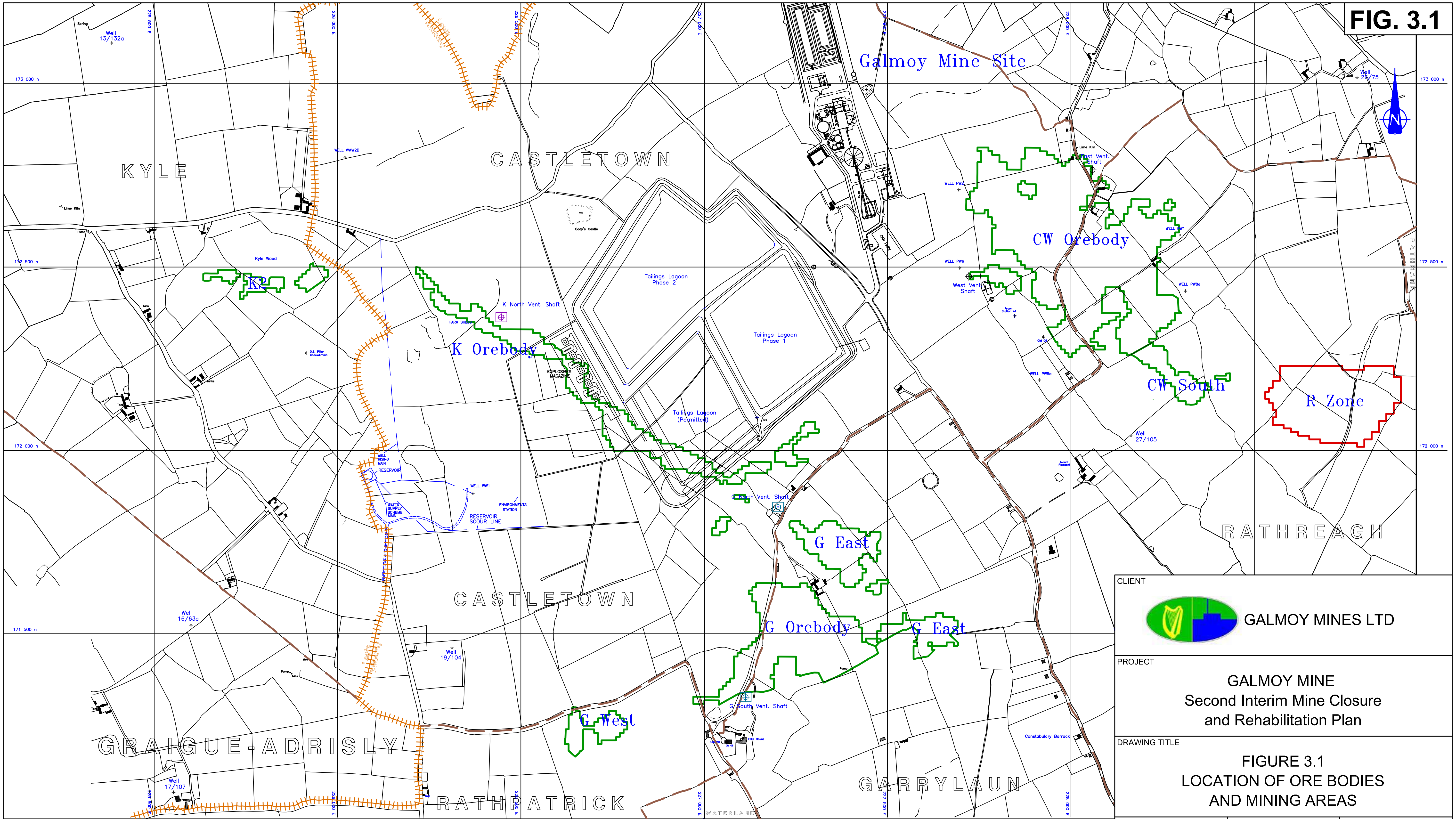
In 2005 Galmoy Mine was acquired by the Lundin Mining Corporation (Canada and Sweden). Lundin is an established mining company and has a long-term interest in Ireland. Galmoy Mines Ltd is a wholly owned subsidiary of Lundin.

The Company propose that, on closure of the mine, the ownership of the site, the remaining assets and liabilities, and responsibility for implementing the CRAMP, will be vested in accordance with one (or a succession) of the following alternatives, to be determined at the time:

1) Galmoy Mines Ltd will continue as an entity, wholly owned by Lundin. Its activities will change from mine production to mine closure.
2) The assets and liabilities will revert to the parent entity, Lundin Mining.
3) A new residual entity will be formed by Lundin, to which all assets and liabilities will be transferred. This new entity will be geared towards long term management of the land in perpetuity.
4) All assets and liabilities, including the rights to the Mine Closure Fund, will be transferred or sold to a third party with a long term interest in managing the land as a potential asset.

At the time of closure the appropriate legal agreements and vehicles will be put in place.

FIG. 3.1



KEY

- COUNTY BOUNDARY
- TOWNLANDS BOUNDARIES
- OREBODY OUTLINE
- R ZONE

CLIENT

GALMOY MINES LTD

PROJECT

GALMOY MINE
Second Interim Mine Closure
and Rehabilitation Plan

DRAWING TITLE

FIGURE 3.1
LOCATION OF ORE BODIES
AND MINING AREAS

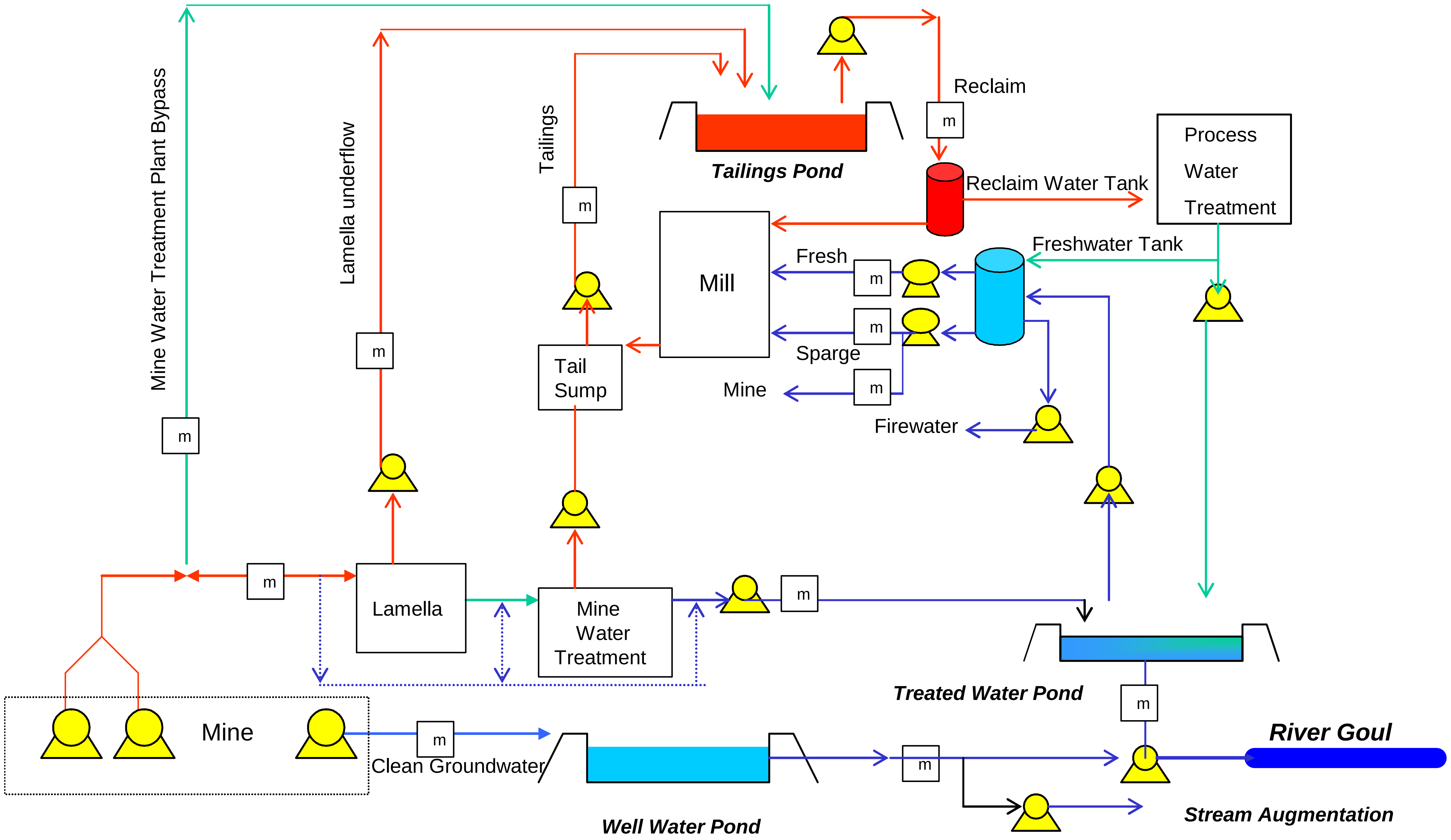
DRG No	SCALE	DATE
51-0241.001	1:10,000	NOVEMBER 2005
DRAWN BY	CHECKED BY	APPROVED BY
BOC		

Wardell Armstrong INTERNATIONAL

Wheal Jane, Baldhu, Truro
Cornwall, TR3 6EH
enquiries@wardell-armstrong.com

tel: 01872 560738
fax: 01872 561079

FIG. 3.2



CLIENT GALMOY MINES LTD		
PROJECT GALMOY MINE Second Interim Mine Closure and Rehabilitation Plan		
DRAWING TITLE FIGURE 3.2 SCHEMATIC OF MINE WATER MANAGEMENT SCHEME		
DRG No 51-0241.002	SCALE NTS	DATE NOVEMBER 2005
DRAWN BY BOC	CHECKED BY	APPROVED BY

Wardell Armstrong
INTERNATIONAL

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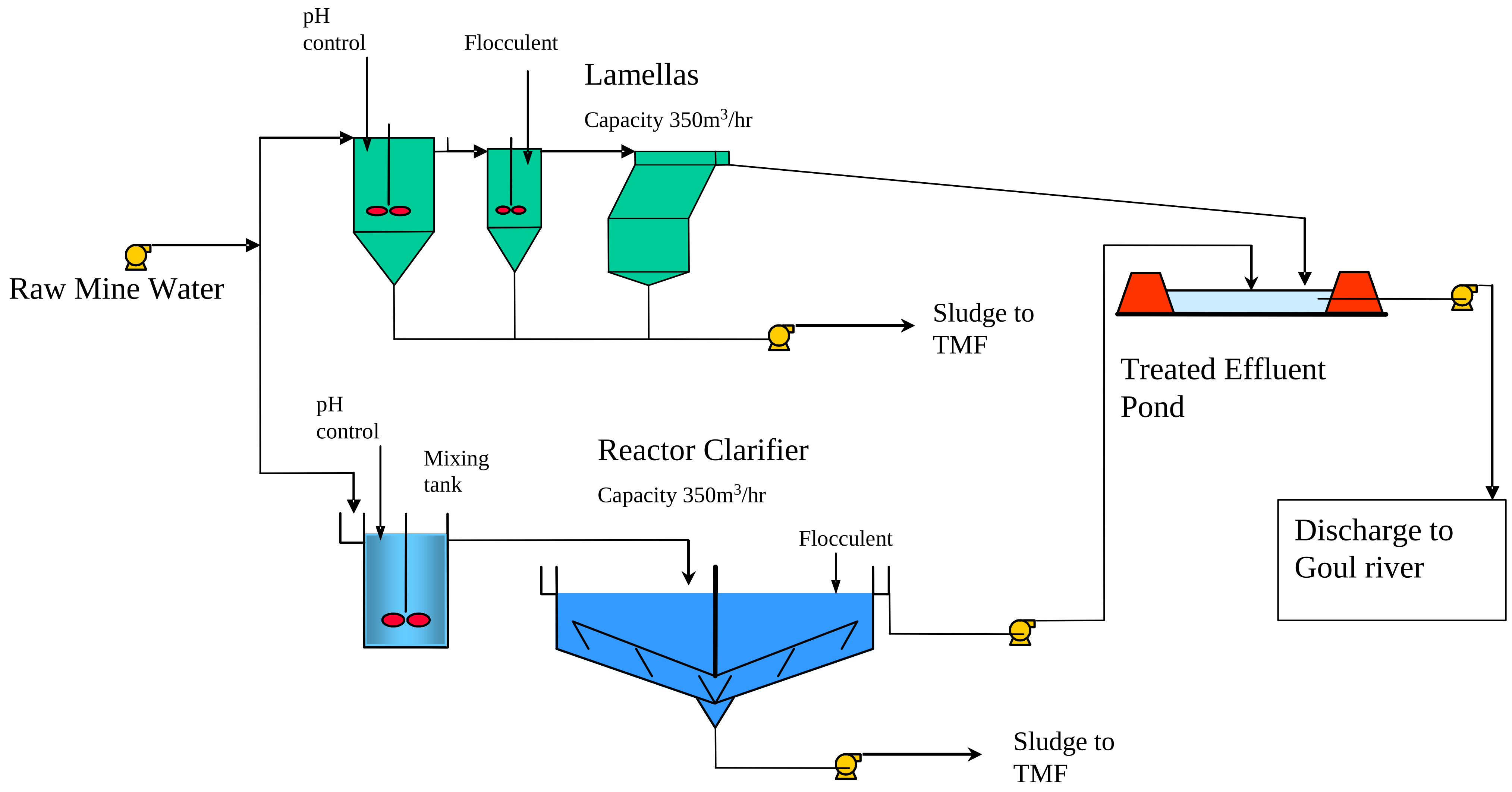
fax: 01872 561079

FIG. 3.3



CLIENT
GALMOY MINES LTD

PROJECT
GALMOY MINE
Second Interim Mine Closure
and Rehabilitation Plan

DRAWING TITLE
FIGURE 3.3
DIAGRAM OF WATER
TREATMENT PLANT

DRG No	SCALE	DATE
51-0241.003	NTS	NOVEMBER 2005
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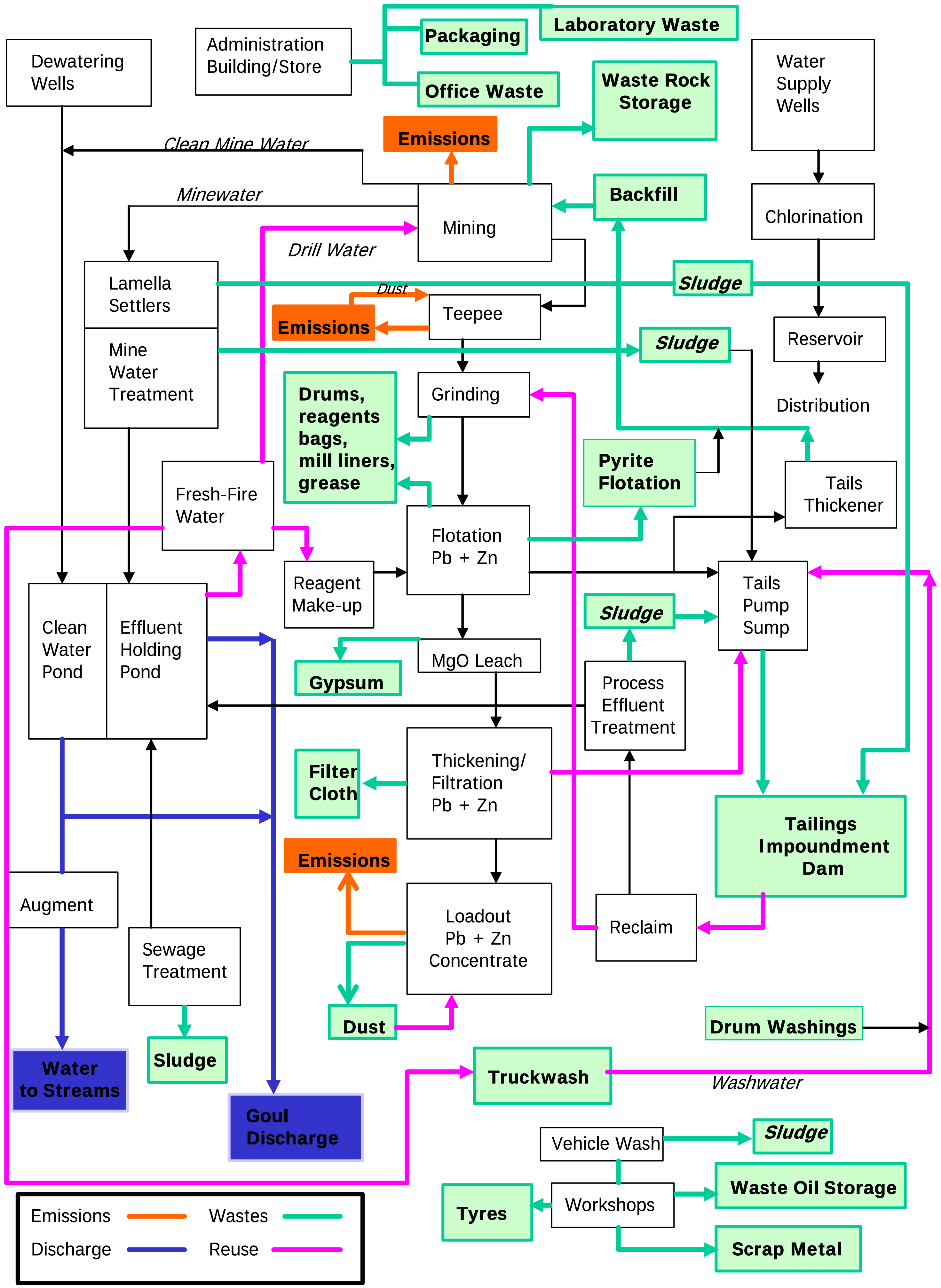
FIG. 3.4



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DRAWING TITLE

FIGURE 3.4
FLOWCHART OF MINE ACTIVITIES

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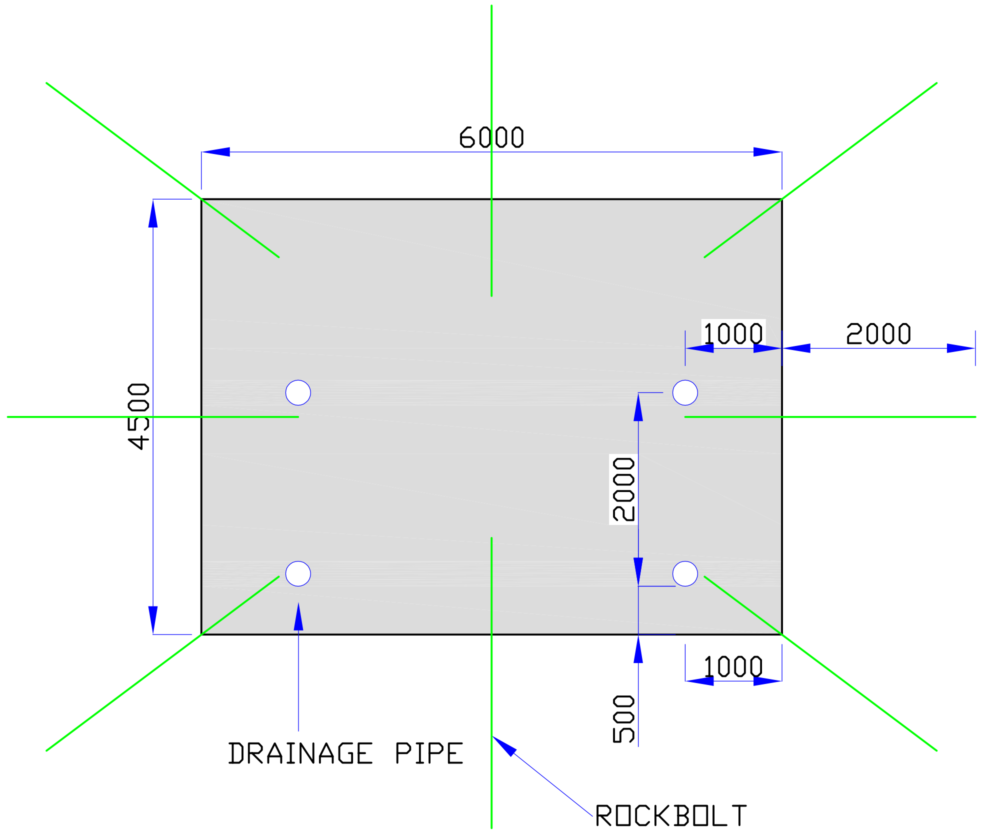
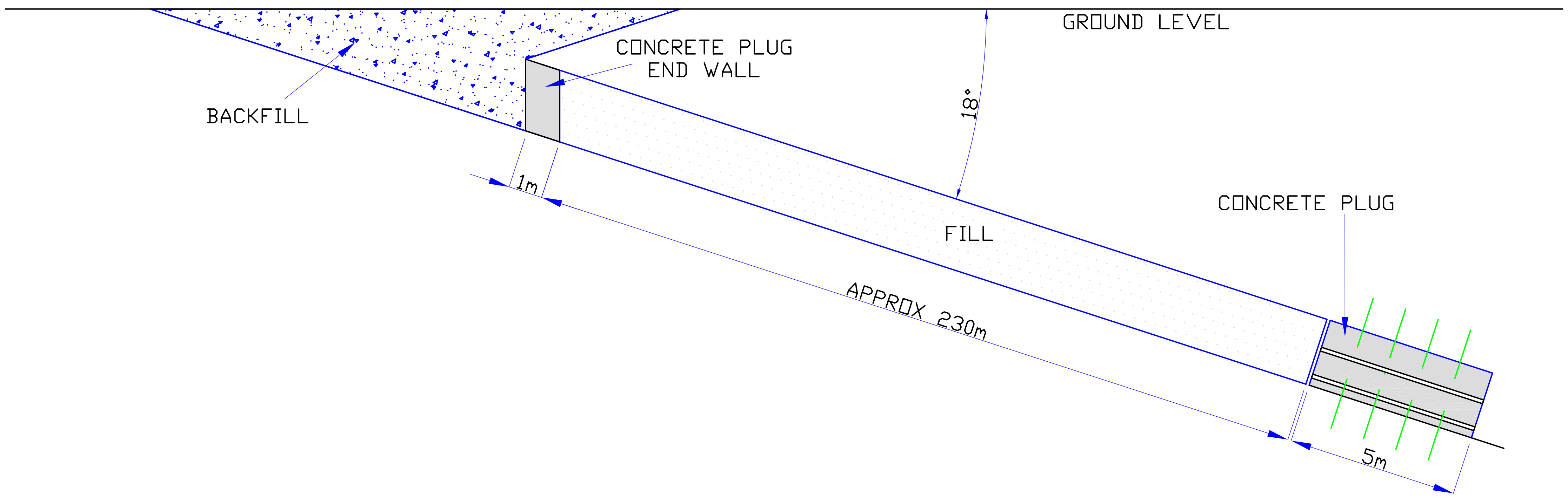
FIG. 5.1



END ELEVATION



SECTION, NOT TO SCALE

CLIENT

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PROJECT

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DRAWING TITLE

FIGURE 5.1
ACCESS DECLINE
FILLING ARRANGEMENT

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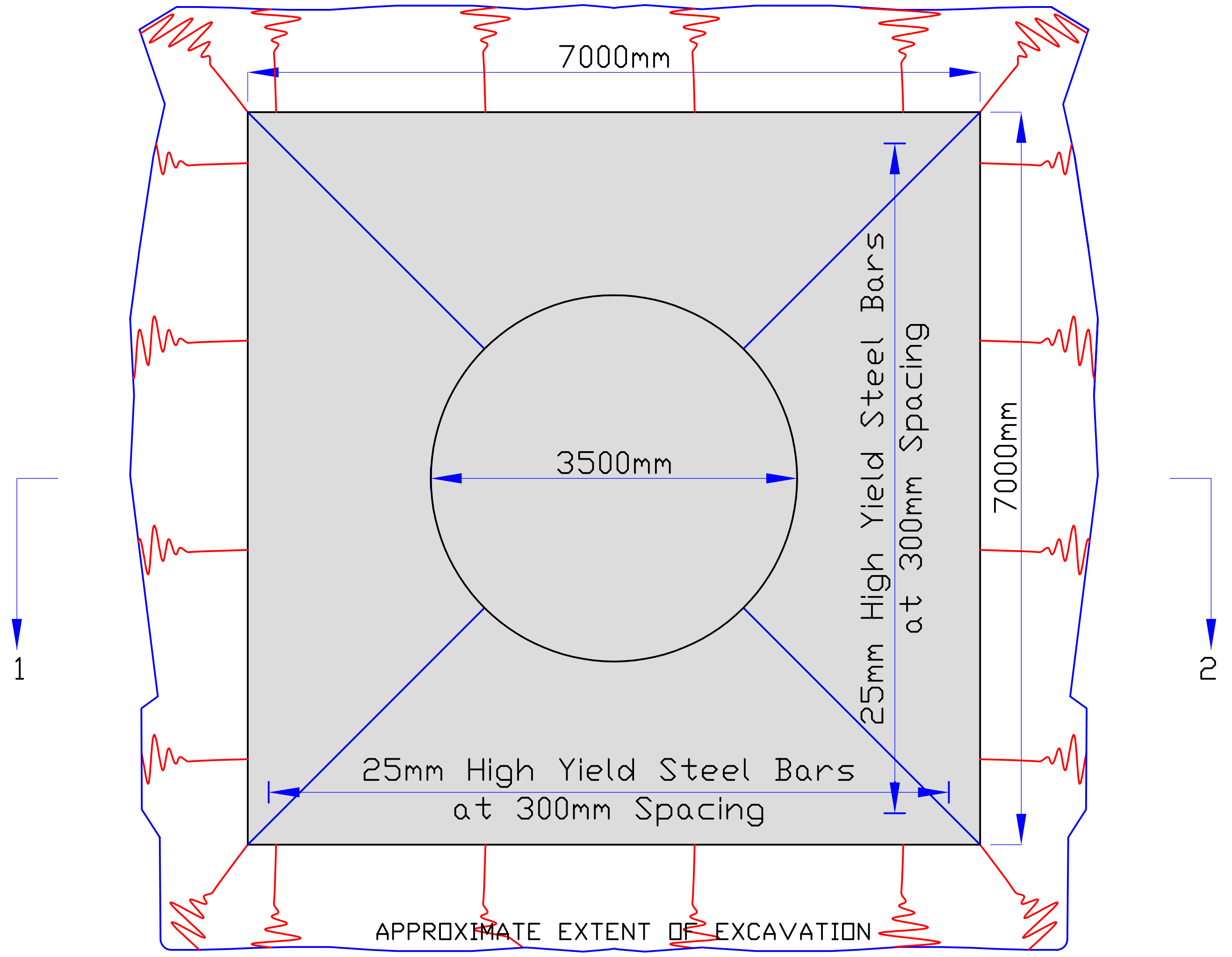
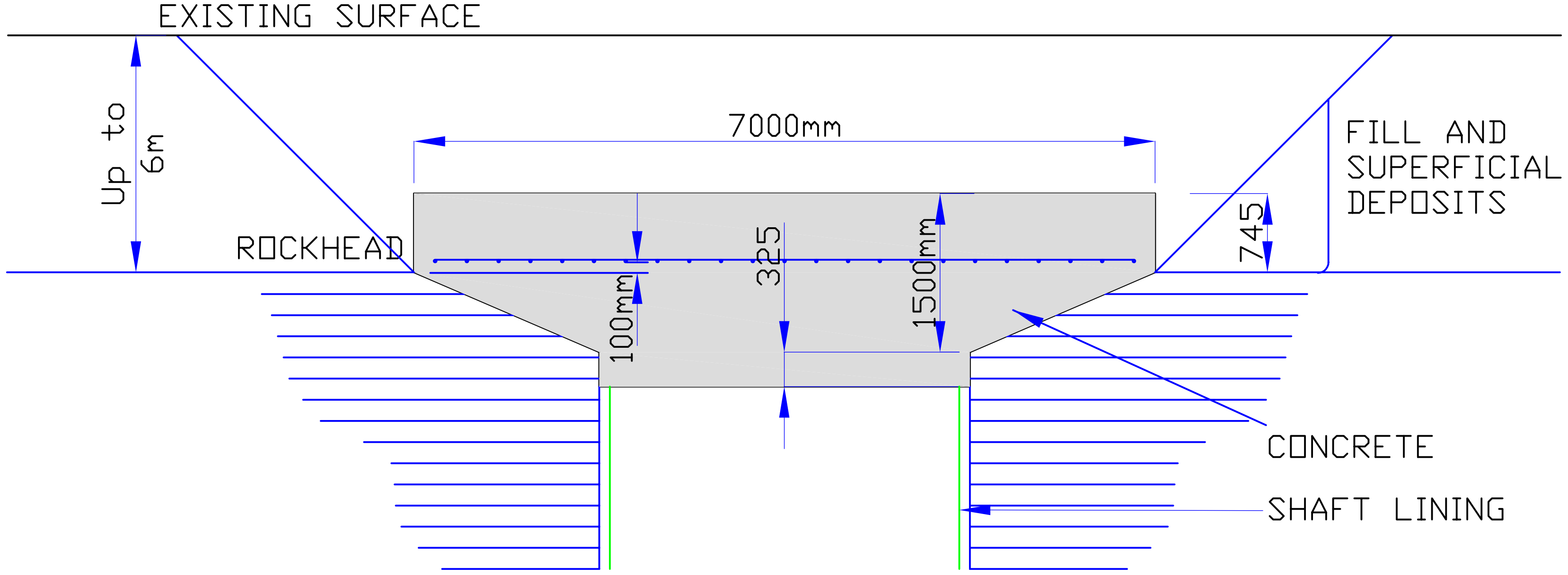
FIG. 5.2



PLAN



SECTION 1-2

CLIENT
GALMOY MINES LTD

PROJECT
GALMOY MINE
Second Interim Mine Closure
and Rehabilitation Plan

DRAWING TITLE
FIGURE 5.2
GENERAL ARRANGEMENT FOR
VENTILATION SHAFT CAP

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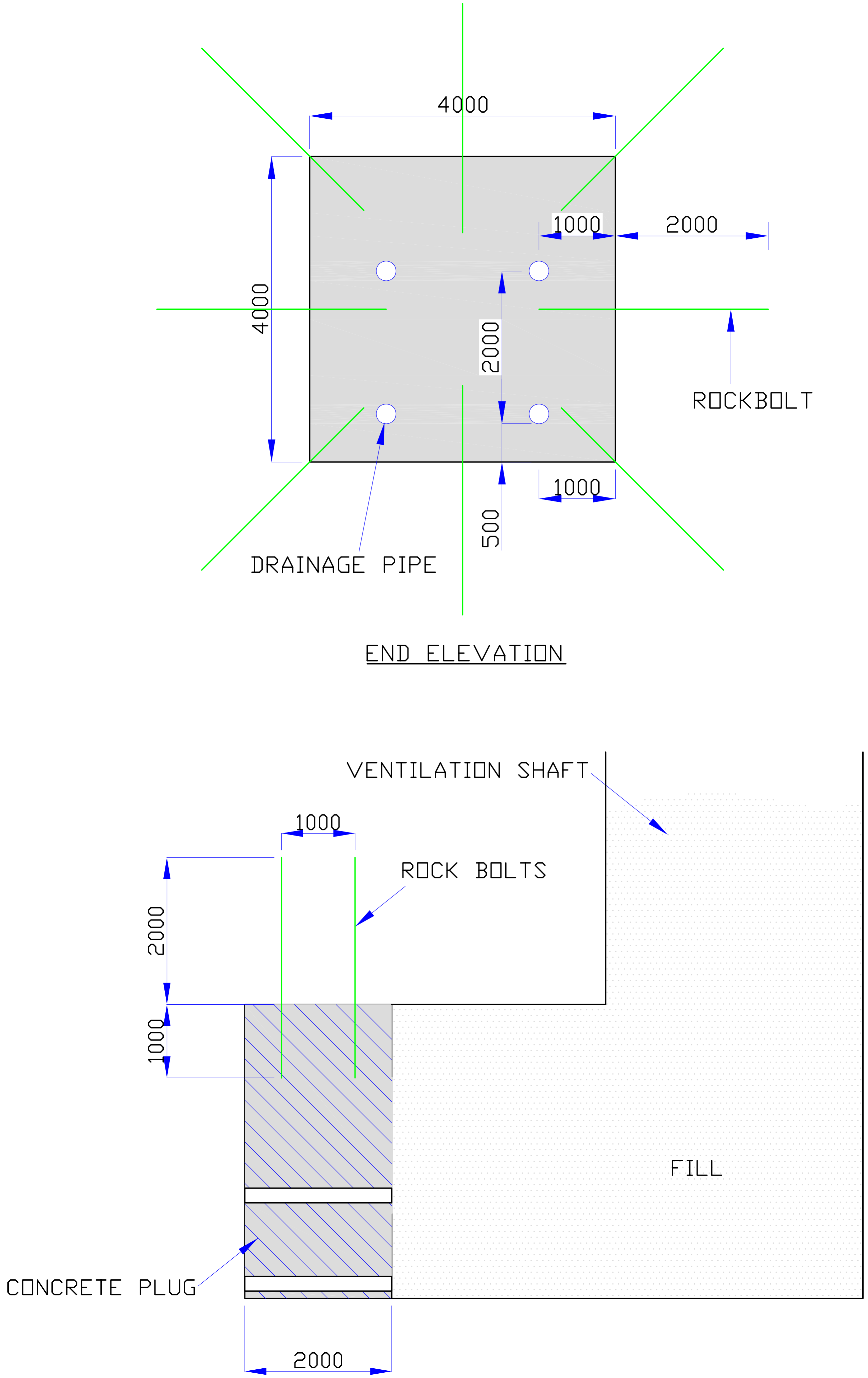
FIG. 5.3



CLIENT: GALMOY MINES LTD		
PROJECT: GALMOY MINE Second Interim Mine Closure and Rehabilitation Plan		
DRAWING TITLE: FIGURE 5.3 VENTILATION SHAFT FILLING ARRANGEMENT		
DRG No 51-0241.007	SCALE NTS	DATE NOVEMBER 2005
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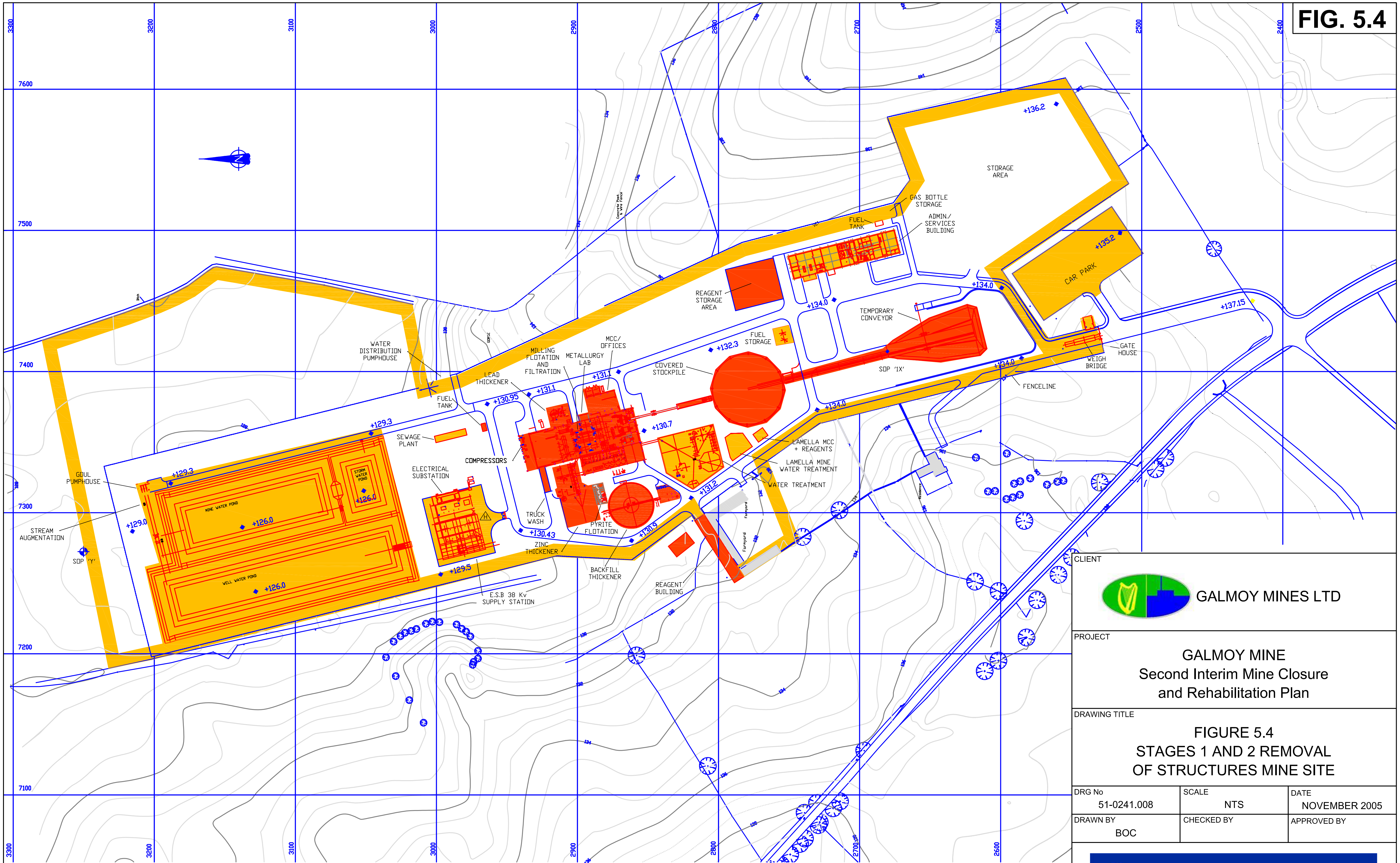
FIG. 5.4



KEY

STAGE 1

STAGE 2

CLIENT

GALMOY MINES LTD

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GALMOY MINE
Second Interim Mine Closure
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DRAWING TITLE

FIGURE 5.4
STAGES 1 AND 2 REMOVAL
OF STRUCTURES MINE SITE

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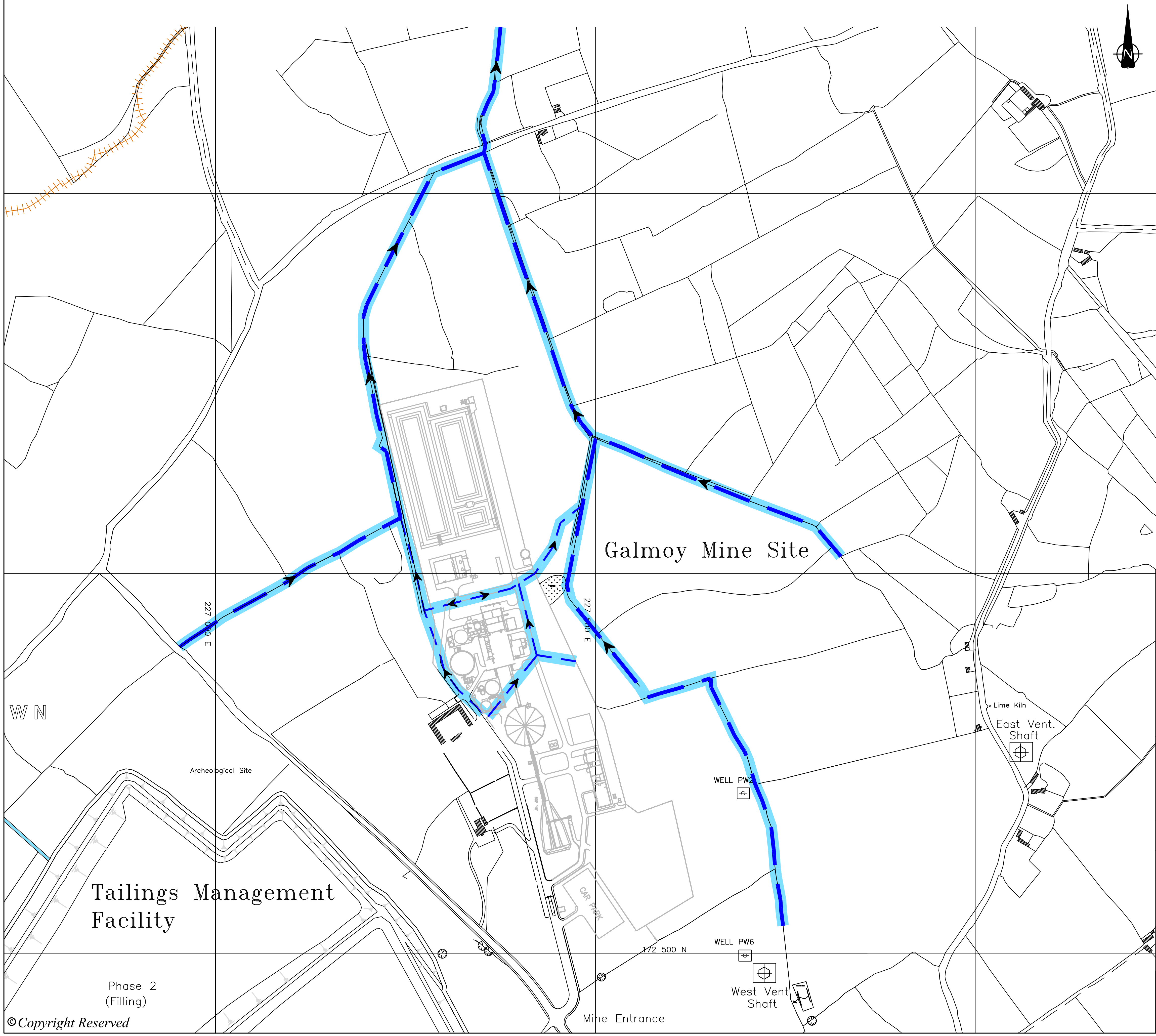
FIG. 5.5



CLIENT
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GALMOY MINE
Second Interim Mine Closure
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DRAWING TITLE
FIGURE 5.5
LONG TERM DRAINAGE - MINE SITE

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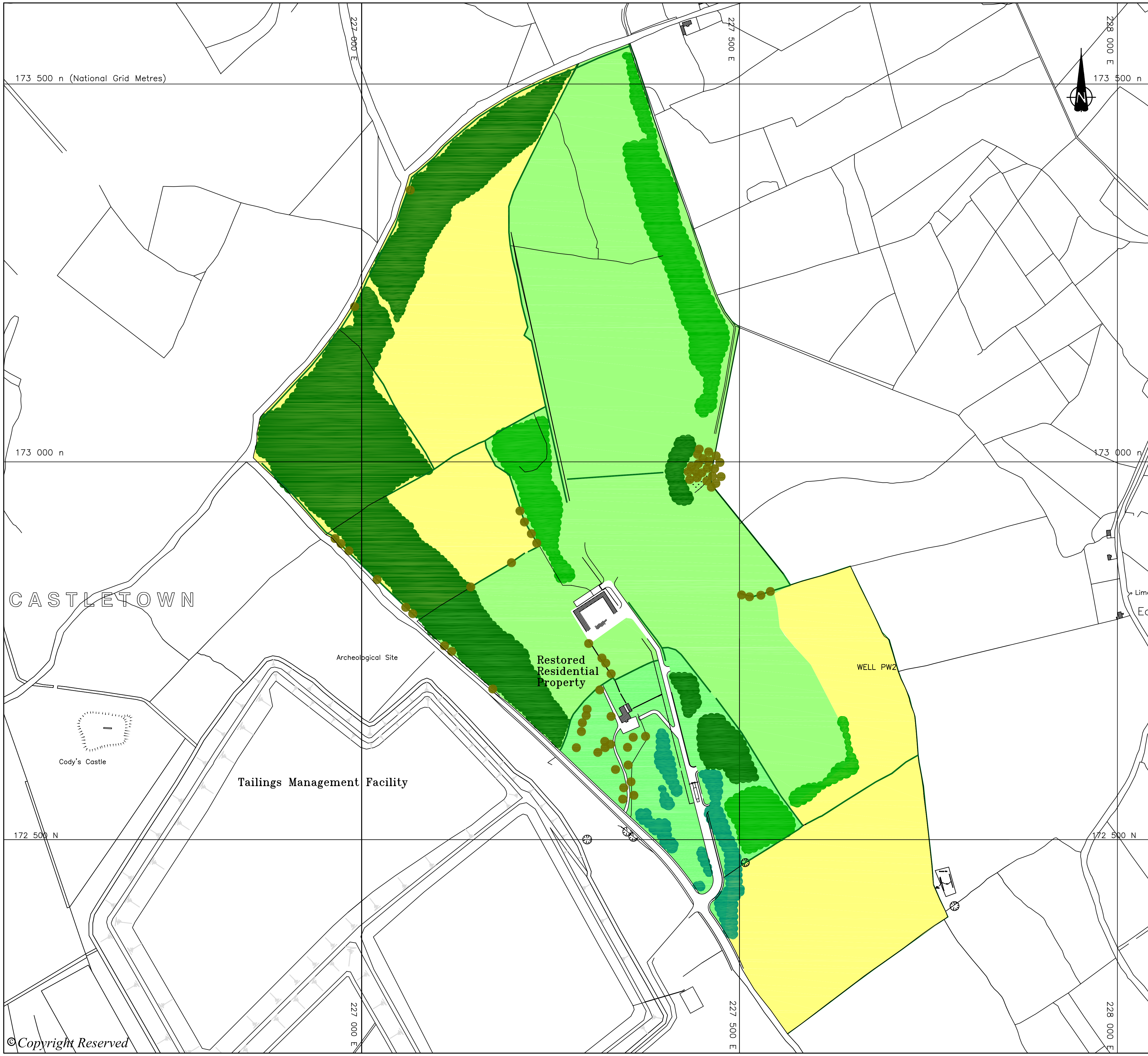
FIG. 5.6



KEY

- EXISTING TREES AND WOODLAND
- EXISTING SCREEN WOODLAND
- PROPOSED AMENITY WOODLAND
- REINSTATED HEDGEROWS
- EXISTING PASTURE
- REINSTATED PASTURE
- PROPOSED AMENITY GRASS AND PLANTING

CLIENT

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FIGURE 5.6
REHABILITATION PROPOSALS - MINE SITE

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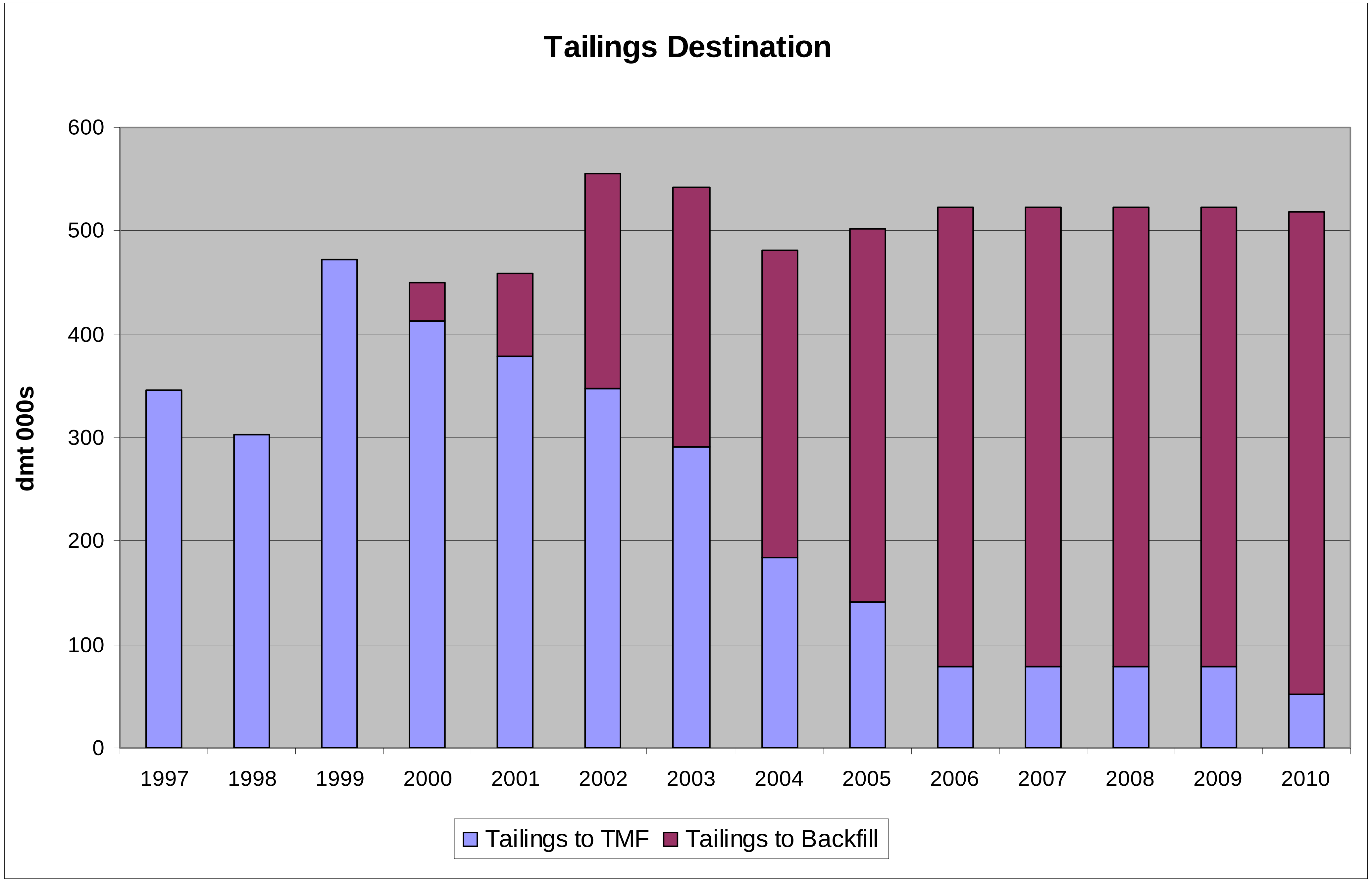
FIG. 5.7



CLIENT: GALMOY MINES LTD		
PROJECT: GALMOY MINE Second Interim Mine Closure and Rehabilitation Plan		
DRAWING TITLE: FIGURE 5.7 TAILINGS DESTINATION		
DRG No: 51-0241.011	SCALE: NTS	DATE: NOVEMBER 2005
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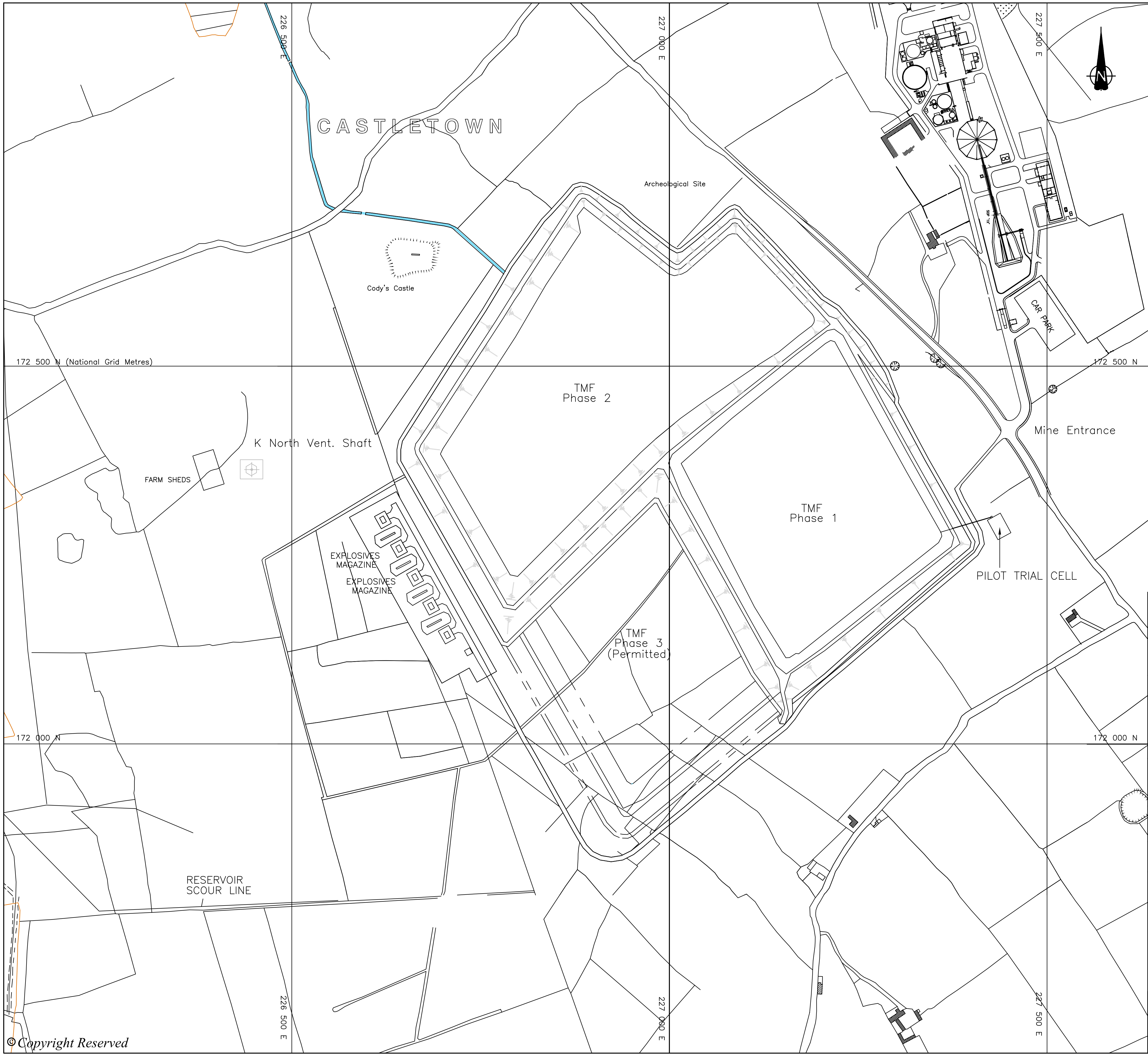
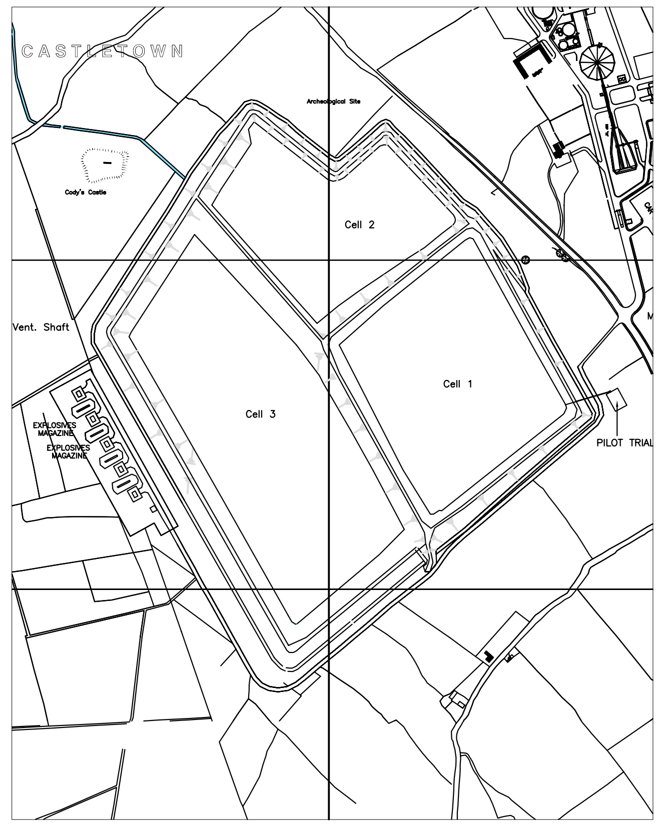
FIG. 5.8



Original 1992 Configuration



CLIENT GALMOY MINES LTD		
PROJECT GALMOY MINE Second Interim Mine Closure and Rehabilitation Plan		
DRAWING TITLE FIGURE 5.8 LAYOUT OF TMF THREE PHASE DESIGN		
DRG No 51-0241.12	SCALE NTS	DATE NOVEMBER 2005
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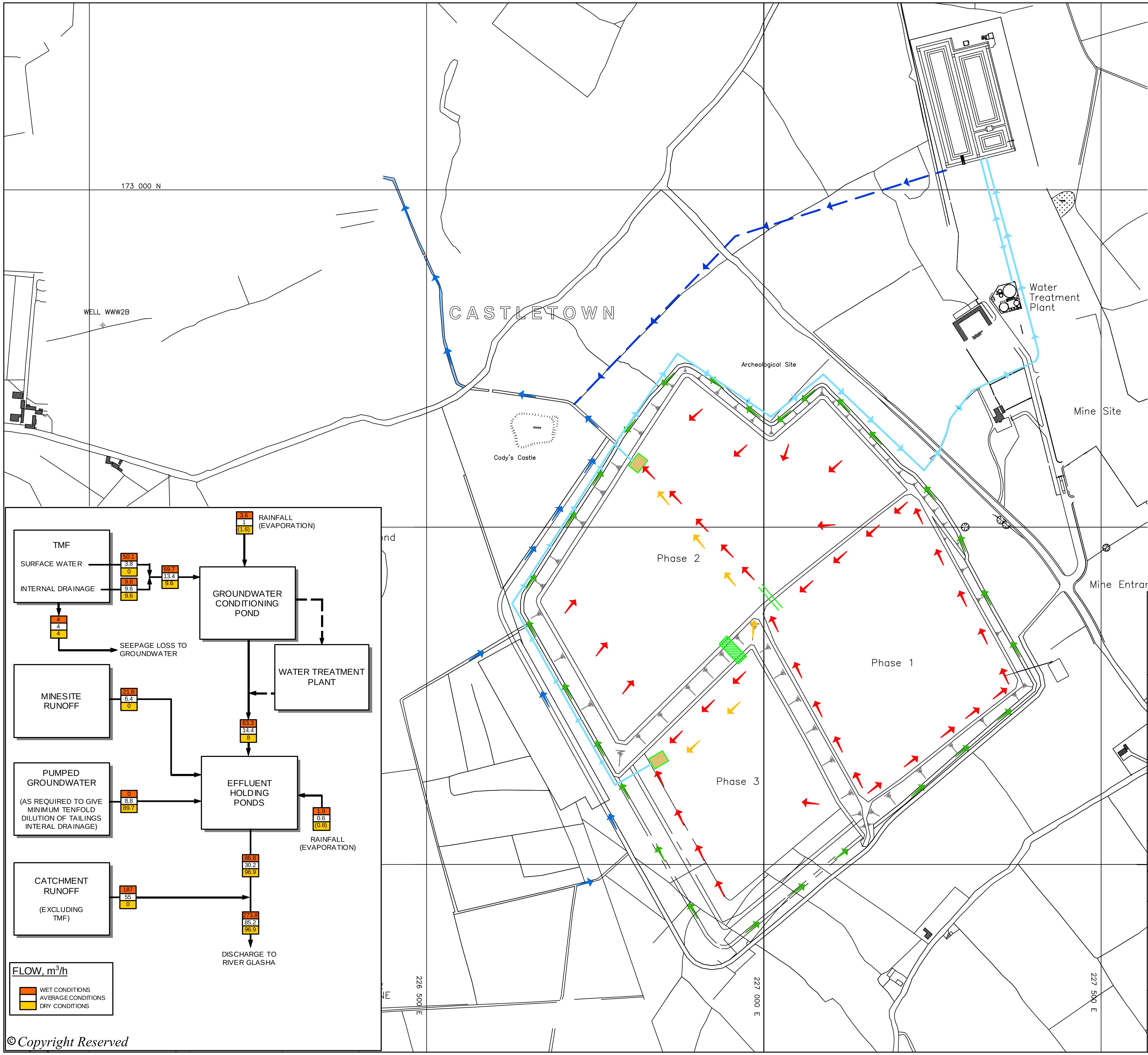
FIG. 5.9



KEY

- TEMPORARY PIPELINE TO WATER TREATMENT PLANT AND PONDS
- DISCHARGE PIPELINE
- MAIN COLLECTOR SUMPS
- SPILLWAY FOR NORMAL FLOWS
- FLOOD SPILLWAY
- SURFACE WATER
- CATCHMENT RUN-OFF
- INTERCEPTOR WATER
- INTERNAL CELL DRAINAGE

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FIGURE 5.9
INTERIM DRAINAGE ARRANGEMENTS
FOR TAILINGS MANAGEMENT FACILITY

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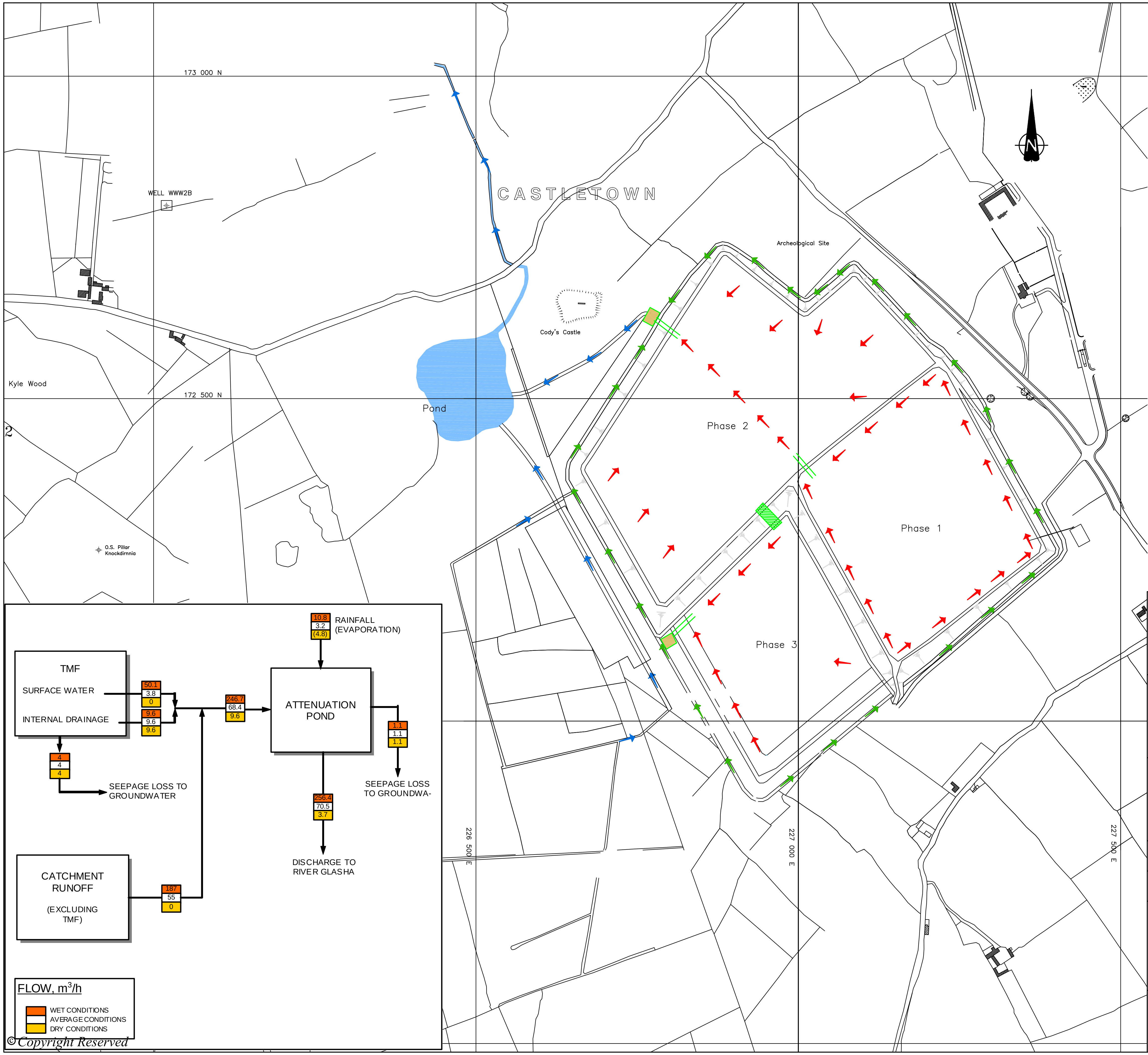
FIG. 5.10



KEY

- MAIN COLLECTOR SUMPS
- SPILLWAY FOR NORMAL FLOWS
- FLOOD SPILLWAY
- SURFACE WATER
- CATCHMENT RUN-OFF / DISCHARGE
- INTERCEPTOR WATER
- ATTENUATION POND

CLIENT

GALMOY MINES LTD

PROJECT

GALMOY MINE
Second Interim Mine Closure
and Rehabilitation Plan

DRAWING TITLE

FIGURE 5.10
PROPOSED FINAL DRAINAGE
ARRANGEMENTS OF TMF

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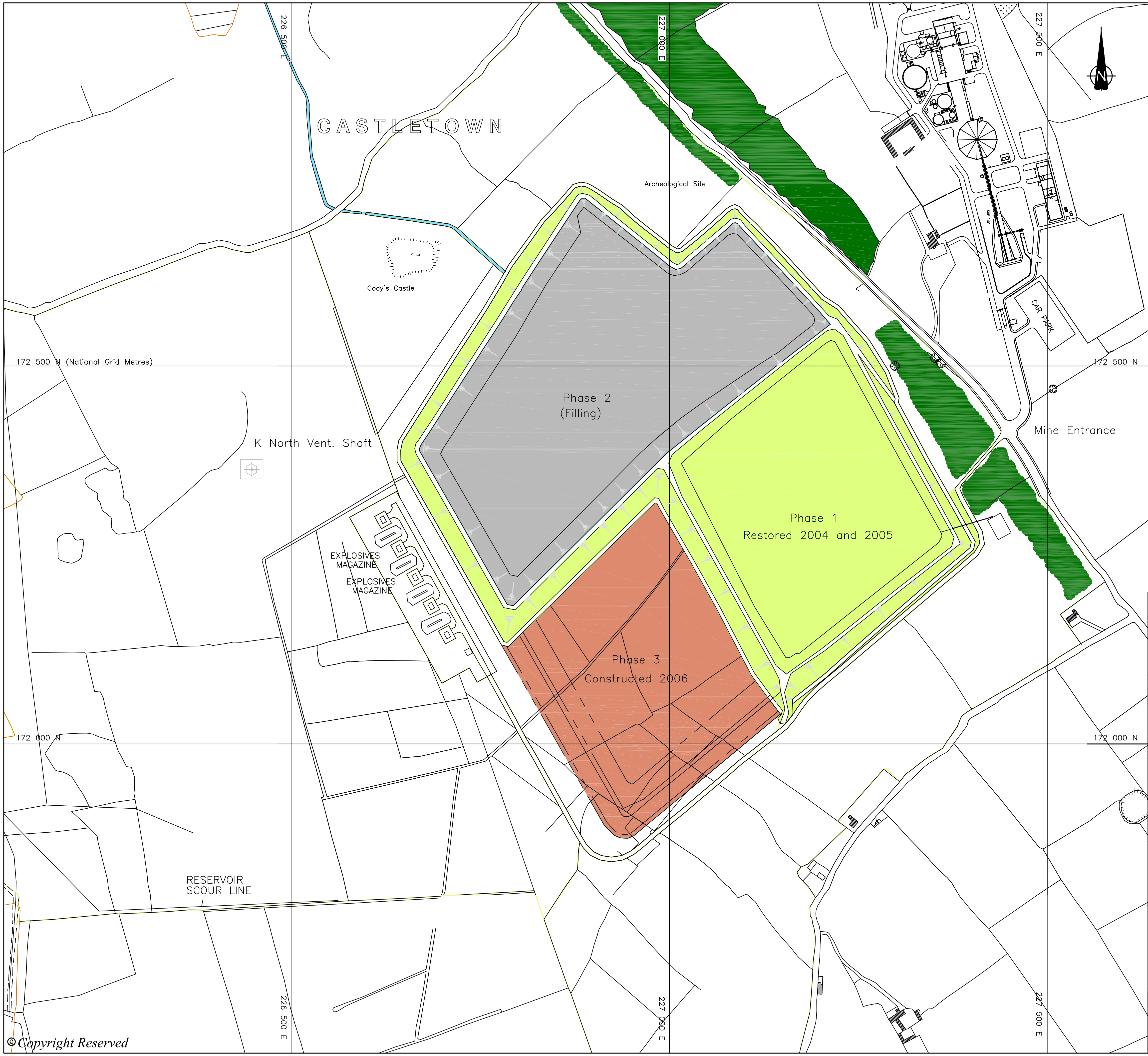
FIG. 5.11



KEY

- WOODLAND AND EDGE PLANTING
- ROUGH GRASSLAND (DAM WALLS AND SURFACE)
- PHASE 2
- AREA UNDER CONSTRUCTION

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DRAWING TITLE

FIGURE 5.11
INTERIM LANDSCAPE PROPOSALS
- TAILINGS MANAGEMENT FACILITY

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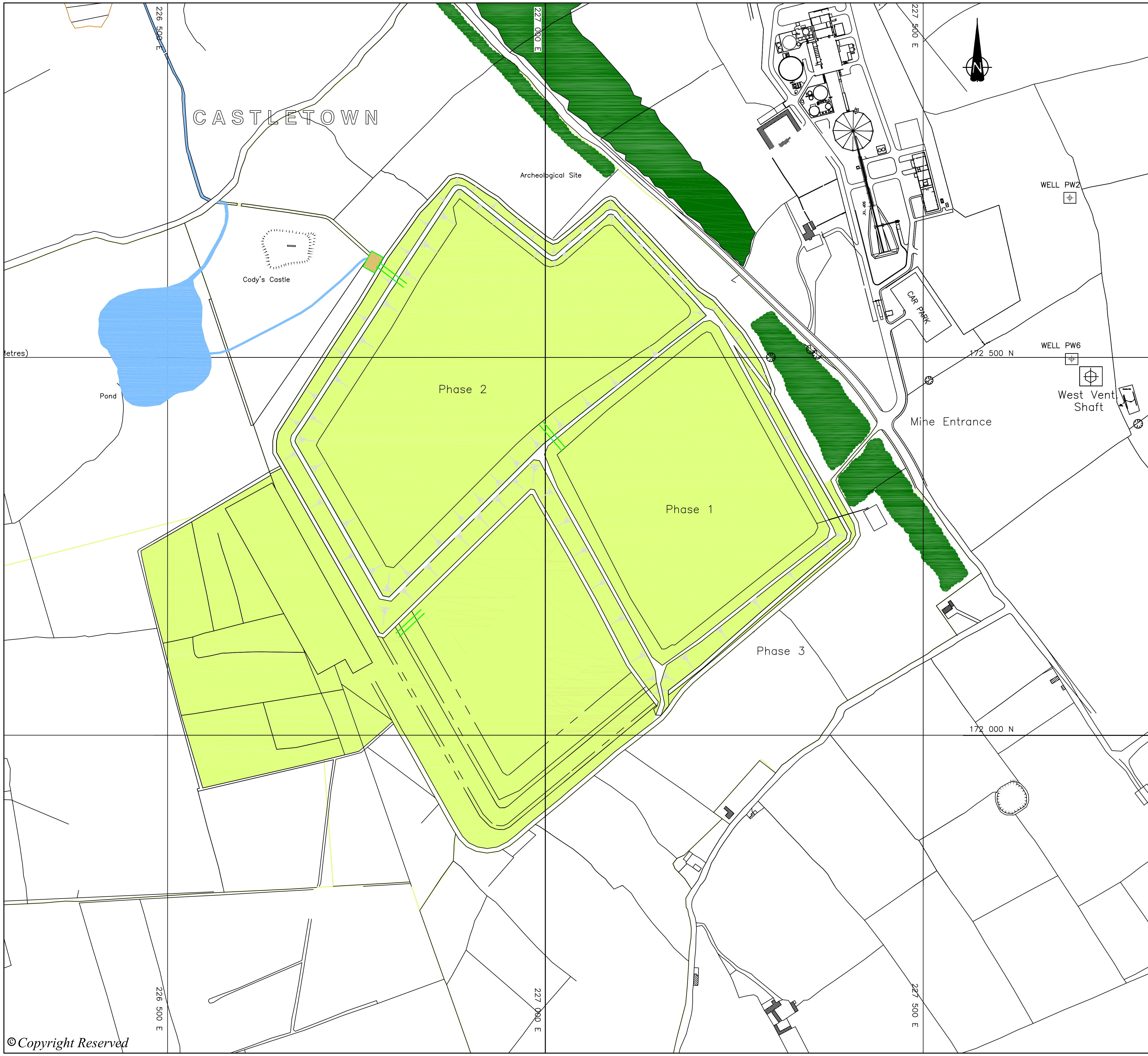
FIG. 5.12



KEY

- WOODLAND AND EDGE PLANTING
- ROUGH GRASSLAND (DAM WALLS AND SURFACE)
- ATTENUATION POND
- SPILLWAY

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GALMOY MINES LTD

PROJECT

GALMOY MINE
Second Interim Mine Closure
and Rehabilitation Plan

DRAWING TITLE

FIGURE 5.12
FINAL LANDSCAPE PROPOSALS
- TAILINGS MANAGEMENT FACILITY

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APPENDIX 1 : REVIEW OF GROUNDWATER REBOUND

Client: Galmoy Mines Ltd

Review of Groundwater Rebound

Prepared by:

David Watkins

Wardell Armstrong International Limited

December 2005

Ref: 51-0241
Report No: ENV/096-1

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REVIEW OF GROUNDWATER REBOUND

1 Introduction

This report presents an overview of the hydrogeological conditions at Galmoy Mine with particular reference to post-closure groundwater rebound. This includes a summary of the evidence supporting the conclusions, however full details of the evidence are referenced for further details.

As part of the planning and permitting of the Galmoy Mine extensive groundwater studies were undertaken, forming part of the Environmental Impact Assessment. The full supporting Technical Report prepared by KT Cullen (1992) is a key starting point for this Review.

Prior to and since the commencement of production operations, Galmoy Mines Ltd (formerly Arcon Mines Ltd) has engaged the specialist services of Golder Associates Ltd ('Golders') to assist in the assessment of underground conditions and groundwater monitoring at the mine. As such, the reports prepared by Golders over this period have also been used as the basis of this review.

In addition, the Company in conjunction with the EPA, KCC and the Department of Communications, Marine and Natural Resources, has formed the Groundwater Model Review Committee which has monitored and reviewed the groundwater conditions since the early days of operation. The work of this committee is recognised and discussions with a member of the Committee, Mr Eugene Daly, have been helpful in preparing this Review.

2 Hydrogeological setting

2.1 Geology and hydrology

The Galmoy mine system is located within the catchment of tributaries of the River Nore. The mine straddles the watershed between two subcatchments. The north and west of the site drain to tributaries of the Glasha stream, which drains to the north, into the River Erkina, which then flows eastwards towards the River Nore. To the south and east of the mine, tributaries drain to the River Goul some 3 km to the east. The River Goul joins the River Erkina 11 km to the north east of the mine. The river systems are shown on Figure 1.

Rainfall in the region is around 800 – 900 mm/annum and potential evapotraspiraton is around 400- 500 mm/annum. The rivers receive around 50% baseflow component from groundwater.

The Galmoy mine system is situated within an area of limestone geology. The rocks present consist of regionally and locally important aquifers. Figure 2 shows the location of the mine system in relation to the surrounding aquifers.

These are described by the Irish Geological Survey as:

- Lm - Locally important aquifer – bedrock which is generally productive.
- Li - Locally important aquifer – bedrock which is moderately productive only in local zones.

- Rkd - Regionally important aquifer - karstified (diffuse) – good development potential.

In addition to the bedrock aquifers, glacial overburden is used locally for groundwater supplies and this tends to interact with the bedrock main aquifer systems.

Average groundwater levels are around 140 – 150 m AOD beneath high ground to the east and west of the site, around 130 m AOD at the mine site, and falls away to 120 m AOD to the north and south of the site. The pre-mining flow pattern is shown in Figure 5.

Immediately to the south of the mine site, the G fault runs east-west. This fault provides an essentially impermeable barrier to groundwater flow. Consequently, groundwater in the Ballysteen Formation to the south of the fault flows in a westerly direction to tributaries of the River Goul and groundwater from the mine area flows generally northwards, in the Dolomitised Waulsortian to the Glasha Stream. A zone of high transmissivity occurs between the G and CW orebodies at the mine site. This causes groundwater to converge from the west and east sides of the mine site before flowing northwards to the Glasha Stream and River Erkina.

The hydrogeological setting is described in detail by Cullen (1992).

2.2 Orebodies and mining area

The main formations are listed by Cullen (1992) and are shown on Figure 3. The ore bodies mined lie at the base of the Dolomitised Waulsortian and above the, less permeable, Ballysteen limestone. Immediately south of the mine workings, the Ballysteen Limestone is thrown up to the surface by faulting, see Figure 3.

The extent, thickness and depth of the ore bodies are summarised in Table 1.

Table 1
Size and depth of ore bodies

Ore body	Extent (m)	Area (ha)	Thickness (range) (m)	Thickness (average) (m)	Approx. Volume (m^3)	Depth (m)
CW	400 × 700	28	3 - 18	6	1,680,000	70
G	400 × 300	12	3 - 24	6	960,000	90
K	1200 × 60	6	3.7 - 21	4.8	324,000	100
G East	250× 120	4.8	3.7 - 27	7.5	268,800	80
CW south	200 × 50	1.0	3.7 – 11.2	4.1	48,000	130
K2	350 × 35	1.225	3.7 - 5	4.1	50,225	130
G West	200 × 100	2.0	3.7 – 6.5	4.3	36,000	40
R	360 x 220	7.92	3.7 - 31	8.4	633,600	120 – 150

Significant dates in the development of the mine are:

May 1995	Underground development began
October 1995	Dewatering began
July 1996	Entered the CW orebody
October 2001	Entered the K orebody
January 2002	Entered the G NE orebody
September 2002	Entered the G orebody
July 2003	Entering the R zone orebody

2.3 Hydrogeological parameters and modelling

Pumping tests reported in 1992 (Cullen 1992) indicate a transmissivity of 40-60 m^2/day for the eastern side of the mine (Rkd, see Figure 1), and 260-600 m^2day for the west side of the mine (Li). The storage coefficient for both aquifers is around 1-2%.

Numerical modelling (Cullen 1992) used a 2-layer model with the upper layer, representing the overburden and the uppermost 5-10 m of bedrock, with a bulk transmissivity of 300 m^2/day and a storage coefficient of 16%. The main body of the aquifer was represented by a layer with transmissivity of 50 – 300 m^2/day and storage coefficient of 1 – 2%. The purpose of the modelling was to predict the scale of dewatering, the extent of the cone of depression, the impact on rivers and wells and the movement of groundwater on closure of the mine.

Further numerical modelling was conducted in 1997 (Golder, 1997a). The purpose of this was to update the model produced by Golder in Cullen (1992) in the light of further hydrogeological information. In particular, the importance of the high transmissivity in the north – south direction in the dolomite was noted, as reflected by an elongated zone of depression, and the importance of water draining at shallow depths in the overburden to small streams and ditches to the water balance.

Further work is reported by Golder (1999). The purpose of this work was to review the previous model predictions in the light of monitoring of actual groundwater levels and to make a preliminary assessment of the effect of dewatering the G and K orebodies. The report notes that actual drawdown is limited to the dolomitised limestone and the cone of depression is smaller than originally predicted. This is attributed to low permeability boundaries of the dolomitised limestone and that a higher than previously assumed recharge rate applies, in the order of 500 mm/year.

One of the original components of the dewatering programme was to lower the water table by pumping from deep perimeter wells. Five wells were drilled for this purpose. These proved, however, to be largely ineffective for dewatering the mine. Whilst 20% of the total dewatering was achieved from these wells, the remaining 80% was derived from pumping directly from the mine (Golder, 1997b).

Golder (2000) conducted empirical estimates of the required pumping rates for dewatering of the CW, G and K ore bodies. This report notes that for small drawdowns in the water table, groundwater flow is dominated by the highly permeable upper weathered part of the limestone aquifers. However, when drawdown is extended to the less-weathered zone then the only significant permeability is restricted to the NNW-SSE trending features, resulting in anisotropic behaviour. These fissures can be largely drained following an initial period of high flows.

Golder (2000) estimated that the G ore body would produce lower flows than the CW as the G fault restricts lateral inflow and the presence of the CW openings intercepts recharge coming from the northeast. The K ore body was predicted to produce slightly larger flows than the G ore body and both would result in diversion of some flows from CW. The maximum total abstraction rate from the mine was estimated to be just under 15,000 m^3/day.

Golder (2003) considered the additional impact of dewatering of the R zone extension. This ore body lies at a deeper level than those previously worked and would require a reduction in water level of 150 m. This would be likely to require an additional nearly 5,000 m^3/day, bringing the total required pumping rate from the mine up to just under 20,000 m^3/day.

2.4 Replacement Water Supply System

A high density of private wells exists in the area. Cullen (1992) identified 73 dug wells and 140 bored wells within 5 km of the mine, though 10 of these were recorded as not in use and many of these wells were of low quality.

A replacement water supply scheme (RWSS) has been put in place to provide reliable supplies to any well owners that might be affected by the impact of mining. This supply system currently services the owners of wells that have been affected by mine dewatering, the Galmoy Group Scheme and the town of Rathdowney. It is unlikely that the public will return to the use of wells and these wells are likely to be abandoned and the RWSS kept in place.

3 Operational Water Balance

3.1 Mine dewatering

Mine dewatering is achieved by abstraction of a combination of “clean water” that is collected from fissures before it reaches the floor of the mine and “dirty water” that has reached the mine floor. The dewatering perimeter wells are no longer in operation as the drawdown cone has reduced water inflow to the well locations.

As the mine has developed, the “dirty water” abstraction has increased from about 4,000 m^3/day in 2000 to about 10,000 m^3/day in 2005. The “clean water” abstraction, though varying between about 0 to 4,000 m^3/day, has averaged around 3,000 m^3day since 2000. The totals abstracted from the mine have risen from about 7,000 m^3/day in 2000 to about 14,000 m^3/day at present, though peaks occur during individual winter and spring times, see Figure 4.

The water abstracted from both supply wells for the Replacement Water Supply System (RWSS) is currently in excess of 1100 m^3/day. The mine has commenced extraction in the K orebody. Dewatering in this area has not yet had any adverse effect on these wells so there may be little interference between the mining zone and the wells. However, as the mining progresses northwest in the K zone, monitoring will provide further information.

"Dirty water" derived from the mine is for the most part treated and passed to the Treated Water Pond, from where it is either pumped to the River Goul with clean water. "Clean water" pumped from the mine is passed to the Well Water Pond from where it is either pumped directly to the River Goul with treated mine water or used in stream augmentation.

3.2 Groundwater Drawdown

Figure 5 shows the water table position in 1992, prior to dewatering. Figure 6 shows the predicted situation for the life of the mine as was envisaged in 2000 (Golders 2000) and was created by subtracting the predicted cone of depression from the 1992 water table surface. Figure 7 shows the actual situation in 2002 based on drawdowns presented in Golders (2003) and Figure 8 shows the case for the predicted cone of depression including dewatering of the R Zone by 150 m, based on superposition of the drawdown in Golders (2003) and the natural water table as presented in Cullen (1992).

The volumes of the drawdown cone are as follows:

Predicted in 2000 (Figure 6)	131×10^6 m^3
Actual in 2002 (Figure 7)	122×10^6 m^3
Predicted including R Zone (Figure 8)	485×10^6 m^3

4 Post operational water balance

The mine is presently backfilling of excavated cavities with cemented tails using cement and ground granulated blast furnace slag in various percentages as binder

As the mine is closed and is allowed to refill with water, void spaces within the backfill material will saturate with water, any mined out areas not backfilled will fill and the cone of depression will fill, as the groundwater rebounds to its natural level.

The time taken for this to happen was estimated by Cullen (1992) at about 4 years. This was based on the assumption that only the CW and G ore bodies would be mined, but later analysis (Golder 1999) indicates that this overestimated the cone of depression by underestimating the recharge.

Table 1 indicates about 4×10^6 m^3 of void space could be created by the end of the mine life, and Appendix 7 of the Mine Closure Plan shows that 85% of the stope volume will be backfilled. The effective porosity of the backfill may vary from 5% to 25% (the very small pores may take many years to fill), so the overall porosity of the mine workings is likely to between 19% and 36%. Thus between approximately 0.75 $\times10^6$ m^3 and 1.4 x 10^6 m^3 of water will be required to fill these workings. At a rate of, say 20,000 m^3/day, this would take between 40 and 70 days. The volume of the cone of depression on closure is expected to be around 485×10^6 m^3. With a mean porosity of 1.5%, about 7.3×10^6 m^3 of void space will need to fill before full recovery occurs. At an average rate of, say, 10,000 m^3/day, accounting for the fact that the head dependent flows will reduce with time, this would take a further 730 days to fill. Thus overall the rebound may take around 2 years to fully stabilise.

The groundwater rebound will be closely monitored through the current system of observation wells. The pumping system in the original perimeter wells will be kept in place so that the groundwater rebound can be controlled should this be deemed necessary.

The RWSS will be maintained for the foreseeable future. It is not envisaged that any of the wells that were decommissioned due to groundwater drawdown will be re-commissioned after groundwater rebound.

The Groundwater Model Review Committee, which meets regularly to consider the implications of the mine dewatering scheme on the environment and water supplies, will continue to meet and consider the groundwater rebound.

Due to the heterogenic nature of the limestone aquifer, it is difficult to predict the flow paths of water in the post-operational situation; groundwater flows being controlled by fissures and weathered zones, the blocky nature of the aquifer and interaction between bedrock aquifer and overburden. The emphasis will therefore be on monitoring and the ability to react to circumstances by resuming pumping, possibly by using the CW wells.

In general, as the water level in the mine rises, flow will be inwards toward the lowest point in the depressed water table, so groundwater flow will be confined to the area within the cone of depression. Once groundwater levels have stabilised, the hydraulic gradient will return to its natural direction, toward the tributaries of the Rivers Goul and Erkina. As the pathway between the mine and the tributaries to the River Goul are obstructed by the G fault, it is unlikely that the Goul would be affected.

It is envisaged that groundwater will revert to flowing toward the mine from the east and west, then move northwards toward the river Erkina, as shown in Figure 9 and previously in Figure 5. As flow to the tributaries of the Erkina, such as the Glasha stream are likely to be mainly fed by groundwater from the overburden and upper weathered zone of the aquifer, any possible contaminated water is likely to travel some distance within the aquifer before emerging into a stream or the overburden. During this time it will be continually attenuated by dispersion and dilution processes.

Figure 9 shows the natural groundwater flow pattern in relation to the RWSS abstraction wells and the dewatering wells for the CW ore body. The flow pattern shown here does not include the effect of the RWSS wells pumping, which would be expected to draw some water from the mined area (K orebody) toward the wells. The southerly RWSS well is upstream of the mine workings and is unlikely to be significantly affected. However, the northern well could potentially be affected by any plume from the mine workings, should such a plume develop.

Whilst contamination of groundwater is considered unlikely (see Section 5 below), if the quality of abstracted water was affected it would be necessary to relocate the abstraction well further to the west or southwest.

5 Potential water quality from underground

The quality of groundwater that is likely to occur downstream of the flooded mine workings will be determined by many factors, including:

- Accumulated pollutants in the mine workings that can be readily flushed through as the groundwater regime re-establishes (NH_3, NO_2, hydrocarbons, $CaCO_3$, SO_4, dissolved metals, etc).
- Leachable contaminants, from both oxidising residual mineralised rock (dissolved metals, SO_4) and placed backfill ($CaCO_3$).
- Permeability of rock and backfill, and thus dilution with groundwater.
- Attenuation of contaminants achieved as groundwater flows through downstream strata.

Minewater is currently pumped to dewater the mine, so at present all groundwater will report to the mine sumps and no groundwater plume will occur. Contaminated mine water is pumped separately from clean water and is re-used or treated before discharge. As a result of mine dewatering there should be very little accumulation of contaminated water within the mine workings that might flush through as the groundwater rises.

It is not possible to make firm predictions about the quality of water in any potential groundwater plume. However, analysis of water draining to the mine sumps and from current and recently backfilled mine areas will give an indication of the likely worst case conditions. Table 2 gives analytical data from recent measurements in 2005, compared with the process effluent limits for the River Goul discharge in the Galmoy Mine IPC licence.

Table 2
Recent Mine Water Monitoring

Samples from:		Parameter, concentration in mg/l										
		pH	$CaCO_3$	SS	NO_3	NO_2	SO_4	NH_3	Pb	Zn	Cd	As
Old Backfill area (5 samples)	mean		136.0	34.2	13.6	2.2	119.6	3.4	0.070	0.211		
	min		68.0	1.0	10.0	2.0	105.0	3.0	0.004	0.010		
	max		240.0	134.0	23.0	2.5	164.0	3.9	0.274	0.633		
Recent Backfill area (5 samples)	mean		778.4	621.0	23.2	1.8	1430.8	6.2	9.93	2.475		
	min		180.0	260.0	2.0	0.8	78.0	2.3	1.75	0.506		
	max		2048.0	1285.0	53.0	2.8	2928.0	9.4	26.40	7.535		
Mine water pumping (Feb – June 2005)	mean	8.17		733.0	12.6	0.26	184.6	1.99	4.44	7.60	0.018	0.139
	min	7.51		9.0	4.0	0.02	111.0	0.71	0.25	1.60	0.005	0.103
	max	10.77		14496.0	49.0	0.03	817.0	6.32	135.0	81.90	0.036	0.195
Process effluent limit (R Goul)		6 - 9		25.0	50.0	2.0	1000	1.00	0.050	0.300	0.005	0.050

From this it can be seen that there is a marked reduction in water contamination as the backfill ages, to the point where average concentrations in water from the old backfill are approaching the process effluent limits. Concentrations of dissolved metals (lead, zinc, cadmium and arsenic) in the mine pumped water are elevated above the limit values, as a result of mine activities and solubilisation of residual metals in the workings. However, the limestone rock through which any resultant water will flow has a high buffering capacity and dissolved metals will be precipitated and immobilised over a short distance.

The potential for ARD in underground workings has been considered throughout the life of the mine to date. Whilst sulphate levels in the mine water fluctuate, pH conditions remain highly alkaline and there are no visible signs of ARD occurrence (such as ochre deposits typical of ARD).

The Company will be continuing to monitor water quality from backfilled areas. The growing database of water quality information will be used to make further predictions about water quality.

During the active care period, mine water can continue to be pumped if necessary, and treated before discharge. It would be expected that following re-establishment of the groundwater regime, the groundwater quality will improve considerably due to a combination of:

- prior removal of the soluble contaminants;
- major reduction in availability of potential contaminants as mining activities cease;
- cessation of pyrite oxidation in remaining mineralised zones, following flooding;
- reduction in permeability of the mine workings with backfilling;
- attenuation, filtration and precipitation of contaminants in the limestone and highly buffered rock strata downstream.

6 Conclusions

Following the cessation of mine dewatering by pumping it is estimated that the groundwater will rebound over a period of about 2 years. The rate of rebound can be controlled by pumping from the mine dewatering wells if necessary.

Mine drainage water from the active mine is currently treated to remove contaminants prior to discharge. Monitoring of water issuing from recently and older filled stopes shows that the levels of contaminants fall steadily with time. A variety of factors indicate that it is unlikely that a significant plume of contamination will occur from the mine workings once the groundwater regime has been re-established. Should a plume develop in the short term it can be controlled and treated in the mine water treatment plant as necessary.

The likelihood of contamination in the existing private wells within the mine area and the production wells for the RWSS is considered to be remote due to very high natural buffering capacity of the local limestone geology.

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Golder Associates, 1999. Assessment of Measured Drawdowns and Predicted Impacts of Future Mine Development: September 1999.

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Golder Associates, 2003. Report on Groundwater Catchment Analysis for the R Zone: Galmoy Mine

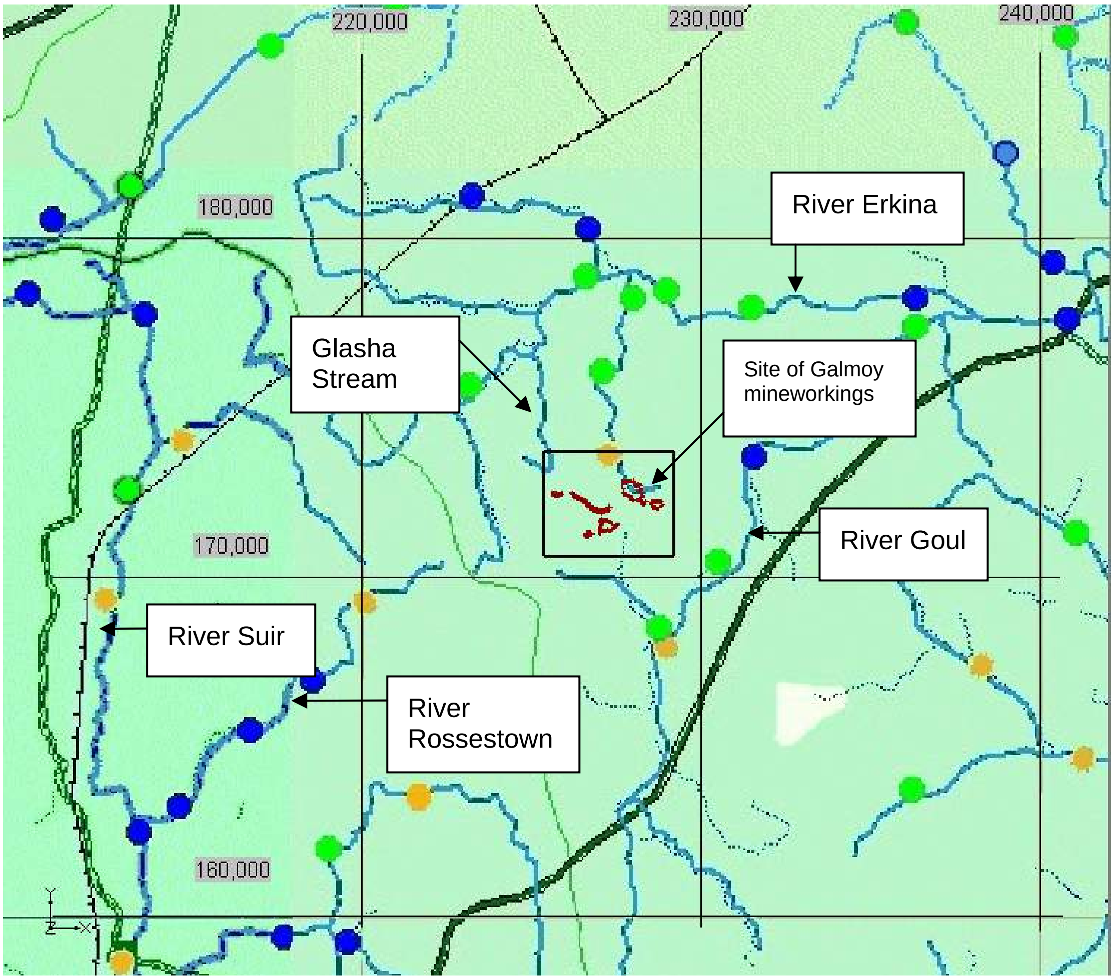

Figure 1 Location of Galmoy Mine in relation to the river systems.
Background map from Environmental Protection Agency (http://www.epa.ie/rivermap/). The blue dots refer to unpolluted river quality, green to slightly polluted and orange to moderately polluted.

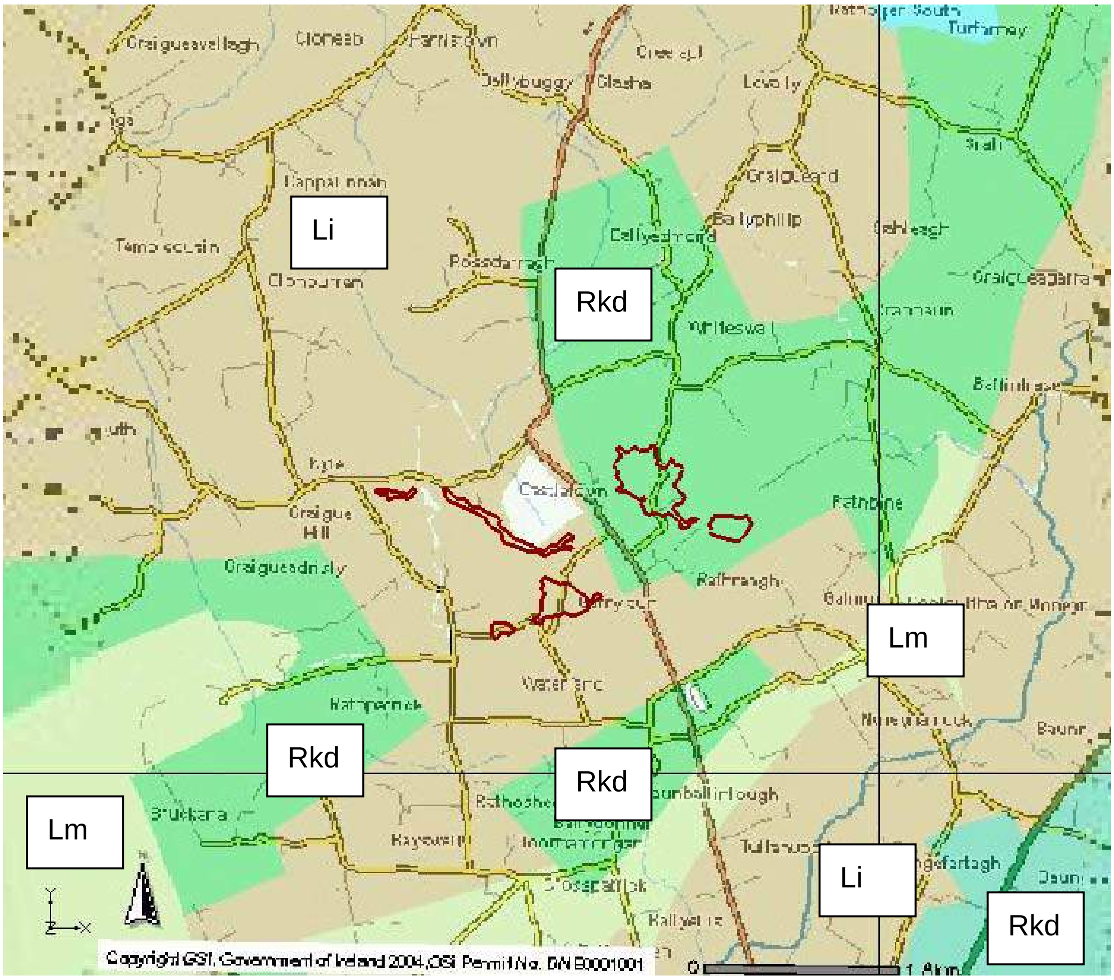

Figure 2 Classification of aquifers.
From http://www.gsi.ie/. See text for key.

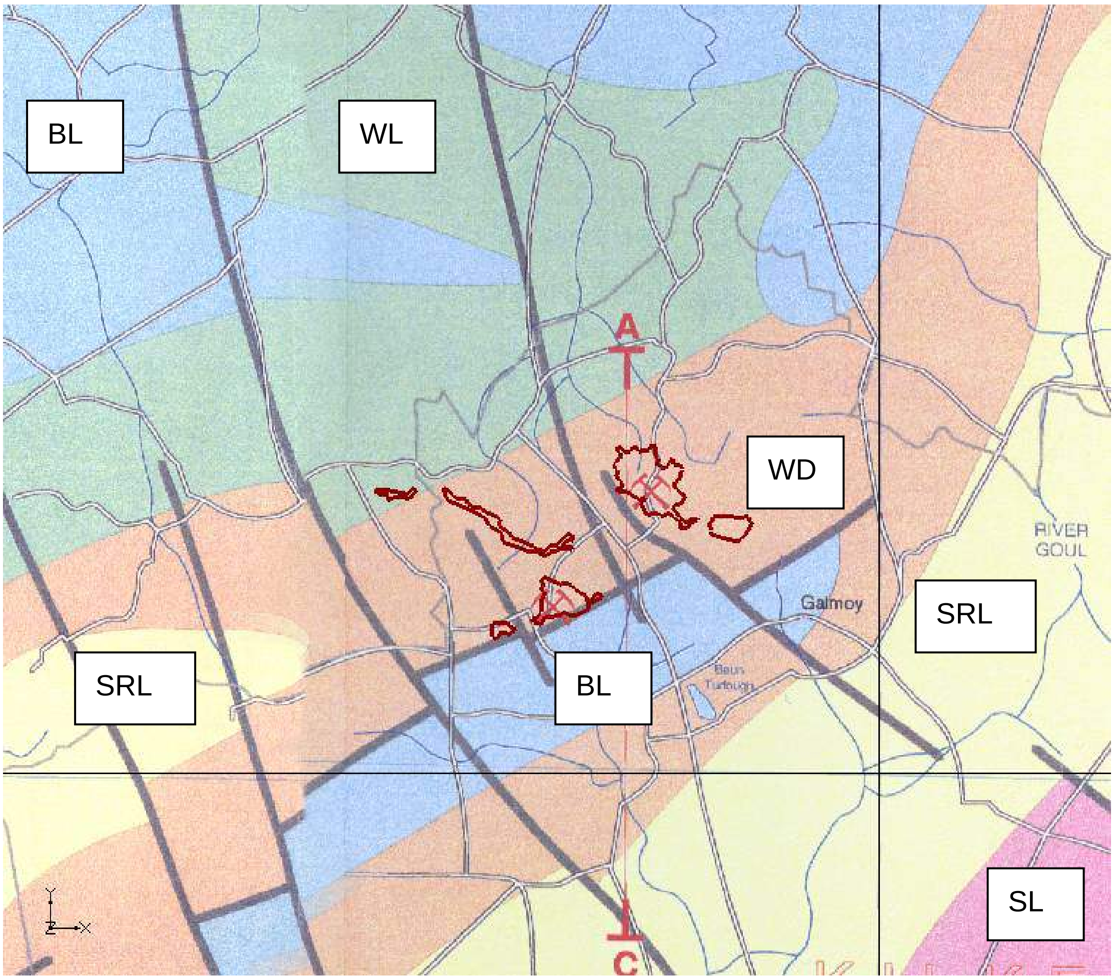

Figure 3 Classification of aquifers.

From Cullen (1992), covering the same area as Figure 2. BL = Ballysteen Limestone, WL = Waulsortian Dolomite, SRL = Supra Reef Limiestone, SL = Shelf Limestone.

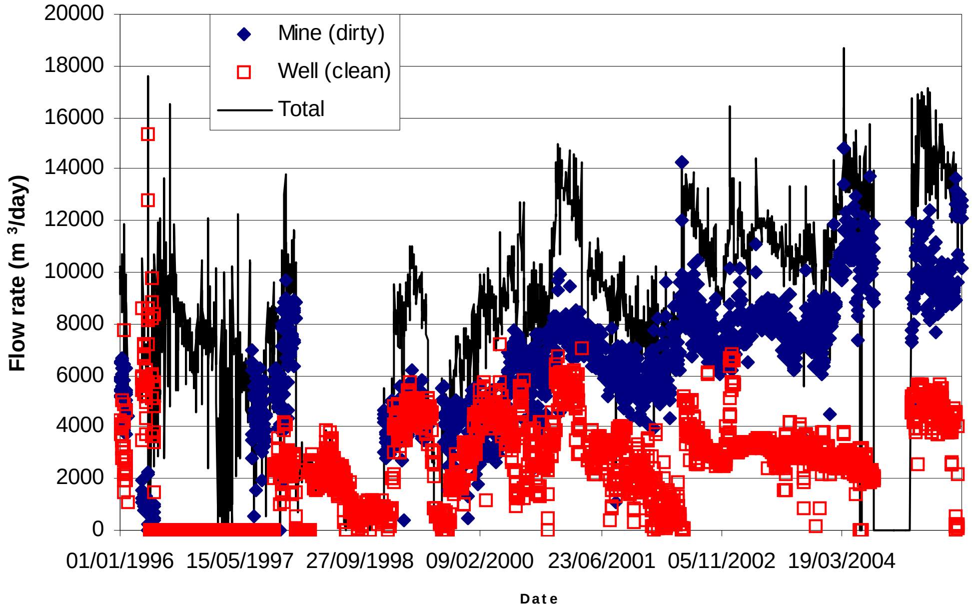

Figure 4 Rates of pumping of water from the mine

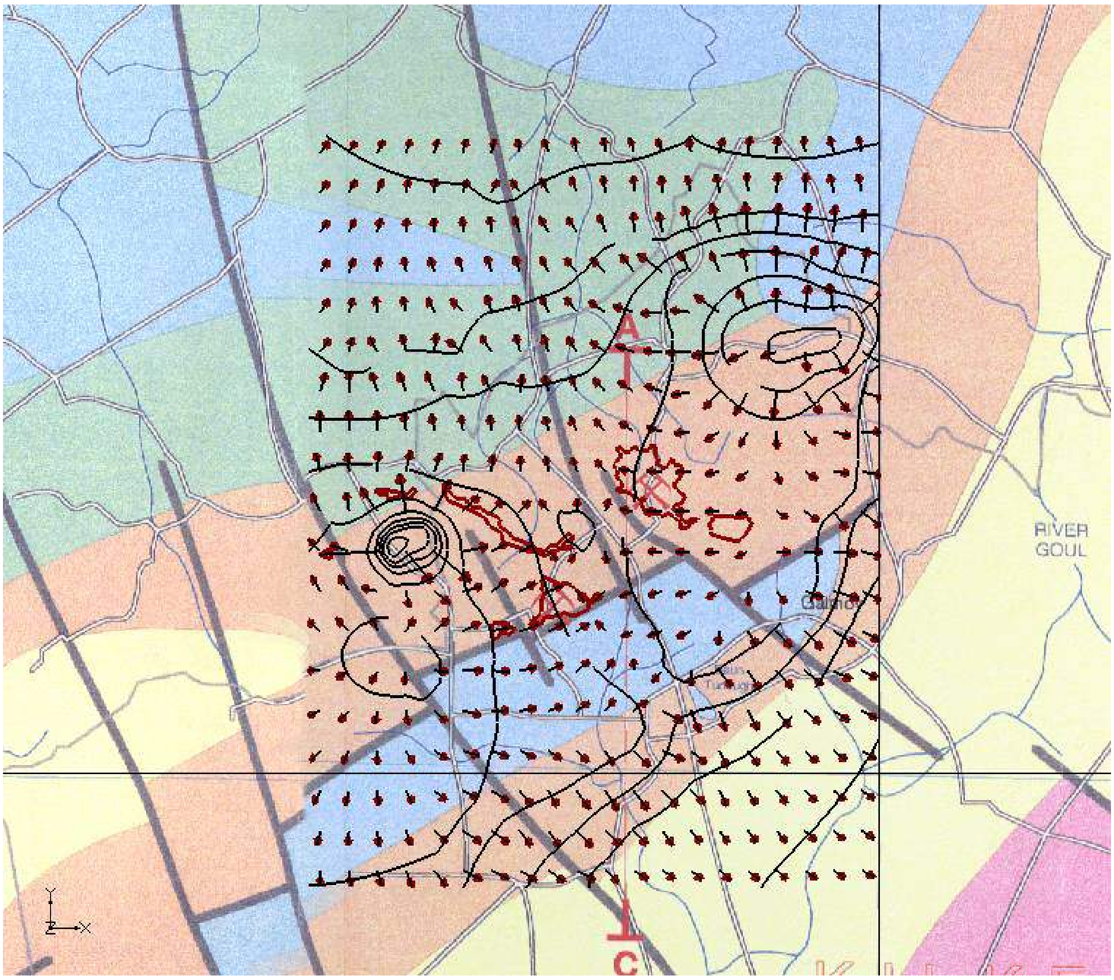

Figure 5 Contours of groundwater head and directions of groundwater flow in July1992.

Based on Cullen (1992).

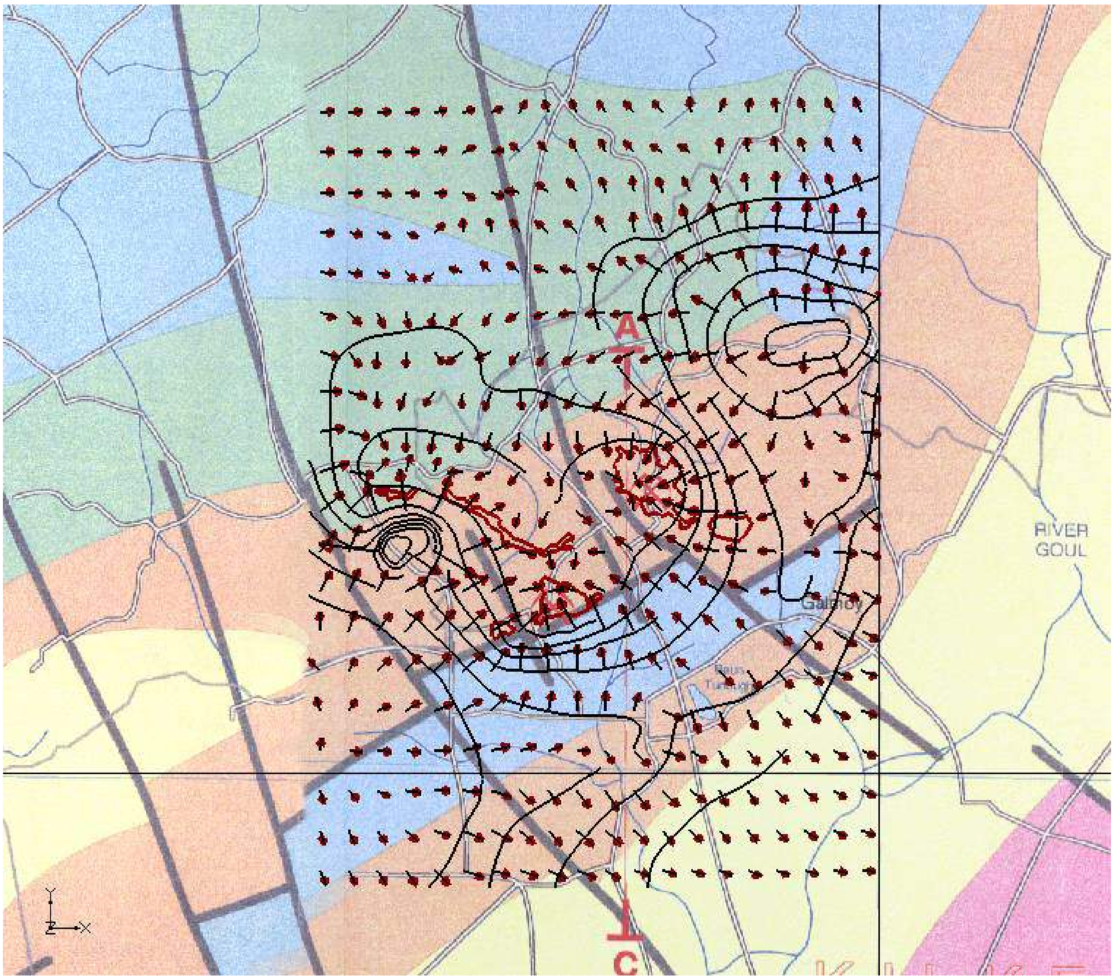

Figure 6 Contours of groundwater head and directions of groundwater flow including the impact of dewatering.

Based on the initial heads in Cullen (1992) with the drawdown in Golders (2000) superimposed.

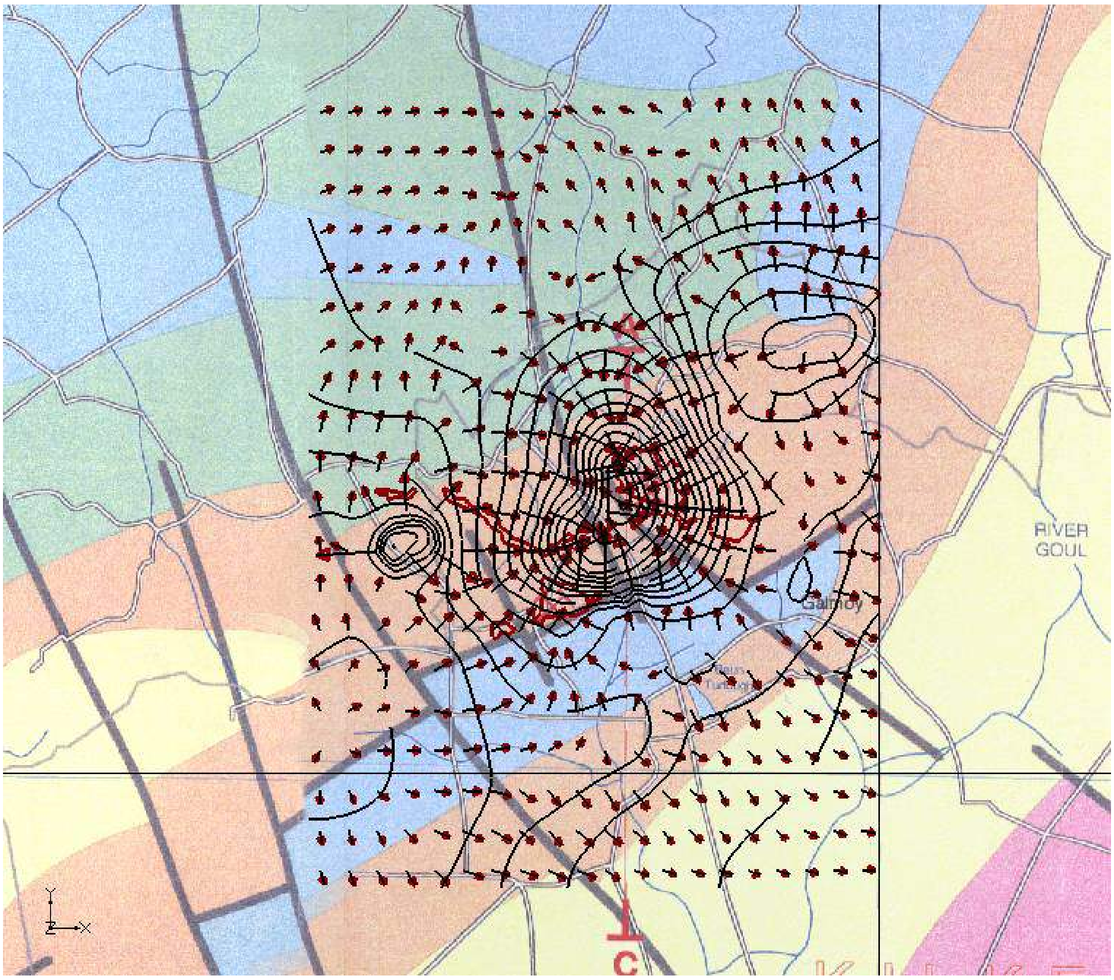

Figure 7 Contours of groundwater head and directions of groundwater flow including the impact of dewatering.

Based on the initial heads in Cullen (1992) with the drawdown in 2002 from Golders (2003) superimposed.

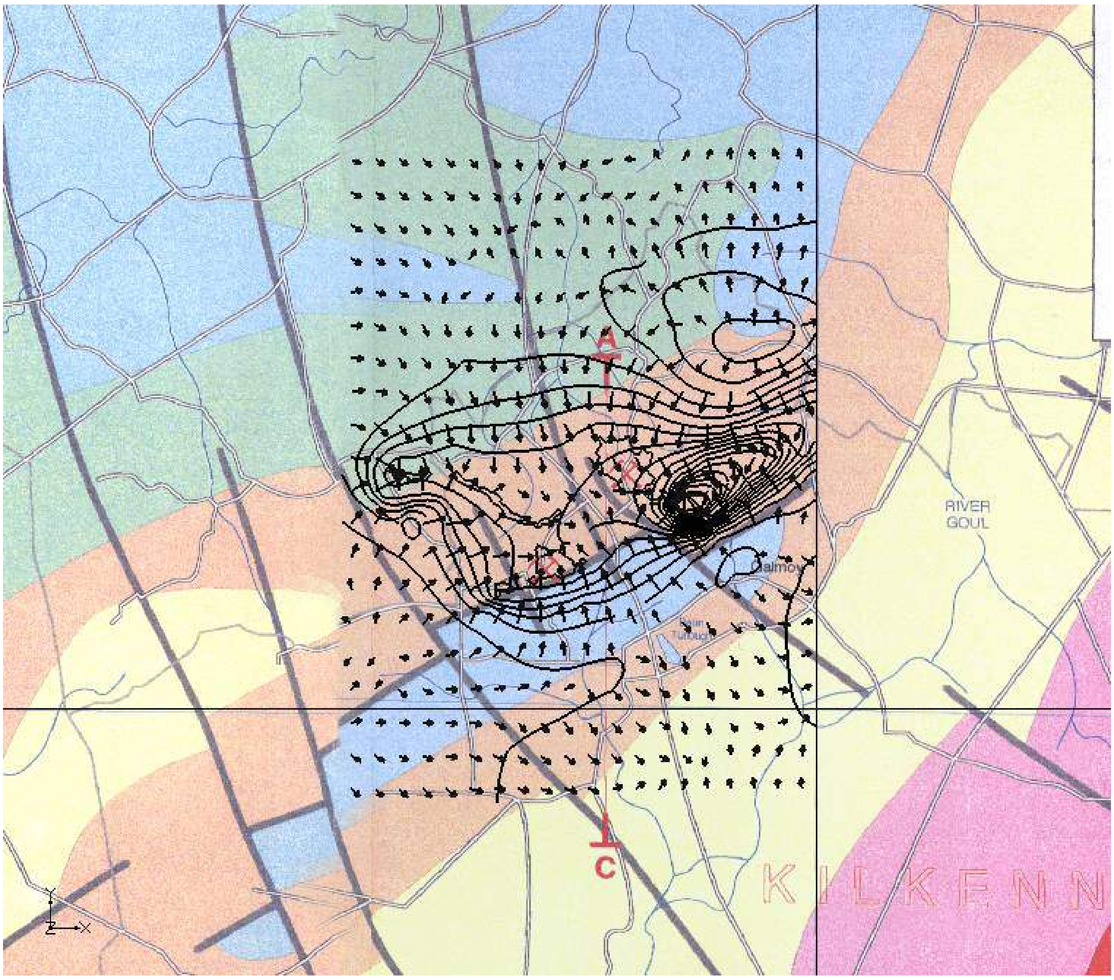

Figure 8. Contours of groundwater head and directions of groundwater flow including the impact of dewatering.

Based on the initial heads in Cullen (1992) with the predicted drawdown for dewatering the R Zone in Golders (2003) superimposed.

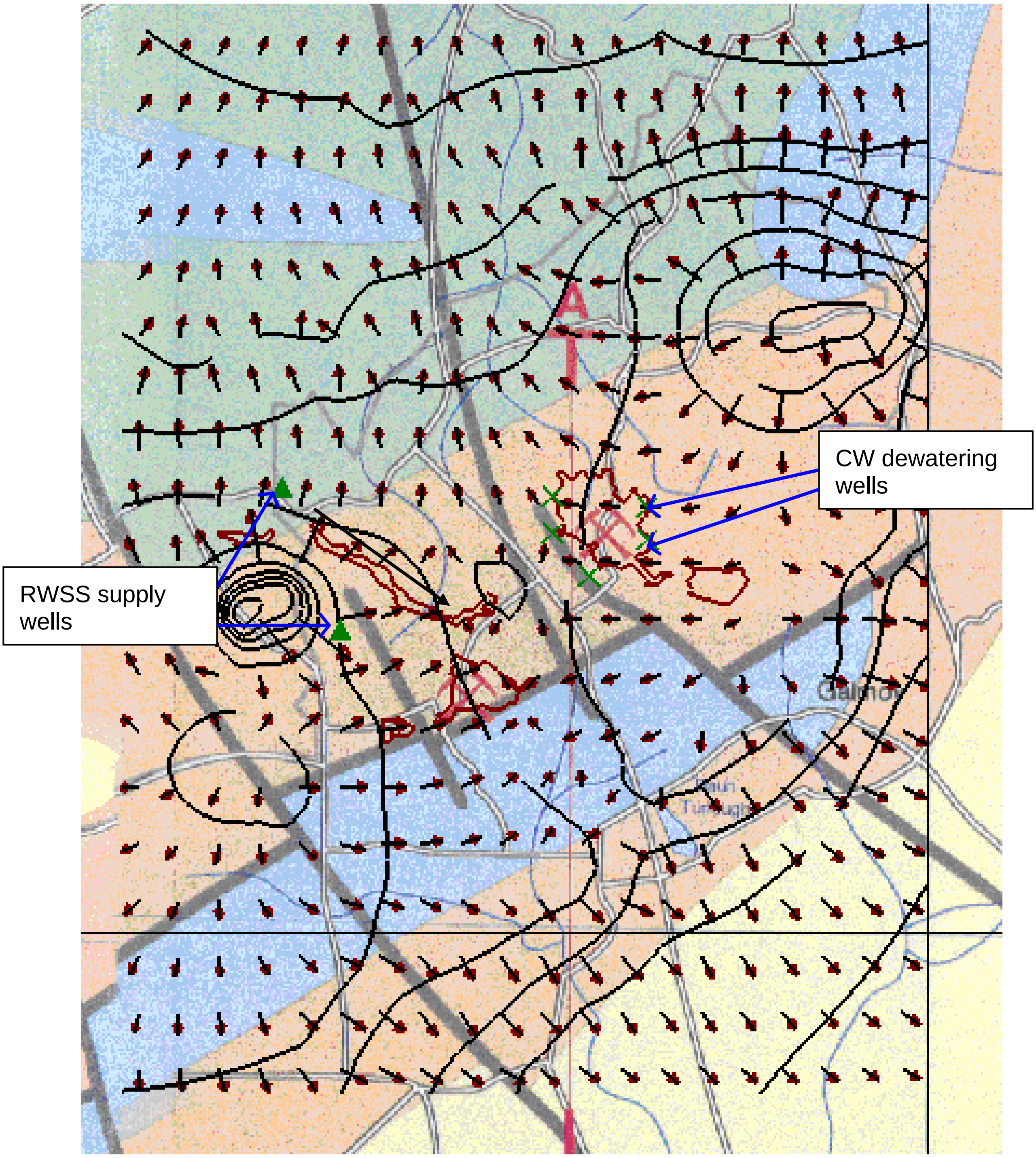

Figure 9. Contours of groundwater head and directions of natural groundwater flow, including the locations of the RWSS wells and dewatering wells.

APPENDIX 2 : SURFACE STABILITY FROM UNDERGROUND MINING

Client: Galmoy Mines Ltd

Review of Surface Stability from Underground Mining

Prepared by:

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Wardell Armstrong International Limited

November 2005

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CONTENTS

1.0 INTRODUCTION

This report presents an overview of the stability of the underground excavations at Galmoy Mine and a summary of the evidence supporting the conclusions.

Prior to, and since the commencement of production operations, GALMOY Mines Ltd (formerly Arcon Mines Ltd) has engaged the specialist services of Golder Associates Ltd ('Golders') to assist in the assessment of ground stability and the design of underground support measures at the mine. As such, the reports prepared by Golders over this period have been used as the basis of this review.

The reports produced by Golders fall into four broad categories:

1) Those associated with the general design of mining method and underground support;
2) Those associated with the mining of the K orebody beneath, and in the vicinity of the Tailings Management Facility (TMF);
3) Those produced following the ground collapse in CW orebody and the resulting surface subsidence in 2002; and
4) Annual audit reports on the underground mining operations.

Those reports reviewed are listed at the end of this report.

In addition to the above, the Company has produced an *'Underground Failure Prevention Plan'* in order to comply with Condition 13 of the Integrated Pollution Control Licence issued by the Environmental Protection Authority.

2.0 PERIOD 1997-2001

The Golders report, *'Review of Rock Mechanics Aspects of Galmoy Mine' – June 1993* was prepared prior to the commencement of mining operations and was based on an assessment of the strata conditions from an examination of the rock core from exploratory boreholes. The report addressed:

- the proposed mining method;
- the stability of the ancillary excavations; and
- hydrogeological aspects.

As regards the proposed mining method, it was recommended that room and pillar mining be utilised in both the CW and G orebodies. Based on an empirical assessment of the borehole core, the mine design was proposed to have 10m wide roadways with 5m square pillars, resulting in an extraction ratio of 90%. It was envisaged that some additional support measures would also be necessary, such as grouted rock bolts.

The pillars were designed to ensure permanent stability of the mine and prevent any surface subsidence effects. Backfill was to be introduced primarily as a waste disposal operation, although it was proposed that this would also provide additional long-term security to the stability of the mine.

Support requirements were also proposed for the ancillary excavations (decline, settlers and crusher stations) comprising rockbolting and shotcreting.

Mining operations in the CW and G orebodies during the first five years of operations (1997-2001) were generally undertaken in accordance with the above principles. Tailings material was not utilised as backfill during 1997 to 1999 and only 8% and 17% of tailings produced, was placed underground in 2000 and 2001 respectively. Orebodies were divided into individual stopes, approximately 80m long and 60m wide, with rib pillars left between the stopes.

In September 1999, Golders produced the report *'Mining of the 'K' orebody and Possible Impact on the Galmoy Tailings Facility.'* This report reviewed the experience of mining in the CW Orebody, indicating that there had been no significant movement of the rock mass around the excavations in the orebody and no evidence was found of fissures intersected underground having migrated upwards to surface.

The report examined the situation with regards to mining of the K orebody adjacent to the south-western corner of Phase 2, and beneath the proposed Phase 3 extension, of the Tailings Management Facility. Particular ground support requirements were proposed for the orebody including cover drilling to identify any fissures or areas of potential water inflow and initial shotcrete support, followed up by rockbolting and additional reinforced shotcrete. It was also recommended that mining of the orebody be completed and the excavation area backfilled prior to construction of Phase 3 of the TMF in order to ensure the long-term security of the area.

A subsequent report, prepared by Golders in December 2000, *'Report on Mining and Stability Assessment, Galmoy Mine'* further reviewed the stability aspects from mining in the CW orebody and further addressed the support requirements for mining the K and K2 orebodies and the extension to the G orebody.

The review of operations in the CW orebody indicated no particular problems with excavation stability to that date. In general, the predicted mining layout of 10m wide rooms with 5m by 5m pillars had been maintained, although pillar dimensions had been increased to 6m by 6m to allow for increases in the orebody thickness and consequently, pillar height. Backfilling had commenced in some areas of the orebody with cemented tailings fill, associated with secondary extraction.

Mention is made of the presence of a number of steeply dipping fissures, some up to 8m wide, intersected by the mining operations. Due to the presence of weak material in these features, they required a range of support measures, from shotcrete through to steel sets. Despite the above, the mass rock quality in the underground excavations was found to be similar to that predicted from the initial exploratory boreholes.

The report also comments on the results of the surface subsidence monitoring that indicated a maximum of 20mm of movement since commencement of mining. In addition, no visual evidence of subsidence at surface had been evident at this time.

With regards to mining of the K orebody, the report observes that ground conditions in the orebody are predicted to be better than that in the CW. The report reinforces the recommendations of the previous report on the mining procedure – probe drilling and pre-drainage of fissures etc; localised support of fissures and areas of weak weathered ground by shotcreting; and progressive backfilling using cemented tailings. To ensure the long-term integrity of the TMF, it is stated that the portion of the K orebody beneath the TMF be completely mined and backfilled prior to construction of the Phase 3 cell.

3.0 2002 COLLAPSE

At the end of January 2002, a major collapse occurred in the K-stope of the CW orebody. Although there were no injuries or damage to equipment, the collapse precipitated significant subsidence at surface, resulting in the closure of a minor road.

Following the collapse, Golders undertook an investigation into its cause and produced a report *'Investigation into the causes of the surface subsidence at Galmoy Mine, CW orebody'* dated March 2002. The report describes the series of events leading up to the collapse and a scenario for the occurrence of the collapse. This is summarised below.

In the first half of 2001, a series of roof collapses occurred in the stopes adjacent to K stope, which were subsequently abandoned and backfilled by August 2001. The collapses resulted from the inability of the support system to control the particularly poor ground conditions in these stopes. Although a subsidence station immediately above the stopes recorded significant settlement (84mm), the seriousness of the situation was not appreciated at the time. As such, secondary mining of the rib pillar was undertaken at the end of 2001. Given the critical condition of the pillars in the O and P stopes, adjacent to K stope, a complete collapse of K stope was precipitated, which resulted in the subsidence of the block of ground above it and the subsidence at surface.

The Golders report provides an opinion that the collapse was primarily due to the particularly poor ground conditions not being taken into account. Also proactive changes to the support system were not implemented. The report recommended the introduction of operational procedures, including the continuous assessment of rock mass quality and its use to determine a more conservative room and pillar layout and the introduction of progressive backfilling as an integral part of the mining operation.

The report also re-addresses the mining of the K orebody and those measures previously proposed for its extraction i.e. subsidence monitoring, cover drilling, enhanced ground support, post-primary backfilling and stability assessment.

4.0 PERIOD 2002-2005

4.1 Underground Failure Prevention

Following the collapse, a more pro-active approach to ground support was implemented. This included the uprating of the backfill programme and various procedures to allow the continuous monitoring and assessment of ground conditions. This coincided with the granting of the Integrated Pollution Control Licence for the mine, which included, as part of Condition 13 '*Accident and Emergency Response',* the requirement for an *Underground Failure Prevention Plan* (Section 13.3). The *Underground Failure Prevention Plan* was introduced in December 2002 and subsequently revised in September 2003 and December 2003.

A copy of the *Underground Failure Prevention Plan* is appended to this report, however in summary, the plan includes the following measures:

- Mine pillar database – This provides measurements of all pillar dimensions, together with a description and numerical condition classification (I to VI, I being intact and VI meaning collapsed) of every pillar in the mine. Each accessible pillar in the mine is to be inspected by a mining engineer or geologist every three months and the results used to update the database.

- Subsidence monitoring programme – The installation of a grid of surface subsidence monitoring stations over the mining areas and their monitoring at a period not exceeding six months or more frequently if necessary.

- Protocol for working within Caution Zones – The establishment of working procedures for all mining within Caution Zones, defined as encompassing all underground workings which fall within a 60deg. angle of potential influence of the base and walls of the tailings impoundment and other surface structures. The protocol covers advance probe drilling, pillar design, stope layout, roof support, backfilling, subsidence monitoring, and long term monitoring and assessment.

- Protocol for all extraction procedures - The establishment of working procedures for all mining areas, including in particular, measures to identify areas of poor ground conditions or water bearing strata and the means by which the mine design and support mechanisms are altered to take account of them. The protocol includes for:

  - the compilation and assessment of geological and geotechnical data;
  - that mine design and support requirements are based on geotechnical data (NGI ‘Q’ values);
  - a review of ground support requirements is undertaken on a weekly basis;
  - stope stability assessments are carried out following primary extraction, prior to any secondary mining;
  - and the preparation of an independent annual audit on the mining operations, specifically examining ground support and subsidence issues.

- Backfill Protocol – The implementation of a backfilling protocol, including an annual backfill programme, filling method statement and quality control procedures to limit post-filling ground movements and ensure the long term stability of the workings.

The annual audit reports prepared by Golders have been used to assess the ground support and subsidence issues at the mine since the implementation of the above protocols. Two reports, '*Report on Mining Operations at the Galmoy Mine'* dated September 2004 and August 2005 (Draft) have been reviewed.

4.2 Ground Conditions

Within the CW Orebody, ground conditions generally stabilised following the 2002 collapse and the implementation of the backfill programme. There have been some issues with regards to pillars in the K stope area, but these have subsequently been backfilled. As of June 2005, less than 10% of the pillars in the CW orebody remain unconfined and these are located along the route of the escape way to the eastern ventilation shaft.

There has been some deterioration of a few pillars in the G Orebody, identified through the pillar database survey, although, in general, ground conditions are good.

In the narrow K Orebody, ground conditions are good and modelling work to evaluate the potential effects of mining beneath the proposed Phase 3 of the TMF is being undertaken.

With regards to the R-zone orebody, the ground conditions in and around the orebody have been found to be very good. In all cases, in the ore zone and in the footwall and hangingwall, the conditions are markedly superior to the conditions encountered in the CW ore-body. In particular, the rock in the hangingwall above the ore is particularly high quality. There has been some deterioration in the pillars; however, these have been stabilised by rockbolting and shotcrete.

Due to the thickness and high grade of the R orebody, alternative mining methods have been adopted, including drift-and-fill and bench-and-fill. These mining methods have been designed to minimise any surface subsidence as well as to maximise the value generated from the resource. Depending on the conditions in the orebody, the mining methods will leave in place permanent ore pillars or stopes filled with high-strength backfill in addition to cemented tailings backfill placed tightly to the roof. This combination of tightly filled excavations and high-strength pillars sized and located specifically for their capacity to restrict the convergence of the rock above the ore-body will be effective in minimising surface subsidence. This system will, however, require full utilisation and effective scheduling of the backfilling operations.

4.3 Backfill Quantities

During May 2005, the cumulative quantity of tailings placed underground since 1999 surpassed 1 million dry metric tonnes. Backfill production as a percentage of total tailings produced has increased steadily since 2001, when the backfill system was modified and re-commissioned. The figure below shows the percentage of tailings placed as backfill on an annual basis since 2001.

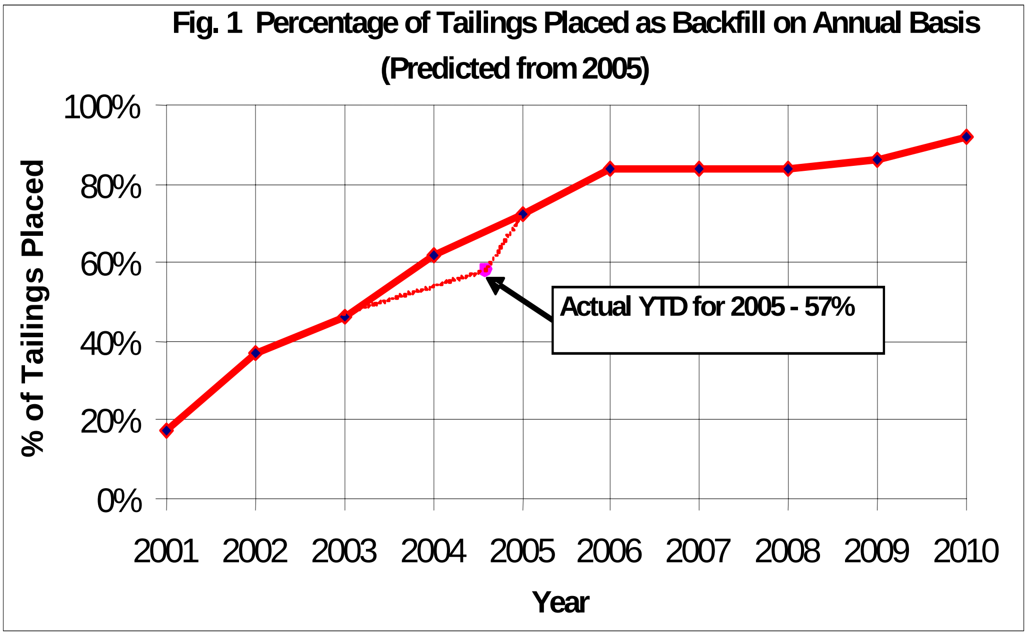

Figure 1 Percentage of Tailings Placed as Backfill on Annual Basis

During 2004, approximately 300,000 dmt (dry metric tonnes) of backfill was placed, representing 62% of the available tailings. Problems with plant availability, lack of tailings from the mill and poor preparation underground were the main reasons for the backfill target not being met.

The year to date value (June 2005) shows that the mine must improve the availability of their backfill plant during the second half of the year to reach their target of 72%. The current backfill upgrade will improve availability significantly and will deliver enhanced capacity, although it is unlikely to be commissioned before January 2006.

Table 1 below shows the programme of backfill placement from 2003 to the end of mine life at 2010

Table 1 Programme of Backfill Placement

	2003	2004	2005	2006	2007	2008	2009	2010	
Annual tailings produced (Kt)	542	482	502	523	523	523	523	518	
Cumulative tailings produced (Kt)	3,127	3,609	4,111	4,634	5,157	5,681	6,204	6,722	
Annual tailings to backfill (Kt)	250	297	361	445	445	445	445	466	
Cumulative tailings to backfill (Kt)	575	872	1,233	1,678	2,123	2,568	3,013	3,479	
Annual tailings to TMF (Kt)	292	185	140	79	79	79	79	52	
Annual % of tailings to backfill	46%	62%	72%	85%	85%	85%	85%	90%	
Cumulative % of tailings to backfill	18%	24%	30%	36%	41%	45%	49%	52%	
Cumulative % of underground void backfilled	32%	42%	51%	61%	69%	75%	81%	85%	
Additional backfill required to meet 50% requirement in event of premature closure (Kt)			823	639	456	273	89	-	
Proposed additional backfill to ensure stability of mine in event of premature closure (Kt)			275	275	275	273	89	-	

Notes:
1. Kt = ,000 dmt (dry metric tonnes)
2. Figures in red (2003 and 2004) are actual quantities, 2005 –2010 predicted.

The preliminary target of 85% of tailings placed underground annually appears achievable and the Company hope to exceed this value during 2006. This backfill plan will result in the mine placing over 50% of their tailings underground over the mine life. This meets the condition of the Planning Consent given by Kilkenny Council in March 2002 Condition 2 (g) and 2(h) 99/1371 and Condition 7.3 of the 2002 Integrated Pollution Control Licence. It can be seen from the table that at the end of the mine life approximately 85% of the underground voids in the mine would have been filled. Unfilled voids will comprise primarily access tunnels, ventilation routes and small areas where total tight fill has not been achieved.

In the event of premature closure, the quantities of backfill to be pumped underground to meet the 50% requirement are shown in the table. For years 2005 to 2007, these are extremely large quantities, requiring up to three years to achieve. This is not considered practicable and it is therefore proposed that up to 2007, an assessment of the unfilled voids would be carried out and those areas of excavation requiring backfill for long term stability would be filled. Partly developed stoping areas in good ground conditions and access drives would be left unfilled. It has been estimated that approximately 275,000dmt of tailings would be placed underground and that the backfill plant would run for about 1 year. Although this would not technically meet the 50% target, this would result in the filling of between 60% and 70% of the underground voids and the backfill would be placed to ensure the surface stability of the most important areas, including all surface structures.

To provide backfill, tailings would be recovered from Phase2 of the TMF and pumped back to the backfill plant at the mine site. The tailings would be thickened, cement added as required and the backfill pumped underground in normal fashion.

4.4 Backfill Quality Control

With regards to the quality control of the backfill, there was some concern at the beginning of 2005, as two stopes reported retarded strength gain in the curing backfill. A significant strength testing program was implemented and setting retardation was found to be related to zinc and lead levels (particularly non-sulphides) in the tailings. The stopes identified did eventually cure and setting retardation has not been an issue at the mine since the end of March. Golders note, however, that a definitive source of the non-sulphides was not proven and the performance of the backfill must continue to be carefully and continuously monitored through undergroud inspection and surface quality control samples.

The backfill system at Galmoy is currently undergoing modernisation with improvements to the surface plant. The modernisation involves the installation of surge capacity between the thickener and backfill plant, which facilitates an important upgrade in process control. Such improvements will enhance the availability of the plant while improving quality control of the backfill product. These changes are being made in advance of increased utilisation and the requirements for stronger backfill in areas of the R Orebody to support the proposed extraction plan.

4.5 Subsidence

A subsidence monitoring network has been installed above the orebodies since the start of production. Most recently this has been extended to the R Orebody. Monitoring surveys are carried out on a six monthly basis. The June 2005 survey indicated that all but two monitoring points, out of a total of 63, were within expected tolerances. One point was located over an area where no appreciable mining had taken place for a period of over 12 months. Further monitoring has indicated a rise of 2mm and 3mm in 2005. The second point lies immediately above the collapse area in CW Orebody and continues to show a small settlement, 2mm net in 2005.

5.0 CONCLUSIONS

The implementation of the protocols within the *Underground Failure Prevention Plan* have resulted in significant improvements in mine stability and ground control since the CW orebody collapse in 2002.

Surface monitoring over the last year has indicated no significant surface displacements and would also indicate stabilisation of the surface over the area of the CW collapse.

Underground monitoring using the pillar database has resulted in continuous proactive assessment to enable ground control resources to be efficiently targeted. Much work has been undertaken to improve the quality control in the backfill and there have been significant increases in the quantities of backfill placed. However, further improvements to the quantity of backfill placed need to be made and programmes are in place to address this

Over the life of the mine, the requirement to backfill at least 50% of the tailings produced would be met under the backfill programme proposed. This results in approximately 85% of the underground voids being backfilled across the mine, which should be sufficient to eliminate any risk of surface instability in the long term. In the event of premature closure of the mine, remedial backfilling would be undertaken in identified areas to ensure the long-term stability of all surface structures.

List of Golder Associates reports reviewed:

- *Review of Rock Mechanics Aspects of Galmoy Mine* – June 1993 (N. Hepworth, R. Hammett);
- *Report on the Mining of K Orebody and possible impact on the Galmoy Tailings Facility* – September 1999 (R. Hammett);
- *Report on Assessment of Tailings Dam Integrity Mining of K Oreb*ody - December 2000;
- *Report on Mining and Stability Assessment, Galmoy Mine* - December 2000;
- *Report on Investigation into the Causes of the Surface Subsidence at Galmoy Min*e – March 2002 (D. Morrison);
- *Report on Mining Operations at the Galmoy Mine* - September 2004;
- *Report on Mining Operations at Galmoy Mine January- June 2005*(Draft) - August 2005

APPENDIX 3 : STABILITYOF THE TMF

Client: Galmoy Mines Ltd

REVIEW OF THE STABILITY OF THE TMF

Prepared by:

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Wardell Armstrong International Limited

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REVIEW OF THE STABILITY OF THE TMF

1.0 INTRODUCTION

This report presents an overview of the physical stability of the tailings management facility (TMF) at Galmoy mine based on the technical documentation (listed at the end of this report) and general knowledge of the site. This report reviews the history of the TMF and summarises the controlling factors for stability and the design features. The report then presents an overview of the potential instability mechanism and describes how they are mitigated during operation and closure.

2.0 HISTORICAL OVERVIEW

From a historical perspective, the design and operation of the tailings disposal system at the Galmoy mine has followed a course commonly experienced with other sites. Initially, potential alternative sites and alternative disposal methods were assessed, and investigations and technical studies have been carried out to support the design. The operation has been monitored and audited, controlling factors have been reviewed in the light of changes to the life of mine plan, and amendments have been made to the design to adapt to these changing circumstances.

The original TMF design (Golder Associates, 1992) comprised three adjoining lined cells separated by internal earthfill water retaining embankments that linked to form a peripheral embankment. Drainage measures comprised a basal drainage blanket above the cell liner, and internal drainage within the embankments.

It was intended that the TMF would be developed in stages; each cell of the TMF would be constructed separately. A cover of supernatant water would be maintained over the tailings surface during operation of each cell. Deposition of tailings would be from a multispiggot system off the tailings delivery pipeline located on the crest of the embankments. The facility would be operated as an open system whereby supernatant water was returned to the processing plant.

During operation, there would be a programme of monitoring and field trials to evaluate performance of the facility and to provide technical data for the closure design.

At closure, it was initially envisaged that the tailings surface would be graded to a central decant structure connected to a piped outfall to remove surface water from the facility under normal conditions. A spillway would be constructed to cater for extreme rainfall events. The surface would be revegetated and the land returned to an amenity usage.

The mine commenced underground mining in 1996, and the TMF has been in constant use since that time. However, changes have been made to the original TMF design. The original concept of three adjoining linked cells remains, but the numbering, size and sequencing of construction has changed. Phase 1 (originally named Cell 2 in the design report) was constructed first to the original design and was operated as originally intended until 2000 . Phase 2 (the footprint overlies part of the original Cells 2 and 3) has been operated since 2000.

The current and original configuration of the TMF is shown in Figure 5.8 of the Second Interim Mine Closure Plan.

The main changes to the life of mine plan that affect the underlying principles behind the design and operation of the TMF occurred following the discovery of new orebodies. The TMF was designed to accommodate tailings produced from processing ore in the 'CW' and 'G' orebodies, which will be worked up to 2007. The mine reserves have now been extended by the discovery of the 'K' and 'R' orebodies, extending the life of mine to 2010.

Although the tailings storage requirement has been increased, the disposal method has been changed since 2000 to include underground high density backfilling using the coarse tailings fraction initially and subsequently total tailings. Consequently there has been a significant decrease in the quantity of tailings reporting to the TMF. The initial use of coarse tailings for backfill was only a temporary measure. The backfill plant has been upgraded and now places total tailings underground, and will do for the foreseeable future.

The 'K' orebody is situated immediately adjacent to the southern footprint of Phase 2 of the TMF and crosses the area allocated to Phase 3 (which is due to be constructed in 2006). Current predictions regarding the storage requirement in the TMF indicate that there is insufficient capacity in Phase 2 to accommodate tailings production up to 2010, and Phase 3 will be needed.

Storage requirements are summarised as follows:

- Galmoy is currently predicted to generate a total of 6.7 million tonnes of tailings over the full operational life (based on a total mineable reserve of 8.7 million tonnes). Approximately 3.5 million tonnes of tailings will be used underground as backfill. Consequently, the remaining 3.2 million tonnes require disposal in the surface tailings management facility. At the calculated tailings density of 1.50 t/m^3, the impoundment is required to have a storage volume of some 2.16 million m^3.

- The TMF is currently divided into two separate cells, known as Phases 1 and Phases 2. Phase 1 had a capacity of 880,000m³ and was filled in July 2000. It is currently undergoing rehabilitation. Phase 2, with a design capacity of 1.167 million m^3 is being currently used for disposal. At the end of December 2004 an approximate volume of 230,000m³ remained in Phase 2 of the facility.

- Phase 3, as yet unconstructed, has a design capacity of 777,000 m3. It is planned to construct this phase in 2006.

3.0 CONTROLLING FACTORS

3.1 Main factors controlling stability

The main factors controlling the stability of the TMF during construction, operation and closure are summarised in this section. These factors were assessed by the TMF design (Golder Associates, 1992), and were reviewed by an independent firm of consulting engineers (MRM Partnership, 1992). The closure situation was assessed initially by the Mine Closure and Rehabilitation Plan (Wardell Armstrong, 1992).

The main stability concern expressed at the planning stage was the potential for a catastrophic collapse due to the presence of paleokarst features in the underlying limestone strata. This potential failure mechanism was reviewed in the site investigation report (Golder Associates, 1992b), by the independent review report (MRM Partnership, 1992). A probabilistic risk assessment report (Golder Associates, 1993) was also carried out to evaluate this mechanism. The risk of collapse was shown to be negligible, and no mitigation measures were required. A large scale field trial was undertaken to flood the impoundment at the time when the water table had been lowered, without identifying any evidence of sinkhole formation.

Construction-related factors addressed by the design are the stability of cut and fill slopes, earthworks suitability, and ground preparation works, all of which are routine for projects of this nature. During the operational life of the TMF, the design makes due allowance for an appropriate water management regime that takes into account exceptional events.

The embankments of the TMF have been designed as water retaining structures and incorporate internal drainage layers (chimney drains, finger drains and downstream filter drains) to control the phreatic surface. Calculations at design stage show that the long term factor of safety against rotational slippage is $F > 1.4$.

3.2 TMF design & construction

A detailed design phase comprising the following preceded the construction of Phases 1 and 2, and will be repeated for Phase 3:

- A site investigation, including the use of geophysical techniques, trial pits and drilling.
- A flood-testing programme on the footprint of each cell to ensure the integrity of the foundations.
- Identification of suitable construction materials in nearby borrow areas.
- The detailed design of the tailings facility incorporated the requirements of An Bord Planeala Planning Conditions reference PL 10.091530, Item 47.
- Lowering of groundwater levels prior to construction.
- Pre-flooding of the impoundment to detect any sinkholes in the underlying limestone.
- Installation of internal drainage zones, chimney dams and protective filters within external walls.
- Installation of a synthetic biaxial geogrid across the base of the impoundment.
- Installation of a double HDPE liner overlying the geogrid.
- Provision of a “fail-safe” berm to contain potential spillage of up to 25% of the dam capacity.
- Installation of dewatering and monitoring wells.

The construction of the TMF is documented in detail elsewhere (e.g. Golder Associates, 2000a). In summary, construction comprised:

- Topsoil stripping to a depth of 400mm.
- Flood testing followed by localised infilling of “soft spots”, areas of peat deposits and other areas as required to achieve the required design ground level.
- Compaction of infilled areas using a 12 tonne Flat Drum roller.
- Construction of chimney drains comprising a 0.5m wide zone of coarse sand and gravel wrapped in geofabric.
- Construction of chimney collector drain incorporating a 225 mm perforated HDPE pipe bedded within a 0.5m wide zone of coarse sand and gravel wrapped in geofabric at the base of the embankment.
- Construction of finger drains at approximately 50m intervals connecting to the centreline chimney drains and feeding into an interceptor channel at the downstream toe to allow collection of seepage in one of three sumps.
- Construction of the earth embankment using glacial till, placed and compacted to design specifications.
- Grading of the cell floor to design level and compaction using a 12 tonne roller.
- Installation of the liner comprising (from the base):
  - A 500g/m2 non-woven geotextile and Huesker 20/20 biaxial geogrid.
  - A 0.75mm HDPE secondary liner overlain by a 1.5mm HDPE primary liner
  - A Pozidrain drainage layer.
- Placement of topsoil on the downstream face of the embankment and seeding with an appropriate amenity grass mixture.
- Excavation of a peripheral drainage ditch to direct surface water away from the facility.

- Installation of 42 standpipe piezometers within the embankment walls for monitoring of piezometric levels and 6 standpipe piezometers along the downstream toe for groundwater quality monitoring.
- Rehabilitation of borrow areas.
- Installation of a 2.44 m high security fence around the facility.

3.3 TMF operation and closure

During operation tailings are deposited in a lined impoundment area. The drainage layer above the liner controls the head of water across the liner and accelerates consolidation of the tailings.

Regarding the long term stability associated with closure, the controlling factors assessed by design are similar to the operational situation. There is however a different emphasis on flood handling and protection against pollution of controlled waters because of the different water balance situation and the requirement for a passive care solution once operations have ceased.

The controlling factors were reviewed (Golder Associates, 2003) using the results of monitoring carried out during construction and operation up to that time. Specifically, their review addressed the water balance and drainage requirements and identified modifications to long term drainage arrangements. At the same time, the construction records and monitoring results were reviewed and the risks associated with the potential for failure by paleokarst collapse and with seismicity were reassessed.

The conclusions of the Golder Associates (2003) report are summarised below:

- The water balance and drainage requirements were reviewed and it was concluded that no major design changes were required to the long term water management system.
- Minor amendments would be needed to the final layout because of design changes to the TMF footprint.
- The CQA data were reviewed and confirmed satisfactory construction of the TMF.
- The monitoring records indicate satisfactory performance of the TMF.
- No design changes were needed as a result of a review of extreme events.

3.4 Risk mitigation features

Table 1 below compares the original design features adopted to mitigate against identified risks, with those currently applicable to the TMF.

Table 1 Summary of design features

Design feature	***1992***	***2005 – changes compared to 1992***	***Comment***
Storage capacity	Storage provided for 2.8 million tonnes of tailings over a 10 year mine life, plus 15% contingency	Current predictions are 6.7 million tonnes of tailings will be produced over full operational life, with 3.2 million tonnes reporting to TMF	Staged construction for flexible approach to meet changing operational requirements
Wet or dry storage during operation	Wet	No change	Prevent dust blow Storage of process water
Open or closed system during operation	Open	No change	Storage of process water
Lining	Basal 1.5mm HDPE, geotextile and geogrid	Double HDPE liner used for Phase 2	Liner for environmental protection. Geogrid for additional security of formation in view of potential karst features
Underdrainage	300mm granular drainage blanket connected to 225mm HDPE connector pipes. Collected in a sump, water pumped back to impoundment	No change	Environmental protection, minimise head on liner, encourage consolidation of tailings to improve stability and maximise storage
Decant during operation	Pump decant, water returned to mill	No change	Operational feature, no spillway
Design storm event	1m freeboard to contain 1 in 100 year 24 hr storm event	Freeboard has not been maintained in phase 1; spillway constructed between Phases 1 and 2.	Original Kilkenny rainfall data validated by review of rainfall data at Galmoy
Embankment slopes	1 in 2	No change	Stability assessed for operation and closure
Design seismic event	Pga = 0.04g, annual probability of 1 in 10,000 year event	No change	Maximum credible earthquake
Construction			
CQA	Full CQA of materials provision and placement	No change	Standard procedure for embankment and liner construction
Ground treatment	Investigation for palaeokarst features, dewatering and flooding testing of ground	No change	Precautionary measure, with no problems identified
Drainage measures	Stream diversion and land drainage	No change	Ground preparation for operation and closure

	improvements required		
Operation			
Tailings density	1.4t/m^3 (assumed)	1.507t/m^3 (calculated)	Update based on operational monitoring
Seepage flows	2l/min for Phase 1 (predicted) seepage through liner	4m^3/hr (66l/min) monitored flow from Phase 1 overdrainage. 5.6m^3/hr (93l/min) predicted from Phase 2 overdrainage	Tailings overall permeability consistent with measured seepage flows
Water chemistry	pH and conductivity of all drains, sumps and monitoring wells	No change	Routine monitoring
Pore pressure	Standpipe piezometers	No change	Routine monitoring
Closure			
Spillway	24hr probable maximum flood event	No change	Open channel for ease of maintenance
Vegetation cover	Sufficient for low level amenity use with light grazing	Open grassland for light grazing	Options under review as trials progress

4.0 STABILITY ISSUES

4.1 Potential failure mechanisms

Potential 'failure' mechanisms are covered under the following headings:

- earthworks structure
- liner
- external factors
- internal factors
- rehabilitation
- long-term drainage function

Some of the geotechnical factors discussed in the original closure plan under earthworks structures operate in the short-term construction phase, rather than in the long term. These were included because of the potential effect of short-term disruption on the long-term stability of the impoundment, such as a stable formation being required for placement of the liner. As both Phases of the TMF have now been constructed, these are no longer relevant. Reference should be made to the various completion and construction quality assurance (CQA) reports prepared by Golder Associates for a detailed record of the impoundment construction and of the quality control measures that were adopted during construction in order to achieve the design standards.

The likely consequences of 'failure' and the measures incorporated into the design of the TMF to mitigate these consequences are also considered. The design measures are justified in the investigation and design reports (Golder Associates, 1990, 1992); for example, engineering parameters, factors of safety from geotechnical calculations, precautionary measures, specifications etc. An assessment is then made of the residual risk of physical instability.

Reference is made in this assessment to factors of safety. Factors of safety (FoS) are used to quantify stability. For foundations, the FoS is a measure of the ratio between the maximum load that can be tolerated before failure occurs and the load to be imposed. Values of FoS >3 are commonly sought in foundation design. With slopes, the factor of safety is a measure of the ratio between the strength of the soil and the forces tending to cause failure. Values of FoS between 1.2 and 1.5 are typically used in slope design, in order to allow for uncertainties in the engineering parameters used for calculations of stability, and to take into account the risk should failure occur.

4.2 Earthworks structure

The earthworks stage of impoundment construction consisted of the excavation of glacial materials to the desired elevation and the construction of Phase walls to contain the tailings. Table 2 summarises the factors affecting the short and long-term physical stability of the earthworks part of the tailings impoundment.

Table 2 Factors affecting physical stability of the earthworks structure

Mechanisms causing deterioration or disruption	***Effect on impoundment***				***Mitigating proposals (ref. Golder, 1992(a))***	
	Cell walls	***Liner and containment system***	***Tailings***	***Underlying and surrounding ground***	***Design measures***	***Monitoring***
Foundation failure	Collapse of embankment.	Damaged liner, blocked drainage.	Short Term; N/A Long Term; tailings exposed, contaminant dispersal.	Disturbed formation.	Staged construction to prevent undrained failure in short term. Long term FoS >3 against bearing capacity failure.	Short Term; All foundations will be examined. Settlement and pore pressure monitoring during construction.
Excavation slope failure (short term)	Collapse of embankment	Damaged liner	N/A	N/A	Slope stability assessment gives FoS=1.4	Visual inspections made during construction.
Cell wall slope failure	Short Term; unstable upstream slope prior to filling. Long Term; unstable downstream slope.	Damaged liner	Short Term; N/A Long Term; tailings exposed, contaminant dispersal.	N/A	Slope stability assessment gives FoS=1.4 in compacted granular fill for long and short term. For long term stability, drainage zones will be incorporated in case of seepages from the tailings.	Earthworks specification will ensure that fill is compacted to required strength.
Groundwater	Localised instability due to seepages in excavation slopes.	Damaged liner due to unstable formation.	N/A	Short Term; Loss of ground in granular horizons in slopes. Long Term; Effect on settlement and bearing capacity of foundation soils.	Groundwater lowering creates dry excavation. Drainage zones will be installed as required. Long term bearing capacity not adversely affected by groundwater changes.	Visual inspection during construction. Settlement and pore pressure monitoring.
Differential settlement	Cracking / distortion of cell walls.	Damaged liner Blocked drainage	N/A	Settlement.	Staged construction proposed to allow settlements to occur. Liner placed when settlement shown to be 70-80% complete.	Settlement monitoring.

FoS = Factor of Safety   N/A = Not Applicable

(1) Foundation failure

Bearing capacity calculations carried out prior to construction of the TMF show that there is a long term factor of safety against failure of greater than 3.0. The construction methods catered for the low, short term bearing capacity of the anticipated pockets of soft clay and the long-term factor of safety against bearing capacity failure is high. Overall, therefore, the risk of foundation failure can be discounted.

(2) Excavation slope failure

Portions of the cell walls have been formed by cut slopes in granular glacial soils at a gradient of 1 in 2. These slopes are now supported by impounded tailings and this category of failure is no longer relevant.

(3) Cell wall slope failure

The cell walls were constructed of excavated glacial till (silty sands and gravels). These materials were placed and compacted in accordance with an engineering specification to meet the necessary design parameters. The completion reports prepared by Golders Associates describe the construction works and the testing undertaken. Previous test work had shown that high densities could be obtained in these materials, and that shear strengths could be obtained that are similar in magnitude to the natural deposits from which the fill material was derived. Slope stability calculations undertaken prior to construction indicated that a factor of safety (FoS) of 1.4 could be achieved using these materials.

There are no specific values for factors of safety in the MIRO Technical Review, however, the Ontario Guidelines recommend values of FoS for the long-term stability of the downstream slopes of impoundments. Using peak shear strength parameters, a FoS=1.5 is required where it is anticipated that severe damage would occur as a result of failure, or a FoS=1.3 where the consequences are not severe. The FoS=1.4 for Galmoy is therefore considered reasonable for long-term stability of 'dry' slopes. The slopes will remain in a 'dry' condition during the short and long term due to the protection afforded to the upstream face by the liner. As an extra precaution, chimney drains have been installed into the cell walls to intercept any leakages, which could potentially reduce the FoS. If the water table rises, or if there are uncontrolled seepages into the cell walls, the FoS will reduce. This is considered further below (4).

(4) Groundwater

The stability of the TMF could be affected by groundwater for the following reasons:

- Localised seepages could occur in excavated slopes, creating instability in the short term.
- In the long term, seepages could occur through the impoundment walls creating unstable downstream slopes.
- After closure of the mine, groundwater levels will rise beneath the tailings impoundment. The bearing capacity and settlement behaviour of the foundation soils will be affected by

the long-term rise in water levels.

These factors have been taken into account in the design of the TMF as outlined in Table 3.

Table 3 Design measures: groundwater (Golder Associates 1992)

Groundwater	*Design Measure*	*Effect on stability*
Seepages out of cut slope	Mine dewatering effectively lowers water table below rockhead	FoS = 1.4 in dry condition. Persistent groundwater seepages controlled by gravel drains
Seepage through iimpoundment wall	Liner to contain tailings groundwater. Surface drainage of tailings prevents water accunmulation and spillage over the top of the liner. Drainage zones incorporated into impoundment walls: - chimney drains within Phase walls - finger drains beneath downstream slopes - sumps beneath internal Phase walls	FoS = 1.4 in dry conditions
Rising groundwater levels	Cell walls designed for long term, shallow goundwater table	Long term FoS>3 against bearing capacity failure with high groundwater.

Measures have therefore been incorporated into the design to either control groundwater or to assume the worst-case situation in the design. The drainage zones within the cell walls have been designed to filter out fines and hence maintain the effectiveness of the drainage paths.

If the liner does deteriorate, allowing water from the tailings to enter the cell walls, the low permeability of the tailings itself will control the rate of seepage. A rapid rise of the water table and water pressure within the cell wall, that would otherwise be associated with an open water impoundment, should not therefore occur.

An annual audit has been undertaken by Golders for Phase 1 and 2 cells since 2001. Both reports indicate that the drainage system, piezometers and monitoring wells are performing in accordance to the design and there are no issues to date relating to the effect of groundwater on the physical stability of the TMF.

(5) Differential settlement

The cell walls are subject to elastic and to consolidation components of settlement, as are the foundation soils. The cell walls were monitored during construction and further monitoring of the walls during operation of the TMF has shown no evidence of settlement.

4.3 Liner construction

The liner is an integral part of the TMF design. The impoundment has been designed on the basis that, in the absence of a liner, uncontrolled vertical seepages into the underlying limestone could initiate a sinkhole formation and potentially lead to failure of the tailings impoundment. The liner system comprised primary and secondary geomembranes, protective sand blanket, biaxial geogrid and geotextile on the cell floors. Further protective geotextile was placed on the embankment sideslopes to protect the exposed geomembrane from deterioration due to ultra violet radiation. Stringent quality control measures were adopted during construction in order to confirm that the liner was installed to the required specification. The factors affecting the long-term stability of the liner is summarised in Table 5 below.

Table 4 Factors affecting physical stability of liner

Mechanisms causing deterioration or disruption	***Effect On Structure***				***Mitigating proposals***	
	Cell walls	***Liner and Containment system***	***Tailings***	***Underlying and surrounding ground***	***Design measures***	***Monitoring***
Liner defective initially or damaged during installation.	Collapse	Damaged liner	N/A	Sinkholes	Protective sand layer. CQA proposals. Provision of internal drainage to cell walls. Protective geotextile layers.	Various tests and inspections.
Liner damaged during operation.	N/A	Damaged Liner	N/A	N/A	Precautionary measures adopted.	Regular TMF audits
Liner deteriorates with time.	N/A	Damaged liner	N/A	N/A	Liner selected to cater for chemical and physical conditions. CQA proposals and protection measures.	Regular TMF audits

N/A = Not Applicable CQA = Construction Quality Assurance

(6) Liner installation damage

The liner was placed on a geomembrane to protect it from damage by large or sharp objects in the underlying formation. Placement of the liner was carried out using recognised strict Construction Quality Assurance (CQA) guidelines (refer to Golders Associates report again ref for report) which indicated that all materials and workmanship conformed to the design specification.

(7) Liner operational damage

Provisions have been made to avoid damage to the liner during the operational life of the mine. These precautionary measures are summarised in Table 6.

Table 5 Design measures: operational protection (Golder 1992)
Liner covered by heavy duty, non-woven geotextile (slopes only)
Soft fenders on barge for pumps
Access to tailings impoundment restricted to ramps overlying the liner

With the adoption of sensible working practices and precautionary measures, the risk of damage to the lining system is minimised.

(8) Liner deterioration

The loss of liner integrity is generally not due to any one factor, but to a combination of factors. The most significant events that contribute to the degradation and eventual loss of integrity of an HDPE liner are summarised in Table 7, together with comments on the design measures to deal with them.

The principal factors affecting the long-term integrity of the system are poor installation/operational procedures and UV degradation by sunlight. Provided that the precautionary/quality control measures are adhered to, the risk of long-term physical instability can be minimised.

Limited long-term information makes prediction of the likely liner life span difficult. Under conditions where liners are relatively unstrained, protected from light, and contained in an anaerobic environment, predictions of life span are of the order of hundreds of years (eg. Gundle, 1992, Lyman et al, 1983, Koerner et al, 1990).

Table 6 Design measures: liner degradation (Golder 1992)

Factor causing degradation	***Design measures***
Poor installation and operational procedures.	CQA measures, protective sand layer and geotextile cover, operational precautions.
Temperature	ASTM tests (D746 and D794) show that temperatures encountered during normal liner operation are not detrimental to physical properties.
Chemical	See Appendix 4
Hydrolysis	See Appendix 4
Biological	Refer to tests by Ionescu et al (1982), which showed no effect on permeability.
Oxidation	See Appendix 4. Anti-oxidants are added to protect HDPE liner.
Sunlight	This is the most important factor. Carbon black is added to protect HDPE liner from UV degradation. The liner on the slopes will also be covered by a geotextile

The performance of the lining system has been evaluated by Golders Associates (2003) using the monitoring results collected during the operation of the facility. The water balance has been revised using the new data.

Estimates of seepage through the lining system have been revised upwards from 0.1m^3/hr to 4m^3/hr to accommodate a more realistic assessment of the potential liner defects. The quality of groundwater around the facility should be monitored because of increased predicted seepage rate across the base of the liner.

4.4 External Factors

The principal external factor that could affect the long-term stability of the tailings impoundment is the presence of paleokarst features in the limestone strata underlying the glacial soils in this area. Geophysical and borehole investigations identified sand-filled karstic features in the limestone, with occasional minor voids. Seismic activity could also affect the stability of the tailings impoundment. These external factors are summarised in Table 8.

(9) Sinkhole formation

With paleokarstic features, there is a risk of future sinkhole formation, which is a form of surface instability due to the collapse of strata into voids formed by karstic processes. Although no significant voids have been identified, it is recognised that future mining operations will alter the existing ground conditions and in the absence of precautionary measures, the changes could initiate collapse. Of particular concern would be changes in the groundwater regime bought about by mine dewatering and vertical seepages from the TMF. Beneath the impoundment, the consequence of a significant sinkhole development is failure of the tailings impoundment itself, tailings migration and liquefaction of the tailings.

Table 7 External factors affecting physical stability						
Mechanisms causing deterioration or disruption	***Effect on structure***				***Mitigating proposals (Golder 1992 (a) and (c))***	
	Cell walls	***Liner and containment system***	***Tailings***	***Underlying and surrounding ground***	***Design measures***	***Monitoring***
Sinkhole formation.	Collapse	Disruption	Collapse	Collapse	Precautionary measures incorporated into design to prevent damage associated with karst features identified by investigation.	[Golder, 1992]
Seismic event.	Collapse	Disruption	Liquefaction	N/A	Seismic risk evaluated and shown to be low. Peak acceleration 0.04g for 10,000 yr return period.	None proposed

A risk assessment associated with the presence of paleokarsts was undertaken during the design stage of the TMF. The risk assessment identified two potential mechanisms causing dam instability. These are the effects of mining and dewatering. Both require the migration of the material infilling the paleokarsts to create a void beneath the TMF which would rise to the surface.

As part of the design for the TMF, a microgravity survey was undertaken to locate the paleokarsts. These were then drilled to determine their extent. The main paleokarstic features were in the Phase 2 cell. Prior to construction of the Phase 1 cell, the area was dewatered by installing wells in the main anomalies and elsewhere to lower the water table and at the same time flood the site. The surface of the ground was monitored for settlement. The operation was to simulate dewatering of the mine. No movements were recorded. Prior to the construction of the Phase 2 cell dewatering from mining had already occurred beneath the TMF with no signs of ground movement. There are specific subsidence monitoring points on phase 1 and 2 which are monitored biannually as part of the subsidence monitoring programme. The annual audits of the TMF have indicated no significant movements of the dam wall crest.

The dam walls are constructed out of essentially granular glacial till and reasonably flexible as are the two low permeability membranes on the upstream dam face. The dam wall would be able to accommodate settlements in the order of 700mm, which would be significantly above any subsidence that is predicted from the mining operations.

(10) Seismic events

Seismic activity could potentially affect the integrity of the TMF by causing liquefaction of unconsolidated tailings. The design criteria for this mechanism is a peak ground acceleration of 0.04g for an annual probability of 1/10,000, which is very low.

The long-term probability of a seismic event of significant magnitude for failure is negligible. Furthermore, the tailings are progressively consolidated by basal and surface drainage, which leads to full consolidation of each cell within a period of a few years after completion of infilling, and the cell walls will be formed using compacted fills, which are not prone to liquefaction. In the long term, the stability of the impoundment structure will not therefore be sensitive to seismic events. The long-term risk of instability by this mechanism can therefore be discounted.

(11) Mining

The K orebody is located beneath the southern corner of the Phase 3 extension of the TMF, and lies close to the south-western limit of Phase 2. Phase 2 is currently in use, and Phase 3 has yet to be constructed. It is planned that the K orebody would be mined and backfilled before Phase 3 would be constructed. Currently there are plans to construct Phase 3 commencing in 2006, the K orebody is being mined and backfilling of the K orebody has also commenced.

The stability of Phase 2 could potentially be affected by mining of the K orebody. Potential instability mechanisms, including collapse of underground workings or shallow sink hole formation induced by a combination of factors, were addressed by Golder Associates (2000) prior to the commencement of mining.

The ground conditions underground are reported to be good and stability problems infrequent and under control. Monitoring of the mining activity underground has indicated no uncontrolled flows of paleokarstic infilling material into the stopes. It is proposed that Golders will carry out a numerical stability analysis to simulate the effect of underground mining of the K orebody on the TMF.

The Golder Associates (2000) report concluded that the (then) proposed undermining should not reduce the stability of the TMF. Operational procedures, including subsidence monitoring and cover drilling, are implemented in the caution zones associated with the TMF.

On current proposals, Phase 3 would not be affected by active undermining but could overlie backfilled mineworkings.

(12) Extreme Flood Events

The facility is designed to operate with no spillway off the TMF, with pond water level controlled by the return water pumps. There is no external catchment area and only rainfall falling onto the TMF surface enters the cells. The Phase 1 cell as completed has less that the anticipated minimum freeboard of 1000mm and in order to facilitate potential flood control on Phase 1 a spillway has been constructed between Phase 1 and Phase 2 (see calculations on extreme flood events in Golder Associates *Technical Memorandum Galmoy Mine TMF phase one decant spillway (2001)*. Phase 2 is not yet filled and the final flood capacity of this cell will be calculated when it is completed.

The likelihood of flood events is considered in Golder Associates, 1992 and 2003, which concludes that the rise in water on the surface of the TMF during a 1 in 100 year 24 hour peak rainfall event, including failure of the decant, will be less than 200mm on any cell. The risk of overtopping of the cell walls is therefore very remote. However, the risk of long-term extreme rainfall events requires that provision be made in the rehabilitated impoundment for a spillway to prevent uncontrolled overtopping of the impoundment wall.

The water balance has been reviewed as follows using recently obtained data (Golder Associates, 2003):

- The rainfall monitoring records at Galmoy have been compared with the baseline records at Kilkenny owned by Met Eireann originally used at design stage and were found to be comparable.
- Seepage estimates across Cells 1 and 2 have been reassessed under different flow conditions, taking into account the operational practices at the facility.
- The predicted inflows to the attenuation pond and downstream environment have been reassessed.

As part of the design of Phase 3 and the detailed closure design, it is proposed that the Phase 3 cell will incorporate sufficient flood storage to accommodate any excess requirements of Phases 1 and 2, in addition to the requirements of Phase 3 itself. This will mean that the spillway between Phase 1 and 2 will become permanent, and a new flood spillway will be constructed between Phase 2 and Phase 3. The Phase 3 design will include a full flood risk assessment so that the requirements can be incorporated.

4.5 Internal factors

Under this heading are discussed the effects of the tailings on the long-term physical stability of the TMF, as summarised in Table 8.

(13) Excess/shortfall of tailings

It is difficult to predict the exact volume of tailings to be produced and hence the precise storage volume required for the tailings impoundment. This is further complicated by the use of tailings for backfill in the underground workings that was not considered in the original closure plan. However, current predictions indicate that the current permitted reserves will not produce much tailings beyond that needed for backfill and completion of Phase 2, and Phase 3 will only be partially filled.

(14) Disposal of other wastes

Residues from the processing plant may contain some lead and zinc (depending on what stage the concentrate is at). The reagent used in the froth flotation includes sodium carbonate, sulphuric acid, hydrated lime, copper sulphate, zinc sulphate, sodium isoproply xanthate, potassium amyl xanthate, aryl dithiophosporic acid, methyl isobutyl carbinol and polyacrylamide.

Sludge from the treatment works will be deposited in the TMF and will contain the above metallic residues.

Table 8 Internal factors affecting physical stability

Mechanisms causing deterioration or disruption	***Effect on structure***				***Mitigating proposals (Golder 1992)***	
	Cell walls	***Liner and containment system***	***Tailings***	***Underlying and surrounding ground***	***Design measures***	***Monitoring***
Excess or shortfall of tailings	Revise design	Revise design	N/A	N/A	Extra capacity available.	Predictions of requirements further updated during life of mine
Liquefaction of tailings	N/A	N/A	Unstable	N/A	Tailings contained by cell walls and liner. Rate of consolidation of tailings maximised by surface and basal drainage.	None proposed
Overtopping of cell walls with floodwater	Severe gullying of downstream slope and slope failure	Disrupted	Exposure of tailings and uncontrolled erosion on to land and into watercourses	N/A	Adequate freeboard to store floodwater within the 3 cells collectively. Reinforced spillways between cells.	Inspection during/after flood event

(15) Liquefaction of tailings

Instability due to liquefaction of the tailings has been referred to under Item (14). Surface and basal drainage incorporated into tailings reduces risk of liquefaction by increasing the rate of consolidation. The design measures are summarised in Table 9:

Table 9 Design measures: Tailings liquefaction (Golder 1992)
Time for 95% consolidation of tailings by double drainage is shown to be 2.5 years Parameters used in analysis of tailings consolidation are: - Cv = 50 m²/Capacity of underdrainage > anticipated quantity of downward seepage - Permeability (vertical) of tailings approximately 10^{-8}m/s (based on gradings) - Permeability (horizontal) of underdrainage approximately 10^{-5}m/s Large, 225mm diam. collector pipes can be inspected. Blockages can be cleared.

The design measures limit the possibility of liquefaction of the tailings to the operational phase of the mine. The risk of long-term liquefaction can be discounted.

4.6 Rehabilitation

Aspects of the rehabilitation of the site which improve the long-term physical stability are regrading, vegetation establishment and drainage measures. Factors causing instability are summarised in Table 10.

Table 10 Rehabilitation factors affecting physical stability

Mechanisms causing deterioration or disruption	***Effect on structure***				***Mitigating proposals (Golder 1992)***	
	Cell walls	***Liner and containment system***	***Tailings***	***Underlying and surrounding ground***	***Design measures***	***Monitoring***
Surface erosion due to run-off	Gullying of downstream slope	Liner exposed above tailings	Exposure of tailings; uncontrolled erosion onto land and into watercourses	N/A	Use of vegetation cover. Use of coarser material at toe of downstream slope of cell wall. Groundwater control by ditches.	Inspections to be made during 5yr aftercare programme. Corrections to be made as necessary.
Weathering and 'ageing' process	Loss of strength leading to slope instability	Reduced effectiveness of liner	N/A	N/A	Use of vegetation cover to stabilise slopes	As above

(16) Surface erosion

Protection against surface erosion has been provided by topsoil and vegetation cover sufficient to reduce the erosion risk to very low, and hence maintain long-term stability of the impoundment walls.

The most effective vegetation cover for controlling erosion is a dense, uniform ground cover of herbs and grass, which has the following effects (Coppin & Richards, 1990):

- intercept a high proportion of rainfall
- prevent or minimise the effect of leaf drip
- promote a uniform pattern of arrival of rain at the soil surface and a uniform pattern of infiltration into the soil
- impart a high level of roughness to runoff

A dense growth of shrubs would have a similar effect, and in the long term the accumulating organic humus layer and plant roots will protect the soil surface from erosion and shallow movements.

The cell walls are constructed using coarser material at the downstream toe in order to minimise erosion. Topsoil and vegetation cover was established during the construction of the TMF. Groundwater and surface run off is controlled by peripheral ditching and further drainage measures to be constructed on completion of the impoundment (see Section 9.3).

(17) Weathering

The cell walls have been constructed using granular soils. The shear strength of these soils is represented by a zero cohesion value and a friction angle of Ø'=35. With time, the strength of the near surface soils will vary due to natural weathering as well as disturbance by root action and burrows. As a worst case, lower bound values of say Ø'=25 could be presumed for long term stability of this near surface layer. For the same reasons, the density of this layer will deteriorate from a compaction density of about 2.1Mg/m^3, to a lower bound value representative of subsoil, say, 1.6Mg/m^3. Due to the inert granular nature of the soils to be used to construct the cell walls, no further deterioration in the strength properties would take place by mechanisms such as softening or progressive failure, which apply to clay soils.

A reduction in strength with time will therefore apply to the near surface zone where the effects of weathering are pronounced. The use of vegetation is essential to maintain an adequate factor of safety for slope stability in this zone. Vegetation improves the stability of a slope by various mechanisms (Coppin & Richards, 1990). In particular the shear strength of the near surface layers can be enhanced by the restraining action of root growth. The mechanical effect is to increase the confining stress and resistance to shearing, and to increase the strength of the soil/root mass through the binding action of roots. With the granular fills of the cell walls, the effect of vegetation is to give the otherwise cohesionless soils an apparent cohesion, although the friction angle will remain unchanged. An additional beneficial effect on stability is an increase in soil suction.

4.7 Long term drainage function

The impoundment walls were constructed from glacial silty sands and gravels and lined with two HDPE geomembrane liners laid on top of a non-woven geotextile. Chimney drains incorporating a 0.5m wide zone of coarse sand and gravel wrapped in a geotextile and chimney collector drain incorporating a 225mm perforated HDPE pipe. Finger drains are located at approximately 50m intervals and connect to the centreline chimney drains. Forty two standpipe piezometers are constructed within the embankment walls and 6 standpipe piezometers around the perimeter of the dam for groundwater monitoring.

Monitoring systems to confirm the environmental and structural integrity of the facility during its operation have been installed. The internal drainage will be inspected for continuing flows and evidence of ochre precipitation. The water table within the tailings and within the impoundment cell walls is monitored via standpipe piezometer tubes installed during the operational phases.

The continuing functioning of the drainage to its full capacity within and around the TMF cannot be considered to be indefinite. The capacity will progressively decline, or it could cease entirely at some time in the future. Table 11 summarises the factors involved and the consequences that would occur.

Table 11 Long term factors affecting drainage function					
Mechanism causing deterioration or disruption	***Potential effect on structure***				***Mitigation (design)***
	Perimeter interceptor channel	***Chimney drains and sumps, etc. in cell walls***	***Internal drainage in cells***	***Impoundment surface drainage***	
Blockage with silts	Reduced capacity	Reduced permeability; build up of pore pressure locally in cell walls	Reduced permeability; internal drainage ceases to flow. Increased seepage through liner	Reduced capacity. Accumulation of water on impoundment surface	High permeability of granular materials. Wrapping of pipes with filter fabric. Large capacity pipes and channels
Blockage with vegetation, especially roots	Reduced capacity and flow; other material collects	Outside of root zone of vegetation. Finger drains would be blocked with roots	Outside of root zone of vegetation	Reduced capacity. Most of structure is outside root zone	Maintenance to remove dense growth
Blockage with ochre precipitation	N/A	Unlikely unless liner leaks significantly	Reduced permeability; internal drainage ceases to flow	N/A	High permeability of granular materials. Cleaning if necessary
Erosion and scour; weathering	Erosion of channel bed	N/A	N/A	Concrete construction will not erode, but concrete could deteriorate.	High quality construction of concrete structures. Low gradients or high roughness in channels

(18) Blockage with silts

Silts migrating into the granular drainage layers along with water flows will gradually reduce their permeability and thus flow rates. In the chimney drains within the cell walls this will result in locally high pore water pressures, which would affect the stability of the slope. However, the grading of materials used in the chimney drains is such that the permeability is maintained.

Migration of tailings into the internal drainage blanket and thus into the drainage pipes is inevitable, but restricted by the filter fabric wrapped around the pipes. However in the long term this fabric could become blocked.

Mitigation of fines into the chimney drains would only occur of there was a substantial water flow in this direction. The liner will effectively prevent flow from the tailings cells and, unless there is open water against the liner, any gradual deterioration in the liner will not result in substantial flows into the cell walls. However, if the flooding option were adopted for any of the cells, then this would lead to open water against the liner. In this event, a sealing layer of tailings will be placed against the liner, to provide long term containment of water within the cell.

(19) Blockage with vegetation

The perimeter interceptor channel will progressively become overgrown with vegetation, unless it is maintained by regular cleaning. Other parts of the drainage system should be outside the influence of plant roots, except for the finger drains at the base of the cell walls.

Surface water run off on the TMF is for the most part in open channels or large diameter pipes. Blockage of these with vegetation is therefore unlikely.

(20) Blockage with ochre formation

Drainage water reaching the internal drainage systems will be very unlikely to precipitate ochre, and any iron sulphates derived from the surface will have largely precipitated within the body of the tailings as hydroxides. However, some ochre formation at the base of the tailings cannot be ruled out.

Ochre would not lead to blockage of any of the surface drainage, which is mainly in open channels.

(21) Erosion and scour; weathering

Erosion of channels could only occur where water flow velocities and flow volumes are high. Where this could occur channels will be concrete lined.

The concrete of these channels will be designed to a high specification, but will still have a finite lifespan. Deterioration of the drainage channels can therefore be expected in the very long term.

(22) Overall implications for the impoundment

The long-term implications for each of the drainage structures is summarised in Table 12. Whilst deterioration and decline in function must be expected, the overall risk to the impoundment is considered to be low. The most critical element is the chimney drainage, which controls water pressures within the cell walls. This structure should maintain its function, however, because there will be little flow of fine material into it.

Table 12 Summary of long term implication for drainage structures
Perimeter interceptor channel Will become progressively clogged with vegetation unless cleared periodically. Surface water could accumulate near the toe of the downstream slope.
Chimney drains in cell walls Should remain effective at guarding against the risk of water pressure build-up within the cell walls over the long term.
Internal drainage Drainage blanket and filter wrapping over pipes will progressively clog, reducing flows. However, the water table within the tailings is controlled mainly by surface drainage, so the cells will not flood. Feeder and collector pipes should remain clear.
Surface drainage The system is open so blockage should not occur. Concrete structures (decant, spillway, cascade) will deteriorate in the very long term.

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APPENDIX 4 : TMF BEHAVIOUR AND WATER BALANCE

Client: Galmoy Mines Ltd

TMF BEHAVIOUR AND WATER BALANCE

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December 2005

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TMF BEHAVIOUR AND WATER BALANCE

1.0 INTRODUCTION

This report has been prepared by Wardell Armstrong International Ltd ('WAI') in support of the Second Interim Mine Closure Plan. The report reviews the current information and behaviour of the Galmoy Mine Tailings Management Facility, in terms of its long-term geochemical, environmental and hydrological stability. It is based on the analysis of these aspects given in the Initial Mine Closure Plan of 1992, updated with recent information and assessment of the risks of future instability. It also seeks to address the questions raised in the Expert Review of the first Interim Mine Closure Plan of 2004.

The Company, Arcon Mines Ltd, has provided information used in this review. The Company's Environmental Department carries out regular monitoring and assessment of a wide range of operational and environmental parameters and produces regular reports to the EPA. Recent data has been obtained from the Company's Annual Environmental Reports (AER) for 2003 and 2004.

Prior to and since the commencement of production at Galmoy, the Company has engaged the specialist services of Golder Associates Ltd ('Golders') for the design and monitoring of the TMF. Reports prepared by Golders for the Company have also been used for this review.

WAI has not carried out any independent monitoring or analysis, nor validated the information and data from the Company or Golders. However, WAI has used its own experience and knowledge to put the information and data in context and has satisfied itself that the data provided, and the methods and procedures used to obtain it, are appropriate and consistent with good practice.

2.0 TAILINGS CHARACTERISTICS

2.1 Physical Characteristics

A typical particle size analysis of total tailings from the plant (2005) is given in Table 1 below.

Table 1 - Typical size and metal analysis of total tailings (2005)

Description	***Size range, μm***	***Fraction %***	***Distribution, %, of***		
			Pb	***Zn***	***Fe***
Sand	> 250	1.74	0.77	0.08	0.33
Fine Sand	63 – 250	37.10	4.75	44.02	24.58
Silt	9 – 63	30.48	9.23	24.52	42.33
Clay	< 9	30.68	85.95	30.69	32.17

Total tailings were deposited in Phase 1 of the TMF, before the backfill plant was commissioned. The total tailings are thickened prior to use in backfill. Initially this meant that only the finer slimes fraction (less than ~20μm material), comprising fine silt and clay sized particles were deposited in the Phase 2 cell. However, improvements in the thickening process, using flocculents, means that now mainly total tailings is being backfilled and the material deposited in the TMF is no longer mainly the fines fraction.
After consolidation, it is predicted that the deposited tailings will have an average in situ permeability of $1x10E^{-8}$ m/s (Golder Associates, 1992).

2.2 Trace Element Chemistry

Prior to the commencement of mining the maximum concentrations of trace elements that are likely to occur experienced in the deposited tailings was predicted from the analysis of high grade samples recovered from the two principal orebodies (CW and G). The results of this were reported in the initial Mine Closure Plan.

Samples of tailings solids collected by Arcon Mines during 2001 and 2004 were analysed as follows:

Table 2 - Analysis of Tailings solids								
		%Zn	S-Zn	%Pb	S-Pb	%Fe	S-Fe	%S
2001 Phase 1	avr.	2.37		0.31		7.08		9.31
	min.	1.56		0.1		6.26		7.38
	max.	4.41		0.54		9.0		12.58
2004 Phase 2 (March)	avr.	3.9	1.91	4.43	0.69	8.61	9.88	12.48
	min.	2.75	1.35	2.76	0.43	7.25	8.32	10.61
	max.	4.6	2.25	6.95	1.08	10.57	12.13	15.45
2005 Phase 2	avr.	2.12	1.09	1.38* (0.58)	0.21	4.19	4.81	6.06
	min.	1.8	0.88	0.41	0.06	0.73	0.84	3.31
	max.	2.6	1.27	7.76* (0.86)	1.2	8.53	9.79	10.86
* Data skewed by one high result; figures in brackets exclude this result.								

Lead levels in the samples from Phase 1 are similar to those originally predicted; zinc levels are slightly higher. In Phase 2, lead levels in 2004 are very much higher than Phase 1 or the original predictions, as a result of mining ore with a higher lead grade in the G and R orebodies. However it reduced dramatically when the modified lead flotation circuit was commissioned in mid-2004.

Data for tailings solids content collected by Arcon Mines between 1997 and 2002 are summarised in the graphs below.

Figure 1 – Tailings Solids Zn

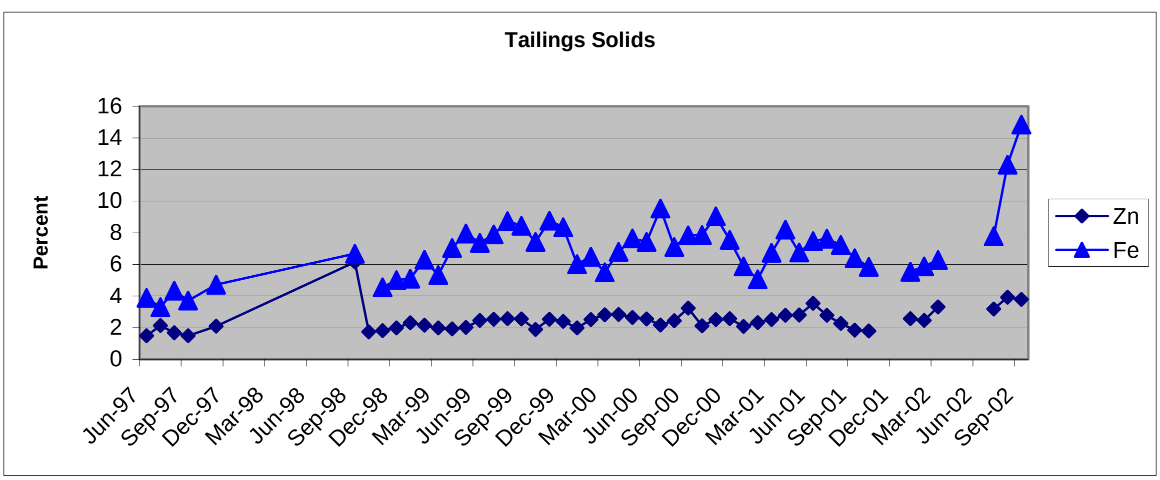
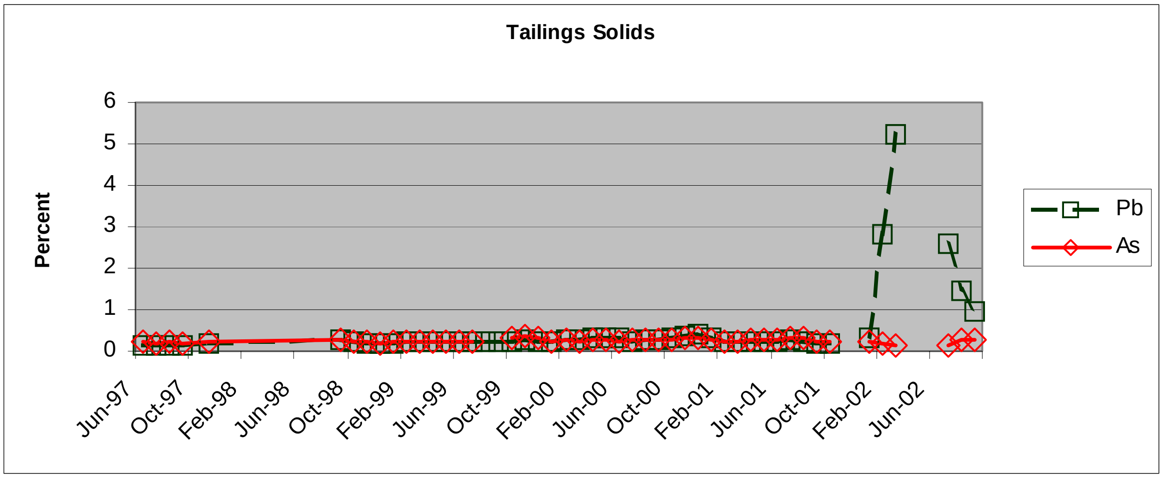
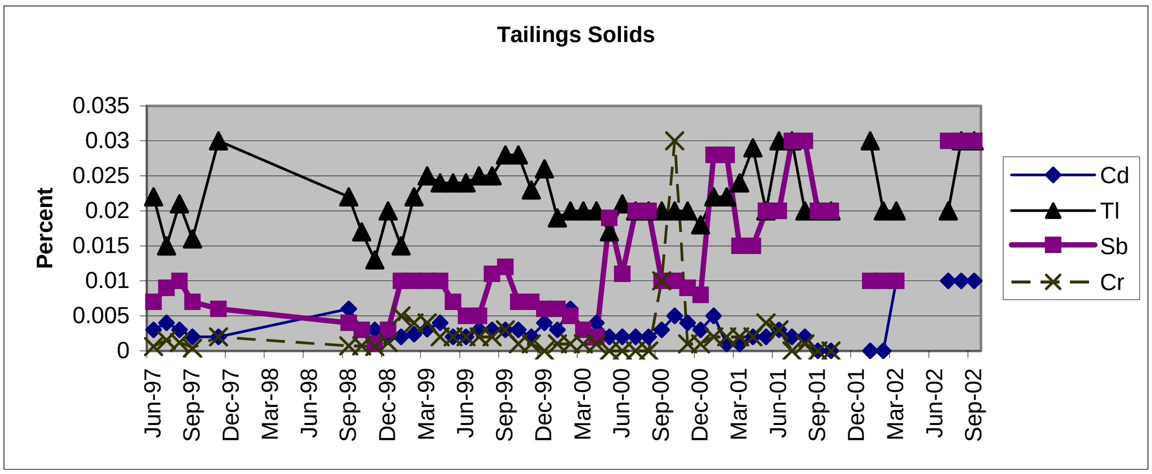


Figure 2 – Tailings Solids Pb/Cd





Data from a sample of tailings analysed in 2005 gives a breakdown of the Lead, Zinc and Iron content with particle size (see graph below). This shows that whilst Iron and Zinc are distributed fairly consistently between the size fractions, Lead appears to be concentrated in the smaller (clay sized) fraction.

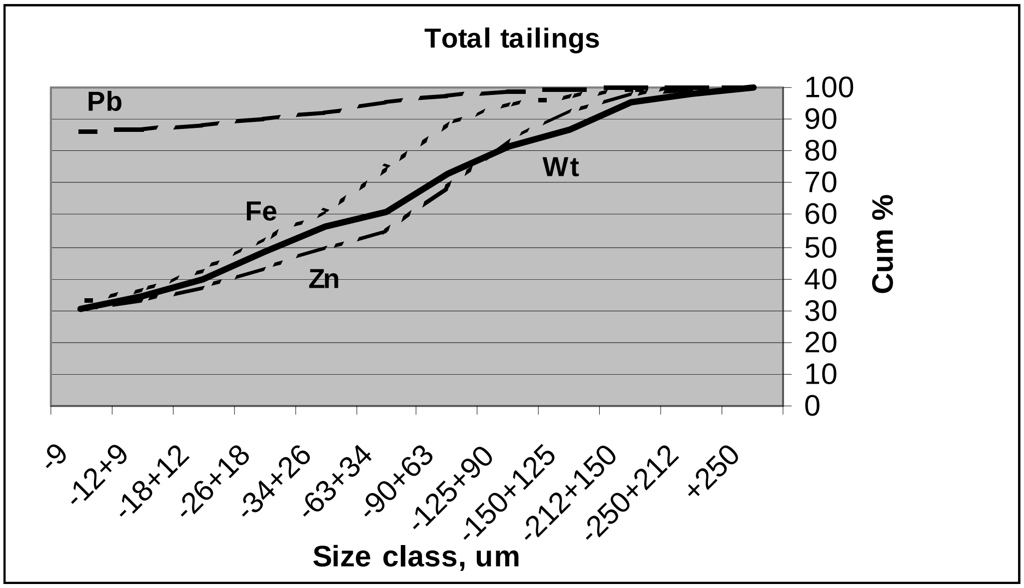


Figure 3 – Total Tailings

2.3 Acid Generation

The potential for acid generation within the deposited tailings is a function of the complex relationship between the rate of pyrite oxidation and the ability of the tailings to neutralise the resulting acid generated. The rate of pyrite oxidation is itself determined by a range of factors, including the concentration of pyrite, the form of pyrite, the particle size and availability of water and oxygen. As acid is generated, it will be neutralised by the dolomitic limestone present in the tailings. The extent to which the acid producing potential of the tailings might exceed the neutralisation potential of the tailings has been estimated using standard acid base accounting (ABA) methods.

Acid base accounting determines a theoretical worst case situation in which it is assumed that every gram of pyrite oxidises resulting the generation of 1.6g of sulphuric acid. Acid base accounting enables material to be classified as acid producing, acid consuming or borderline. The net neutralisation potential (NNP), is the balance between the acid producing potential (AP) and the acid consuming (neutralising) potential (NP) and gives an indication of the potential for net acid generation. Similarly the ratio between NP and AP gives an indication of the 'factor of safety' in the NNP.

Samples collected by Arcon Mines from the Phase 1 area in 2001 and from Phase 2 in 2004 and 2005 were analysed for ABA in accordance with standard procedures. The results of this are summarised as follows:

Table 3 - Acid Base Accounting Tests, Galmoy tailings					
Sample		***Acid production potential (AP)***	***Neutralisation potential (NP)***	***Net Neutralisation potential (NNP)***	***Ratio NP/AP***
All	Avr	363.4	614.0	250.7	1.99
	Min	103.5	44.4	-349.0	0.11
	Max	567.8	990.6	646.0	5.55
2001 Phase 1	Avr	290.9	471.3	180.4	1.65
	Min	229.9	44.4	-349.0	0.11
	Max	393.0	794.4	533.0	3.00
2004 Phase 2	Avr	429.0	557.1	128.2	1.37
	Min	303.8	400.0	-102.7	0.80
	Max	567.8	990.6	613.7	2.63
2005 Phase 2	Avr	189.4	704.5	515.0	4.07
	Min	103.5	575.0	318.1	1.94
	Max	339.4	828.1	646.0	5.55
2005 Phase 1 surface	Avr	420.7	668.8	248.0	1.61
	Min	265.0	312.5	47.5	1.18
	Max	542.4	780.0	454.0	2.39
All data in tonnes of $CaCO_3$ equivalent per 1000t tailings material. A negative NNP and ratio of NP/AP >1 indicates net acid producing.					

Figure 4 – Frequency of AP and NP 2001, 2004 & 2005 (Kg)

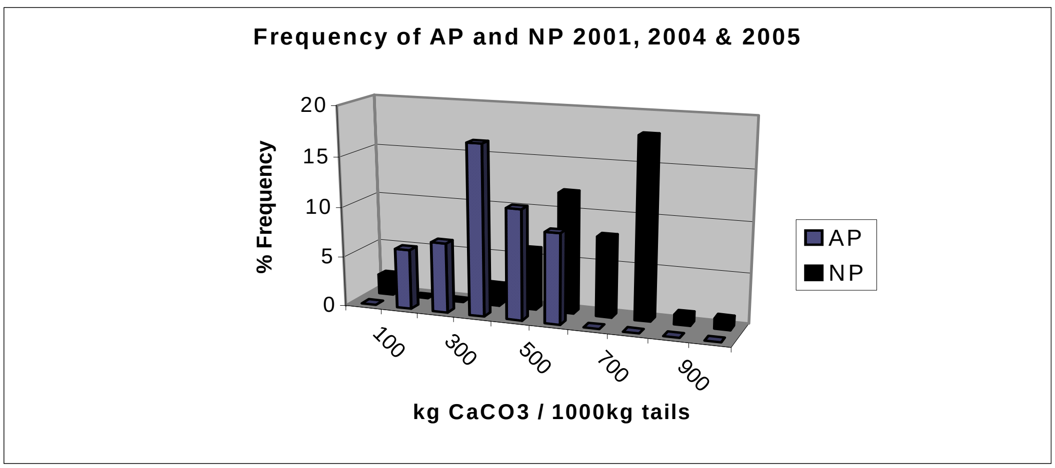
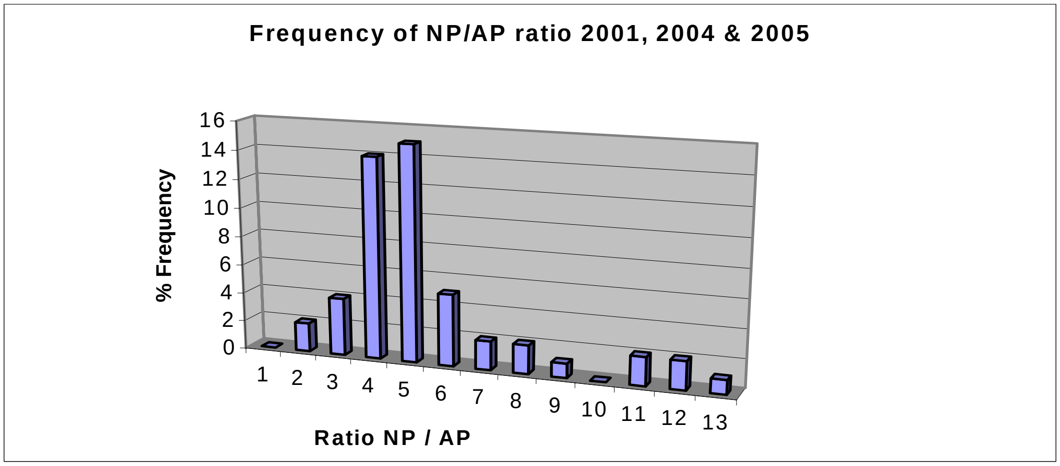


Figure 5 – Frequency of NP/AP ratio 2001, 2004 & 2005 (%)



The frequency histograms show that the NP is consistently higher than the AP, and that the majority of samples have a NP/AP ratio of 3 to 6 and in many cases is much higher. This is what would be expected for a mine operating in a limestone (calcite and dolomite) environment.

These data indicate that the tailings in both Phase 1 and Phase 2 are net acid consuming, ie. that there is only very limited potential for acid production. Whilst occasional samples were acid producing, the nature of the deposited tailings and their distribution does not indicate that there would be any hot-spots developing. Overall, these data confirm the predictions made in 1992 based on testwork on lab scale samples.

2.4 Long term behaviour

2.4.1 Chemical factors affecting the TMF

Table A4.4 summarises the possible chemical processes that could take place within the cell wall, containment system and tailings components. In some cases these are direct effects, or mechanisms, in others they are indirect consequences. The tailings are the principal chemically active component. The cell walls are not chemically active, and are effectively isolated from the tailings, so interactions are not likely. However, if the liner did cease to be effective, then a small amount of seepage liberated from the tailings could enter the cell walls.

The TMF, at the time of decommissioning and rehabilitation, will comprise three distinct zones:

- an aerobic uppermost layer to a depth roughly equivalent to the rooting depth of established vegetation (say 1 metre, including any soil cover);
- an anaerobic central zone extending between the rooting depth to almost the bottom of the tailings impoundment;
- a very thin and, probably insignificant, aerobic layer at the base of the tailings impoundment, in close proximity to the drainage blanket layer.

Processes within the two main zones therefore have to be considered. The testing carried out on the tailings materials, and discussed in Section 7.6, was designed to provide information on the likely chemical behaviour of the tailings and thus on the potential impacts on the surrounding environment (discussed in Section 10.5). The main mechanism anticipated is oxidation of the residual pyrite in the tailings. The various consequences of the processes identified are discussed in the following sections.

Table 4 - Factors affecting chemical stability of the tailings impoundment

Disruptive/ Disturbing Process	***Effect on:***			***Mitigation***	
	Tailings	***Containment System (liner and drainage)***	***Cell walls and structures***	***Design***	***Monitoring***
Presence of processing chemicals	Side reactions with tailings	Liner deterioration	Chemical attack if liner failure	Degradation within impoundment (u/v and O_2)	Visual inspection
Natural solubilisation of metallic species	Increased metallic ions in solution				Tailings water analysis
Pyrite oxidation in aerobic zones	Acid production and subsequent reactions	Acid attack on liner		Remove pyrite at mineral processing stage Tailings are not net acid generating	Tailings water analysis
Ochre formation	Precipitations in pore space; Reduction in permeability	Precipitation in drainage blanket; Reduction in permeability		High permeability and flow rates	
Acid neutralisation by limestone and subsequent salt formation	Increase in osmotic potential	Liner degradation in high salt concentrations	Chemical attack if liner failure Sulphate attack on concrete	Resistant liner Sulphate-resistant concrete	Tailings water analysis
Enhanced solubility of metallic species	Increased metallic ions in solution			Ensure tailings not net acid producing	Tailings water analysis
High ambient pH	Precipitation of metals and reduction in solution concentrations	Aggressive chemical attack on liner			Tailings water analysis
Degradation due to weathering		Increased permeability of liner; Brittle failures		Ensure covering of liner at all times	Destructive testing
Growth of vegetation	Increased aeration of surface zone			Shallow rooting vegetation	Visual inspection

2.4.2 Pyrite oxidation and subsequent processes

Pyrite oxidation would only occur in the surface aerobic zone and will result in the production of acid. However it has been demonstrated in Section 2.3 that the tailings are net acid consuming, and the excess of lime means that the pH will stabilise at around pH 7.5. As a result there should be no net acidifying effect or enhanced solubility of metallic species in the oxidising zone. The solubility of all metallic species is shown to be extremely low in all testwork conducted (see Appendix 6 of Mine Closure Plan).

The rate of the oxidation and neutralisation processes, and the proportion of the pyrite that will oxidise, cannot be predicted at this stage. The rate of oxidation depends on inter alia the availability of oxygen, which will decline with depth and is effectively absent below the water table. The most active oxidation zone will therefore be at the surface, until such time as the pyrite is exhausted. This will occur within a finite time, though how long this will be is uncertain.

2.4.3 pH conditions in the tailings

The testwork carried out on tailings representing the typical material deposited in the Phase 1 and 2 cells of the TMF is discussed in Section 2.3. Based on this testwork it is projected that neither of the cells ultimately will be net acid producing and that their pH will fluctuate between 7 and 8.

The situation in the TMF during its lifetime will however be affected by certain external influences, including the dilution effects on the tailings water by rainfall and emergency water discharges. However, it can be predicted with reasonable confidence that, whilst the aerobic zone of the impoundment will stabilise just above neutrality at pH 7, the anaerobic zone, comprising the bulk of the tailings, will stabilise at a significantly higher (more alkaline) level, whilst the tailings water remains within it.

The ambient pH of the tailings will be the primary force determining the level of potential contaminants that enter the aqueous phase and hence surface or drainage waters. In general, metals tend to be more soluble under acidic conditions than under alkali conditions. The results of the laboratory testing presented in Section 7.5 indicate this in practice.

2.4.4 Liner stability

2.4.4.1 Chemical degradation

In general, materials which are described as being potentially aggressive to HDPE liners can be categorised as follows):

- acids
- alcohols
- aromatic solvents
- oils

None of these materials will enter the TMF in quantities that might pose a threat to the liner. However, sulphuric acid could be generated in the tailings, leading to changes in pH. It has been shown (see Section 2.3) that there is very unlikely to be net acid production in any of the three tailings cells; pH's are likely to start at 11, resulting from the mineral processing techniques, and over a period of time the pH will fall to between 7 and 8.

Whilst research into long-term stability of liners at different pH is limited, study of the compatibility of various geomembranes, including HDPE, with waste liquids at a range of pH by various authors indicate that it is very unlikely that the HDPE liner used for the Galmoy tailings impoundment will be adversely affected in terms of chemical degradation and loss of physical strength by the chemical nature of the tailings, even over the very long term.

2.4.4.2 Weathering and ageing

The HDPE liner used in the TMF is covered with a black non-woven geotextile on the slope. This in turn will be covered with tailings or soil material on decommissioning. This will ensure that the liner is not exposed to any major weathering effects. Weathering and ageing can, however, occur in several less obvious ways, which are described below.

- Temperature effects. HDPE liners can be impacted on by extremes of temperature, both high or low. Under normal Irish climatic conditions, extreme or prolonged high or low temperatures are unlikely to occur naturally. Process waters will enter the impoundment cold and no exothermic reactions are expected in the body of the tailings. American Standard Test Methods (ASTM) D794 and D746 address the effect of extremely high and low temperatures on liners and conclude that temperatures encountered during normal geomembrane liner operation are not detrimental to the polymers used in geosynthetic manufacture.

- Water effects. In common with other polymers, HDPE has a tendency to take up water and thus to swell over time. This very small amount of swelling (as discussed in the previous section on chemical degradation) is unlikely to cause detrimental effects in the liner.

- Biological degradation. Biological attack on liners can only occur where molecules of suitably small molecular weight are eligible for attack. In general, the molecular size of the polymers in HDPE liners are too large and thus unavailable for biological attack. Degradation by this route should not be relevant to the integrity of the liner.

- Oxidation degradation. The effects of oxidative reactions which involve free radical attack of liner polymers have been overcome in liner design by the incorporation of anti-oxidation additives.
- Sunlight degradation. It is known that the impact of sunlight (and particularly ultraviolet (UV) wavelengths) on HDPE liner life is potentially the most significant of all long-term ageing/weathering pathways. As stated previously, every attempt is made to keep the liner concealed from sunlight during the operation of the TMF by the use of a geotextile. Once decommissioned, the liner will be covered during rehabilitation works. Research into the effects of sunlight on HDPE liners (see for example Hsuan et al, 1991) indicates that certainly in the short-term (up to seven years of exposure) there is no significant impact. This can be attributed not only to the inherent stability of liner polymers, but also to the additions of anti-oxidation additives (which reduce the oxidative reactions involved in sunlight degradation) and carbon black (which screens or absorbs the UV light).

The maximum length of sunlight exposure of the liner in each of the cells will be equivalent to the expected lifetime of the cells plus a one year safety factor post operation, during which time rehabilitation work will commence (ie. 3½ years, 4 years and 6½ years for Cells 1, 2 and 3 respectively), after which the liner will be totally covered. During this period the liner is protected by a non-woven geotextile. It is therefore unlikely that this length of sunlight exposure will significantly impact on the integrity of the liner.

2.4.4.3 Lifetime of liners

Liners will have a finite life when used at any site, but the limited experience makes the determination of the liner life span difficult to predict. Estimates of the anticipated geomembrane liner life have been estimated to be anywhere between 20 years (typically the warranty provided by liner manufacturer; Gundle, 1992) to hundreds of years. Under conditions where liners are relatively unstrained, protected from light, and in an anaerobic environment, the latter scenario may be possible.

The lifetime of a geomembrane is difficult to predict due to the limited experience that industry has with geomembranes. Currently, accelerated testing is being used to predict the life expectancy of geomembranes, but variations in testing methods and interpretation give wide variances in geomembrane life expectancy estimation. While the exact life expectancy of geomembranes is unknown, it has been generally concluded by numerous researchers (that the life of geomembranes can be several hundreds of years.

3.0 WATER QUALITY

3.1 Supernatant Water

During operation of the mine, the supernatant water present in the TMF will comprise a mixture of some or all of the following:

- Mineral processing effluent
- Rainfall
- Emergency tailings top-up water from the mine dewatering scheme
-

The quality of this water during operations is largely determined by the quality of the effluent from the mineral processing operations. The final effluent from the plant may contain traces of process (flotation) chemicals, notably Sodium-isopropyl-xanthate and di-isobutyl-di-thiophosphate. An analysis of the tailings decant water undertaken by Arcon Mines in 2003 is given in Table 5.

Table 5 - Tailings Decant Water Chemistry Summary

Parameter	***Species***	***2003***			***2004***		
		Max	***Min***	***Average***	***Max***	***Min***	***Average***
pH	units				8.59	6.98	7.81
S.S.	mg/L Solids	370	1	28			
C.O.D.	mg/L O_2	147	5	32			
Nitrite	mg/L $N0_2$	17.05	0.18	8	14.23	0.73	2.57
Sulphate	mg/L $S0_4^{2-}$	6777	27	3371	10825	1374	3583
Total Ammonia	mg/L NH_3	17.69	1.93	10	15.56	4.73	10.80
Lead	µg/LPb	6900	70	983			
Zinc	µg/L Zn	35845	31	7393			
Cadmium	µg/L Cd	106	2	28			
Copper	µg/L Cu	219	10	46			
Iron	µg/L Fe	3300	63	347			
Arsenic	µg/L As	893	9	61			
Magnesium	µg/L Mg	534	195	293			
Mercury	µg/L Hg	0	0				
Chromium	µg/L Cr	4	2	3			
Aluminium	µg/L Al	128	5	24			

These results are broadly consistent with the range predicted in the initial Mine Closure Plan. After cessation of operations, the influence of process effluent within the tailings on the quality of the supernatant water in the tailings impoundment will gradually decrease as the residual process effluent is diluted with incident rainfall. At this time the key determinant of water quality will be the solubility of metallic residues in the tailings slimes.

3.2 Water in contact with tailings

The long-term solubility of metallic residues in the tailings slimes was assessed in 1992 using two methods: contact cell testing and humidity cell testing. In contact cell testing, samples of tailings slimes are mixed with either process effluent (to produce an environment comparable to that experienced during operations) or deionised water (to produce an environment where the main input is rainfall comparable to that experienced post-closure). In humidity cell testing, the leachates generated during testwork to predict acid generating potential were analysed for trace metals.

In contact cell tests the tailings material is wholly immersed in water and, consequently, the results of this test are indicative of the likely metal solubilities resulting during anaerobic conditions that exist when the tailings are saturated. In contrast, the results of humidity cell tests are indicative of the likely metal solubilities resulting during aerobic conditions that exist when the tailings is free draining. In practice, given that the tailings impoundment is fully lined and that the compacted tailings has a low permeability, the greater part of the tailings will be saturated in perpetuity. However, evapotranspiration will at times result in near surface tailings being exposed to aerobic conditions more comparable to those in the humidity cell test environment.

The 1992 predictive tests indicated that, under either anaerobic or aerobic conditions that will be present in the deposited tailings, the concentrations of trace metals in solution would be low (see Tables 6 and 7). The slightly elevated concentrations of some trace elements in the contact cells tests, notably zinc, reflect more the influence of residual process effluent than mobilisation of zinc from the tailings solids.

Table 6 - Results of long term contact cell testing (tailings slimes leachate from CW orebody, 34.9% Fe headgrade)

Parameter (mgl^{-1})	1 month	4 months	8 months
Al	<0.01	<0.01	<0.01
As	<0.01	<0.01	<0.01
Ba	0.025	0.02	0.01
Be	<0.001	<0.001	<0.001
Ca	155	388	193
Cd	0.003	0.007	0.003
Co	0.19	0.37	0.25
Cr	<0.004	<0.004	<0.004
Cu	0.048	0.016	0.011
Fe	0.23	0.003	0.007
Hg	n/d	n/d	<0.001
Mg	40.0	112	140
Mn	0.058	0.32	0.17
Mo	0.009	<0.007	<0.007
Na	204	196	174
Ni	0.05	0.33	0.24
P	<0.03	0.10	0.06
Pb	0.14	0.007	0.04
S	344	576	449
Sb	0.02	<0.02	<0.02
Se	<0.005	<0.005	<0.005
Si	0.38	0.33	0.21
Sn	<0.02	<0.10	<0.02
Te	<0.04	<0.04	<0.04
Tl	0.01	0.65	0.43
Zn	0.57	1.56	1.33
Conductivity	1634	2960	2190
μScm^{-1}	550	1430	1060
Hardness	7.81	7.68	7.49
pH	798	1730	1330
SO_4	n/d	<0.1	<0.5
S=	n/d	n/d	0.01
CN(T)	n/d	<4.0	<4.0
BOD	n/d	17.0	21.7
COD			

Source: Lakefield (1992) n/d = not determined

Table 7 - Humidity cell leachate analysis

Sample	***Concentration in CW tailings slimes (headgrade 10.8% Fe)***		***Concentration in G tailings slimes (not scalped) (headgrade 13.8% Fe)***	
Week >	**1**	**6**	**1**	**6**
pH	7.90	7.85	7.70	7.80
Al	<0.2	<0.2	<0.2	<0.2
As	<0.1	<0.1	<0.1	<0.1
Ba	<0.05	<0.05	<0.05	<0.06
Be	<0.01	<0.01	<0.01	<0.01
Ca	240	100	306	120
Cd	<0.05	<0.05	<0.05	<0.05
Co	0.13	0.08	0.06	<0.05
Cr	<0.05	<0.05	<0.05	<0.05
Cu	<0.05	<0.05	<0.05	<0.05
Fe	<0.05	<0.05	<0.05	<0.05
Mg	74.7	30	91.2	40
Mn	<0.05	<0.05	<0.05	<0.05
Mo	<0.1	<0.1	<0.1	<0.1
Na	3.65	0.34	4.15	1.1
Ni	0.08	<0.06	<0.05	<0.05
P	<0.2	<0.2	<0.2	<0.2
Pb	<0.1	<0.1	<0.1	<0.1
S	311	120	462	150
Sb	<0.1	<0.1	<0.1	<0.1
Se	<0.5	<0.5	<0.5	<0.5
Si	0.29	<0.1	0.33	0.1
Sn	<0.2	<0.2	<0.2	<0.2
Te	<0.1	<0.1	<0.1	<0.1
Zn	0.34	0.28	0.09	<0.05
Hardness	906	370	1140	460
All data in mgl^{-1} except pH				

3.3 Seepage

Monitoring data for the TMF internal drainage sumps is summarised in Table 8. This would be representative of the medium-term seepage water, which contains constituent process water. In the longer term the quality will change (for the better) as this is replaced by rainwater seepage.

Table 8 - Summary of seepage water quality, 2004

Sump no.		***pH***	***Sulphate, SO_4***	***Lead***	***Zinc***
				mg/l	
IDS 1	**avr**	**7.8**	**1755**	**0.030**	**0.215**
	min	7.6	301	0.010	0.110
	max	7.9	5762	0.063	0.377
IDS 2	**avr**	**7.8**	**3160**	**0.016**	**0.044**
	min	7.5	13	0.005	0.014
	max	7.9	7630	0.028	0.112
IDS 3	**avr**	**7.6**	**21**	**0.029**	**0.038**
	min	7.3	13	0.003	0.015
	max	7.8	32	0.142	0.058
IDS 4	**avr**	**7.6**	**244**	**0.008**	**0.018**
	min	7.3	7	0.003	0.012
	max	7.9	1407	0.015	0.026

3.4 Long term water quality

3.4.1.1 Quality standards

The significance of any potential contamination resulting from the TMF can be assessed by comparing it with relevant national and international standards. In the case of surface waters the most relevant standards are those defined by the European Community Directive on Surface Water Quality (75/440/EEC) (SI No. 294 of 1989), and Freshwater Fish (78/659/EEC) (SI No. 293 of 1988). For groundwater, the Directive on Groundwater (80/68/EEC) (no SI enacted) will be the most appropriate, though Surface Water Quality may also apply if it is abstracted downstream. These standards are summarised in Table 9. Table 10 summarises the standards for process effluent applied to the mine in the EPA licence.

Table 9 - Summary of EC Water Quality Standards

Parameter (mg/l)	Surface Water 75/440/EEC A3 I/MAC Value	Freshwater Fish 78/659/EEC Salmonid 1/MAC Value	Ground Water 80/68/EEC
Aluminium	NV	NV	List 2
Antimony	NV	NV	List 2
Arsenic	0.1	NV	List 2
Barium	1.0	NV	List 2
Cadmium	0.005	NV	List 1
Chromium	0.05	NV	List 2
Copper	0.05 (A1) [1]	0.112 [2]	List 2
Cyanide	0.05	NV	List 1
Iron	2 (A2)	NV	-
Lead	0.05	NV	List 2
Manganese	1	NV	-
Mercury	0.001	NV	List 1
Nickel	NV	NV	-
Selenium	0.01	NV	List 2
Sodium	NV	NV	-
Tin	NV	NV	List 2
Zinc	5	$\leq$0.3 [2]	List 2
pH	NV	6.0 - 9.0	NV

(1) Alternative limit quoted where A3 no limit
(2) For hardness >300mg/l $CaCO_3$
NV = No value given in standard
List 1 = discharge to groundwater must be prevented
List 2 = discharge to groundwater must be limited

Table 10 - Process effluent standards, EPA Licence 517		
Paremeter	***Emission Limit Values***	
	Discharge to R. Goul	***Discharge from Treated Effluent Pond***
pH	6 – 9	6 – 9
Toxic Units	1	2
	mg/l	
BOD		20
COD		200
Suspended solids	<25	<25
Mineral Oil	1	1
Ammonia (as N)	1	1.5
Nitrate (NO3)	50	50
Nitrite (NO2)	2	4
O-Phosphate	0.05	0.05
Sulphates	1000	2000
Cyanide (total)	0.01	0.02
Arsenic	0.05	0.05
Mercury	0.001	0.001
Cadmium	0.005	0.005
Lead	0.05	0.08
Zinc	0.3	0.5
Aluminium	0.2	0.2

During the Stage 1 active care period, all waters draining from the impoundment will be retained, diluted and, if necessary, treated prior to discharge to the R. Goul. Water quality will therefore be maintained to the appropriate standard. The likely long-term quality of drainage, following Stage 2, is considered in the following sections.

3.4.1.2 Surface drainage

Surface water from the impoundment will originate as rainfall and will be affected by the aerobic zone of tailings. Most of the surface water will flow directly over the tailings surface and will not have an opportunity to dissolve materials resulting from tailings oxidation and neutralisation. However, a small proportion will, especially just after the summer moisture deficit has been satisfied by late summer and early autumn rains. Late summer is therefore the most likely time that surface water will be affected by the tailings.

The very worst case for water quality in surface drainage could be similar to the humidity cell leachate analysis, given in Table 7.4. The samples analysed had high original pyrite (based on the % Fe headgrade) and the analysis does not take account of any dilution that would occur in reality. As can be seen from Table 10.21, only Zn just exceeds the EC standard for Salmonid waters for one test, and none exceed the Surface Water standard (as tested).

The BOD is high in one sample, but is not generally so. The conductivity (Table 7.5) is high in some samples, reflecting the sulphate resulting from acid neutralisation, but is within the range present in many streams and rivers.

3.4.1.3 Internal drainage

The hydro-chemistry of tailings deposits is very complex and it is difficult to predict how solutions percolating through them will be affected. In the case of Galmoy, water will percolate through the tailings to the internal drainage system in two stages:

- Initially it will comprise tailings water, which has been in contact with the anaerobic tailings.

- Eventually it will comprise rainwater, which has first infiltrated the aerobic zone and then passed through the anaerobic zone.
-

The tailings water passing through the tailings could be similar to the contact cell leachates. As a worst case, Table A4.6 indicates that Pb, Cd and CN are borderline or below the Surface Water Standard, but Zn exceeds the Salmonid Waters Standard in the long-term tests.
The pH of the tailings water may be more alkaline than that in which the test was carried out, so it is likely that metal levels will be lower, due to precipitation. This is confirmed by the Zn levels in the pH 11 contact test (Table A4.6.6). Sulphates, which will give rise to high conductivities, should not be present from the anaerobic condition.

4.0 HYDROLOGY & DRAINAGE

4.1 Post-closure Water Balance

4.1.1 Rainfall

The water balance of the TMF is an important aspect in relation to the amounts of water that will be dispersed via different routes into the surrounding environment. The water balance estimates are used in the drainage design and in the assessment of impacts on waters.

The water balance of the facility at closure is dependant on the rainfall and evapotranspiration, which determines the effective rainfall into the facility and the seepage emanating through the sides and base of the TMF.

The original rainfall data used in design was based on data for Kilkenny between 1960 and 1984. This data has been compared with rainfall data collected at Galmoy and the data are comparable as in Table 11.

Table 11 - Comparison of rainfall figures

Month (2002)	Rainfall Galmoy (mm)	Rainfall Kilkenny (mm)	Rainfall Galmoy Ave.(mm)	Rainfall Kilkenny Ave.(mm)
January	97.8	109.8	68	86.3
February	116.6	116.9	62	66.1
March	37.6	41.5	44	63.9
April	66.4	86.8	61	51.4
May	99.2	80.3	64	61.9
June	77	77.0	74	50.5
July	39.4	61.4	42	52.5
August	48.8	52.1	83	69.4
September	20.2	25.7	77	73.5
October	118.4	150.5	95	84.9
November	125	165	102	73.8
Sub total	846.4	967	772	734.2
December	Not Available		65	88.6
Total			837	882.8

Based on the above comparative data for precipitation, the original meteorological data from Kilkenny and used in the design is valid. No evaporation data at the mine site is measured and therefore the evapotranspiration values used in the design have been used in the updated water balance.

4.1.2 Seepage

The seepage emanating from the TMF will be dependent on the following key factors:

- defects in the geomembranes after installation,
- defects in the geomembranes due to operations,
- the hydraulic head acting across the liner,
- the permeability of the tailings and

- the effective rainfall.

Even with the most thorough quality control and quality assurance procedures carried out during the installation of the geomembrane, some defects will occur. There is a considerable amount of data on the potential number and size of holes that can be expected for a competently supervised geomembrane installation.

Recharge of tailings water to the over drainage system above the geomembrane is controlled by the permeability of the tailings. Based on the grading analyses of the tailings, its mass permeability is likely to be of the order of $1x10^{-8}$m/sec. As the tailings are discharged into the TMF, a significant degree of segregation occurs with the coarser material deposited near the crest and the finer material deposited in the basin area. The segregation of the fines reduces the vertical permeability of the tailings although the horizontal permeability tends to be an order higher. It can be expected that the likely maximum vertical flow of water through the tailings will be of the order of 80m3/day for the Phase 1 cell and 120m3/day for the Phase 2 cell.

The hydraulic head on the geomembrane is controlled by the over drainage system which has been installed above the geomembrane and as can be seen from the above data, a lower head, reduces the potential seepage through the TMF but also assists in the consolidation of the tailings. The lower hydraulic head is applicable when the valve to the over drainage system is open and the full head is with the valve shut. With the valve opened from the Phase 1 cell, the mine is monitoring about 4m^3/hr (96m^3/day), which is reasonably constant. It can therefore be expected that the water emanating from the Phase 2 cell would be of the order of 5.6m^3/hr (134.4m^3/day).

The water from Phase 1 is pumped from the sump and back into the Phase 2 cell. The valve connecting the sump with the Phase 2 cell drainage system is not open at the present time in order to allow for a significant build up of tailings over the floor of the facility.

Vertical groundwater flow through the tailings material itself is restricted by the liner. If the liner was not present then the flow would be controlled by the hydraulic conductivity of the tailings, 10^{-8} m/s. Under a vertical flow condition with atmospheric pressure applying at the base of the material, the head difference and the length of flow path are equal, resulting in a hydraulic conductivity of unity. The specific discharge, or flow per unit area is therefore numerically equal to the hydraulic conductivity of 10^{-8} m/s. Over the whole area of the TMF (Phases 1, 2 and 3 - 31.5 ha) this would result in a volumetric outflow rate of 8160 m^3/month. As this is greater than the leakage rate through the liner, of 3944 m^3/month, then it is the latter flow that will control the leakage out. Should the liner deteriorate further, then the outflow would increase until the rate was controlled by the tailings permeability, ultimately 8160 m^3/month.

4.1.3 Flow balance for the TMF

In order to conduct a flow balance the following assumptions are made:

- The catchment areas for the TMF comprise 9.6 ha for Phase 1, 13.4 ha for Phase 2 and 8.5 ha for Phase 3, totalling 31.5 ha overall.
- Inflow from rainfall is taken as average monthly rainfall, as shown in Figure 1, from Cullen (1992).
- Outflow due to evapotranspiration is taken as the average monthly potential evapotranspiration, as shown in Figure 1, from Cullen (1992). It is assumed that actual evapotranspiration will be equal to potential evapotranspiration as there is unlikely to be any significant soil moisture deficit within the TMF.
- Possible leakage from Phases 1 and 2 through the geomembrane liner are taken to be 4 m^3/hr, or 96 m^3/day, Golders (2001) based on estimates of typical no and size of defects in such liners. The total for Phases 1, 2 and 3 was therefore taken to be 5.5 m^3/hr (131 m^3/day or 3944 m^3/month).

For the flow balance calculation, the water level in the TMF model was initially set equal to the decant level. The flow balance was conducted in monthly time steps. An inflow was made equivalent to the difference between average monthly rainfall and average monthly evapotransration. In summer, when evapotranspiration exceeds rainfall, then the water level volume is removed from the TMF. The new water level is then calculated assuming a 30% effective porosity. If this water level is below the decant crest then this is passed to the next time step. If the new water level is above the decant level then it is reset to the decant level and the volume discharged in order to achieve this is recorded. This is the estimated volume of water passed to the attenuation pond, in addition to water intercepted from the base of the liner.

Figure 2 shows the resulting flow rates and also the water levels resulting from the flow balance calculation. The flow balance was run for 4 years but, as can be seen from Figure 2, it settled down to a repeating condition within one year. After an initial flow of around 30 L/s (approximately 100 m^3/hr) due to the initially full start, the flow balance predicts an outflow occurring during December, January and February each year reaching just under 10 L/s. During the remainder of the year the water level drops below decant level, by up to just 0.13 m. It should be noted, however, that these calculations are based on average meteorological conditions as an indication of the likely behaviour of the TMF and actual conditions will cause a variation in this behaviour.

Figure 6 - Average monthly rainfall and potential evapotranspiration

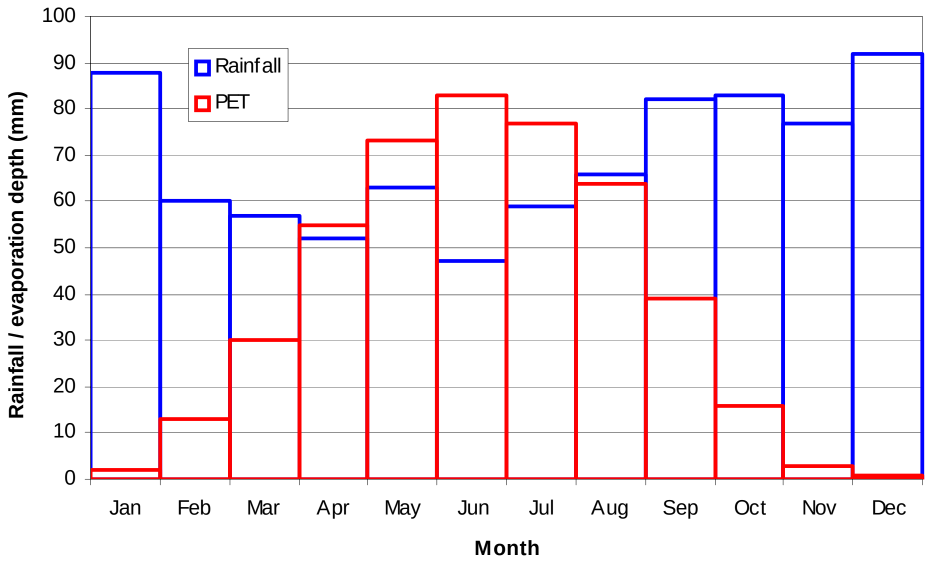
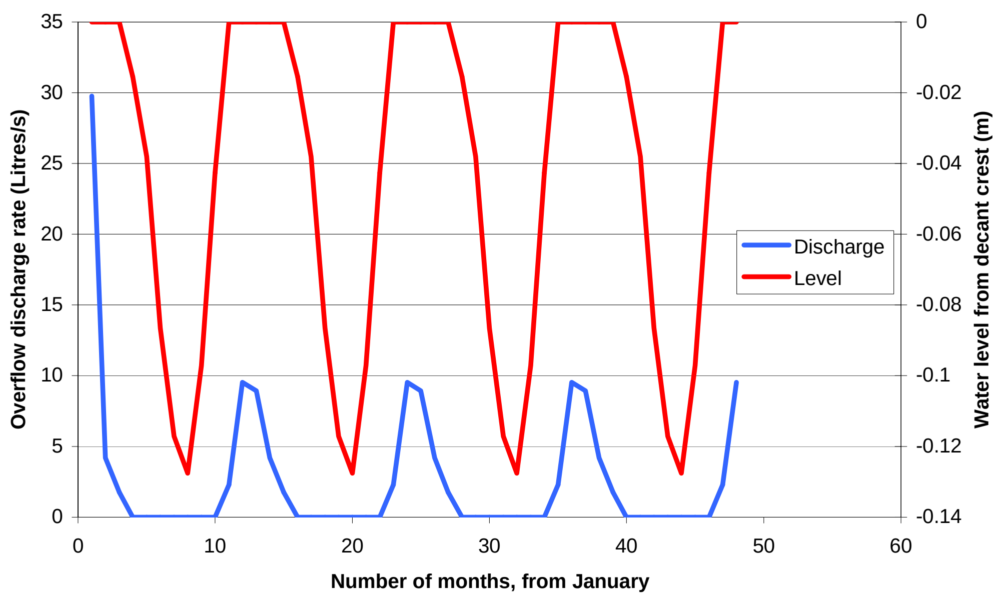


Figure 7 - Likely average discharge rates and water level in the TMF



4.1.4 Flooding

The likelihood of flood events is considered in Golder (1992), which concludes that the rise in water on the surface of the TMF during a 1 in 100 year 24 hour peak rainfall event, including failure of the decant, will be less than 200mm on any cell. The risk of overtopping of the cell walls is therefore very remote. However, the risk of long-term extreme rainfall events requires that provision be made in the rehabilitated impoundment for a spillway to prevent uncontrolled overtopping of the impoundment wall. Details are given in Golder (1992).

Any shortfall in flood capacity in the Phase 1 and 2 cells will be made up in the Phase 3 cell. Thus a total freeboard of max. 1m depth will be required on Phase 3. As stated in the Mine Closure Plan it is proposed to leave 2m of freeboard on Phase 3 on closure. A Spillway to transmit flood water from Phase 1 onto Phase 2 has been constructed. Following construction of Phase 3 a spillway between phase 2 and 3, will be constructed.

References

Cullen, 1992. Hydrogeology and Dewatering of the Galmoy Mine.
Golder, 1992. A Tailings Disposal Facility Design for the Galmoy Project

APPENDIX 5 : CONTAMINATION ASSESSMENT

Client: Galmoy Mines Ltd

Contamination Assessment, Galmoy Mine.
County Kilkenny, Ireland

Prepared by:

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Contamination Assessment, Galmoy Mine
County Kilkenny, Ireland

1.0 INTRODUCTON

1.1 As part of the Mine Closure and Rehabilitation Plan Wardell Armstrong International (WAI) have undertaken a contamination assessment of available data from the Galmoy Mine Site to determine the nature and extent of contamination currently existing at the site. Contamination samples from the site were taken by Galmoy Mines Ltd and analysed for elements associated with the mining processes at the site.

1.2 The site is currently operating as a Lead Zinc mining operation. Within the mine operation site are the mine buildings including offices, service buildings, concentrator mill, electrical housings and transformers, sewerage treatment plant, water treatment plant, gatehouse, weighbridge and the conical coarse ore stockpile building. Along with this is the associated infrastructure and services. The tailings disposal site is located adjacent to the mine operation site, and is not considered as part of this assessment.

1.3 In preparing this factual and interpretive report, a risk assessment of the contamination analysis has been undertaken, including the preparation of a conceptual model for the site addressing the potential contaminant sources, pathways and receptors as required by the CLEA regulations. The ground contamination risk assessment has considered the potential for harm to the environment (ie. human, plant and animal). Remediation strategy options for the site are also briefly outlined. This report does not deal with contamination of groundwater, this is covered separately within the Mine Closure and Rehabilitation Report.

1.4 Samples were taken from the general mine site area as shown on Figure 1, no samples were taken from the area of the TMF (see Appendix 6).

2.0 CURRENT SITE INVESTIGATION

2.1 The site investigation was undertaken at various available points across the main Galmoy Mine Site. Samples were collected by a representative of Galmoy Mines Ltd and analysed by Bord Na Mona Environmental Ltd and OMAC Laboratories. The data was supplied to Wardell Armstrong International (WAI) by Galmoy Mines Ltd. As the site is an operational site there are restrictions on locating sampling points, therefore only 12 sampling points were used for this investigation.

2.2 The soils have been tested for a range of contaminants at depths of 0.00-0.30m and 0.30-1.20m depth below current ground level. The contaminants tested are listed below:

- Arsenic
- Cadmium
- Copper
- Nickel
- Diesel Range Organics
- Boron
- Cobalt
- Mineral Oil
- Zinc
- Barium
- Chromium
- Mercury
- Lead
- Selenium
- Molybdenum

2.3 The general location for each trial pit is detailed in Table 1 along with a description of the material tested at each sample location.

Table 1 Location of Trial Pits and Description of Sample Points, Galmoy Mine Site			
Trial Pit Ref	Description of Location	Primary Use	Description of Sample
1	North Eastern Tip of Storage Area	Storage of coarse rock	Gravel
2	Middle of Storage Area	Storage of coarse rock	Gravel
3	South Western wall of storage area	Storage of coarse rock	Gravel
4	East of south end of Storm water Pond	Waste Storage (mill filters, oily wastes)	Gravel
5	East of south end of effluent pond	Waste Storage (oily wastes, machinery)	Gravel
6	East of centre of effluent pond	Recyclable waste storage	Gravel
7	West of concreted area	Heavy vehicle Parking	Gravel
8	South of Workshops	Vehicle workshops area	Gravel and Clay
9	South East of storm water pond	Diesel storage tank and bund	Gravel
10	North east of concentrate loading area	Concentrate trucks drive through the area	Gravel
11	West of Teepee	Backfill pipes run through the area	Clay
12	South east of teepee	Diesel storage tank and bund	Gravel

3.0 RISK ASSESSMENT

Introduction

1.1 The main issue considered in the risk assessment is how likely it is that the environmental risks identified affect the closure of the site. This is considered against a background of continuation of the current use and the return of the site to agricultural amenity use once mining operations have ceased

Risk Assessment

3.2 The risks posed by contamination have been assessed on a site-specific basis using "source-pathway-receptor" methodologies in line with the Contaminated Land Regulations introduced (in April 2000) under Section 57 of the Environment Act 1995.

Environmental Issues

Sources of Contamination

3.3 Conclusions have been drawn from the risk assessment information in terms of potential sources of contamination, possible receptors that may be affected by any sources of contamination and the pathways that exist between source and receptor. This basic risk assessment allows identification of the suitability of the site for its current and future use and evaluation of any potential environmental liability that may attach to the site. The issues can be broadly addressed as follows:

- Land contamination;
- Groundwater contamination;
- Surface water contamination;
- Air pollution; and
- Other.

3.4 An assessment of the current land use within the mine site has identified the following potentially contaminative uses on the site.

Potentially Contaminative Uses on Site

- Underground Mining;
- Waste oil storage tank;
- Ore stockpile building;
- Concentrator Mill with associated tanks and silos;
- Materials and machinery (scrap) in the storage yard;
- Water Treatment Plant;
- Sewerage Treatment Plant; and
- Transformers.

3.5 As a result of the above land use the site has a number of potential sources of contamination. Table 2 details the potential sources, pathway and receptor and their inter-relationship.

Table 2 Potential Sources, Pathways and Receptors			
Source	**Pathway**	**Receptors (Current)**	**Receptors (Future)**
PCB's from transformers	Surface run off	Sewer/drain, shallow ground.	Drains, shallow ground.
Surface soils contamination with various metals, oils or acids from scrap materials degreasing agents. waste oil drums	Surface run off, groundwater, leaching, fill materials, (nature unknown), surface soils (nature unknown), superficials, solid geology (joints, fractures etc). Skin absorption/dermal contact.	a) Human ie. Occupier. b) flora & fauna. c) Surface and Groundwater.	a) Human – Occupier, general public, demolition and remediation workers, b) flora, fauna. c) Surface and ground water
Heavy metals/hydrocarbon contamination from mining/stockpiling of mined material	Surface run off, groundwater, leaching, fill materials (nature unknown), surface soils (nature unknown), superficials, solid geology (joints fractures etc). Skin absorption/dermal contact.	a) Human ie. Occupier. b) flora, fauna. c) Surface and ground water.	a) Human ie. Occupier general public, demolition and remediation workers, b) flora, fauna c) Surface and ground water.
Inorganics eg. sulphates and sulphide metals from mining/stockpiling of mined material	Surface run off; groundwater; leaching; fill materials (nature unknown), surface soils (nature unknown), superficials, solid geology (joints fractures etc). Skin absorption/dermal contact.	Buildings and services.	N/A.

3.6 Although Polychlorinated Biphenyls have been listed as a potential contaminant source it should be noted that these were tested as part of the mine closure plan update in 2004. Oil from the transformers on the site were tested and found not to contain PCB's. Therefore they haven't been tested as part of the current site investigation.

3.7 The likelihood of significant contamination, pollution or other environmental issues affecting the site or the surrounding area in connection with the present use of the site are considered to be:

On Site - Moderate risk, due to potential presence of heavy metals, hydrocarbons and oils.

Groundwater Vulnerability

3.8 From examination of the geological and hydrogeological data the risks to groundwater and surface water are assessed as follows:

On Site - High risk, the site is underlain by a regionally important aquifer. The greatest risk to groundwater at the site would be considered to be potential contaminants leaching into groundwater as a result of mining activities at the site. However, it must be noted that during mining operations groundwater is pumped from the mine to the water treatment plant. Therefore any potentially contaminative material would be removed at this point. Following closure the groundwater regime will re-establish, this aspect is covered within Appendix 1 of the mine closure plan.

Surface Water Vulnerability

3.9 High risk, there is potential for surface water to become contaminated due to the condition of the site before entering the effluent/stormwater ponds on the site.

3.10 It should also be noted that the risk to groundwater and surface waters was recognized at the time of the planning applications for the mine (as set out in the Environmental Impact Statements, undertaken for the site in 1992).

Summary

3.11 From an assessment of the above it is considered that the overall likelihood of a significant environmental liability arising in connection with the site is moderate with regards to the ground conditions at the mine site and high in regards to ground and surface water vulnerability.

4.0 GROUND CONTAMINATION: RISK ASSESSMENT HUMAN HEALTH

4.1 This ground contamination risk assessment of the Galmoy Mine site has considered the chemical testing data obtained from the site investigation undertaken by Galmoy Mines in 2005.

4.2 Risk assessment analysis of the site has been carried out in accordance with the UK CLEA Regulations and other relevant guidance documentation.

Post Closure Land Use

4.3 It is understood that once mining operations have ceased at the site the surface land is to be returned to agricultural use (crops, grazing) and/or amenity (forestry). A risk assessment has been carried out to identify the risks posed by the existing ground contamination on the Galmoy Mine site and to ensure that end users of the site are not exposed to significant levels of contamination. This risk assessment will also help determine the likely extent of contamination which will assist in costing remedial works during the closure, decommissioning and restoration of the mine site.

4.4 This risk assessment identifies and assesses the types and levels of contamination present and evaluates the possibility of harm being caused. The proposed final land use of the site is not covered under the CLEA model. For the purposes of this risk assessment the CLEA land use of an allotment with a risk receptor of a six year old girl has been utilised. This represents a ‘worst case scenario’ for the site based on the potential for the site to be used for agricultural or amenity use.

CLEA Model

4.5 The CLEA model only assesses the risk to human health from contamination at a site and not the impact of contaminants upon grazing animals or plant life. As it is intended for the site to revert to agricultural or amenity use once mining operations have finished a separate assessment has been undertaken of the impact of contaminants upon grazing animals and plant life and is covered in Section 5.

Risk Assessment Model: Pre-Assessment

Source- Pathway- Receptor

4.6 The risks posed by contamination have been assessed on a site-specific basis using “source-pathway-receptor” methodologies in line with the Contaminated Land Regulations introduced (in April 2000) under Section 57 of the Environment Act 1995.

Contaminants

4.7 Contaminants (source) are only a risk if there is a pathway that allows them to affect a receptor, e.g. human, animals, plant, water etc. A pre-assessment conceptual model identifying various sources, pathways and receptors is presented in Figure 2. This pre-assessment conceptual model for the Galmoy Mine site addresses the potential contamination sources identified. This model highlights the different pathways between the source contaminants and the receptors. The potential receptors at the Galmoy Mine site are humans (particularly children), animals, plants, surface watercourses and groundwater. However, only human health (children and adults) are covered by the CLEA risk assessment.

4.8 This risk assessment for ground contamination at the site has addressed:

- Potential hazards to human health (decommissioning and ground workers and future site users) through contact with ground affected by contamination;

Grazing animals and plant life have been covered separately in Section 5.

Risk to Human Health

4.9 Risk to human health arising from long term exposure to ground contamination at the site has been assessed using the Contaminated Land Exposure Assessment model (CLEA model) developed for the UK Department of Environment, Food and Rural Affairs (DEFRA) and the UK Environment Agency and published in March 2002. The CLEA model combines information on the toxicity of contaminants with estimates of potential exposure by humans living and working on land affected by contamination over long periods of time.

CLEA Conceptual Model

4.10 Contaminants are only a risk to human health if there is a pathway that allows them to be taken up by the human body. Using the CLEA conceptual model approach, the possible exposure pathways for the proposed agricultural or amenity woodland end use at the site are:

- Outdoor ingestion of soil;
- Indoor ingestion of soil;
- Skin contact with outdoor soil;
- Skin contact with indoor dust;
- Outdoor inhalation of fugitive dust;
- Indoor inhalation of dust;
- Outdoor inhalation of soil vapour;
- Indoor inhalation of soil vapour.

These are shown in Figure 2.

Category of Allotment

4.11 The intended land use for the site is agricultural or amenity woodland. As this is not a land use covered by the CLEA model the category of allotment has been used in assessing the risk of contamination to end users of the site.

CLEA: Soil Guideline Values

Soil Guidance Values

4.12 The CLEA model is used to generate Soil Guidance Values (SGVs) which provide a level of contaminant concentration in the soil that is protective of human health. SGVs can therefore be used as a screening tool, serving as "intervention" indicators, i.e. contaminant levels above an SGV value are deemed to present an unacceptable risk to human health. In such circumstances, remedial actions are needed.

4.13 The site investigations carried out at the site have detected the presence of the following contaminants that are harmful to human health and which have CLEA soil guideline values. The associated soil guidance value (SGV) limits derived for these contaminants for allotment land use are listed below.

	Contaminant	*CLEA Soil Guidance limits for Allotments*
•	arsenic	20 mg/kg;
•	cadmium	8 mg/kg (at pH 8);
•	chromium	130 mg/kg;
•	lead	450 mg/kg;
•	mercury	8 mg/kg;
•	nickel	50 mg/kg; and
•	selenium	35 mg/kg.

CLEA SGV Risk Analysis

4.14 This analysis is based on the site investigation data. The approximate locations of all site investigation positions are shown on Figure 1. Table 3 summarises data from the site investigation including the number of samples, the range of sample values, the calculated arithmetic mean value, the U_{95} value, and SGV for each of these contaminants. (Note: the U_{95} value is the 95^{th} percentile, that is the value that excludes the most unlikely scenarios but also includes a wide range of scenarios.) If the U_{95} value determined is less than the SGV then no further actions are required in respect of the contaminant. The SGV risk analysis results are provided in Appendix 2 for each contaminant assessed.

Table 3 SGV risk analysis of contaminants found at the Galmoy Mine site					
Contaminant	**Number of samples**	**Range of Values (mg/kg)**	**Mean value mg/kg**	**U_{95} value mg/kg**	**SGV (residential) mg/kg**
Arsenic	24	<5-1150	350.9167	440.6	20
Cadmium	24	<1-121	32.2083	41.9	5
Chromium	24	8-18	12.33	13.3	130
Lead	24	26-14,319	3990.875	5053.3	450
Mercury	24	<1	1	1	8
Nickel	24	19-337	97.125	131.4 4	50
Selenium	24	<10	10	10	35

U_{95} Values

4.15 Comparison of U_{95} values obtained against the SGV's for chromium, mercury and selenium in Table 3 demonstrates that the contaminant levels of these determinands at the site do not present a risk to the human health of future site users. No mitigation measures (remedial action) are required for these determinands.

4.16 The U_{95} values obtained for arsenic, cadmium, nickel and lead exceed the SGVs for allotments. Further actions are therefore required.

Sample Results

4.17 Inspection of the locations of lead and arsenic sampling show elevated concentrations between 0.0-0.30m in all trial pit locations with the exception of trial pit 11 where arsenic and lead were identified at levels below the soil guideline value. Arsenic and lead at elevated concentrations were also identified between 0.30-1.20m within trial pits 2, 4, 5, 6, and 9. Figures 3 & 4 illustrate the approximate zones within the site affected by these elevated concentrations of arsenic and lead contamination. The exact dimensions of the areas of elevated concentrations are not known due to the limitations if the site investigation, therefore the zones shown on the drawing should be used only as a visual guide.

4.18 Nickel and Cadmium were again identified at elevated in all trial pits between 0.00-0.30m with the exception of trial pit 11 where nickel and cadmium were identified at levels below the soil guideline value. Nickel and Cadmium at elevated concentrations were also identified between 0.30-1.20m within trial pits 2, 4 and 5.

4.19 The zoning of the site has been carried out for the two depth ranges from which contamination samples were taken. For the depth range 0.00-0.30m the elevated concentrations of arsenic, lead, nickel and cadmium extend throughout the whole of the site. Therefore this depth of material comprises one zone within itself. For the depth range 0.30-1.20m the site has been zoned as elevated zones (where levels of contaminants exceed soil guidance values) and remainder of area (levels of contaminants below soil guideline values).

4.20 Table 4 shows U_{95} values obtained for arsenic, lead, nickel and cadmium within the Galmoy Mine site at depths of 0.00-0.30m. Table 5 shows U_{95} values obtained for arsenic, lead, nickel and cadmium following the zoning of contaminants within the Galmoy Mine site at depths of 0.30-1.20m into elevated zones and remainder of area (unelevated zones).

Table 4 Further SGV risk analysis of arsenic and lead contaminants found at the Galmoy site following zoning of contamination at depths of 0.00-0.30m

Area	**Contaminant**	**Number of samples**	**Range of Values (mg/kg)**	**Mean value mg/kg**	**U_{95} value mg/kg**	**SGV (residential) mg/kg**
Elevated arsenic zone 0.00-0.30m	Arsenic	12	12-1150	481.2	580.8	20
Elevated lead zone 0.00-0.30m	Lead	12	60-14,319	6827.8	7830.4	450
Elevated nickel zone 0.00-0.30m	Nickel	12	19-315	126.2	165.4	50
Elevated cadmium zone 0.00-0.30m	Cadmium	12	<1-121	51.60	63.7	8

Table 5 Further SGV risk analysis of arsenic, lead, nickel and cadmium contaminants found at the Galmoy site following zoning of contamination at depths of 0.30-1.20m						
Area	**Contaminant**	**Number of samples**	**Range of Values (mg/kg)**	**Mean value mg/kg**	**U_{95} value mg/kg**	**SGV (residential) mg/kg**
Elevated arsenic zone 0.30-1.20m	Arsenic	5	49-1074	517	707.5	20
Remainder of Area 0.30-1.20m	Arsenic	7	5-15	8.8	10.7	20
Elevated lead zone 0.30-1.20m	Lead	5	740-6104	2630.2	4003.9	450
Remainder of Area 0.30-1.20m	Lead	7	26-301	103.4	164.1	450
Elevated nickel zone 0.00-0.30m	Nickel	3	97-337	185.6	272.0	50
Remainder of Area 0.30-1.20m	Nickel	9	22-43	28.9	33. 49	50
Elevated cadmium zone 0.00-0.30m	Cadmium	3	28-62	43.6	54.0	8
Remainder of Area	Cadmium	9	<1-7	2.56	3.856	8

4.21 The results in table 5 demonstrate that in the 0.30-1.20m zone “remainder of site” the arsenic, lead, nickel and cadmium contaminant levels do not present a risk to human health and no mitigation measures (remedial action) is required in this zone. However, in the 0.30-1.20m zones identified as having elevated concentrations of arsenic, lead, nickel and cadmium there is risk of harm to human health. Remedial action will be required in these zones.

4.22 Figures 4 and 5 visually demonstrate the conjectured extent of the elevated contaminants identified at the site for depths 0.0-0.3m and 0.30-1.20m. The exact extent of the elevated contaminants could be ascertained from further investigation of the site once mining has ceased.

CLEA: Non SGV Analysis

CLEA Regulations

4.23 For other contaminants the CLEA Regulations do not currently provide SGVs. For these contaminants it is necessary to calculate a site specific assessment criterion using the SNIFFER framework.

SNIFFER Framework

4.24 SNIFFER was derived by the Scotland and Northern Ireland Forum for Environmental Research and provides a method for deriving site specific human health assessment criteria for chronic exposure to contaminants in soil. In the absence of a published SGV, the guidance given in SNIFFER Report No. LQ01 'method for Deriving Site-Specific Human Health Assessment criteria (SSAC values) for contaminants in Soil, April 2003' has been used. This document provides a method of calculating site specific levels of contaminants in soil with respect to protecting end users of the site.

4.25 Copies of the SNIFFER worksheets used to derive the SSAC for the contaminants listed in 4.25 are attached in Appendix 3

Galmoy Mine Site

4.26 For the Galmoy Mine Site the following determinands have been assessed using the SNIFFER framework and relevant health criteria values to derive SSAC values:

- Boron;
- Copper;
- Zinc; and
- Diesel Range Organics.

Tolerable Daily Intakes

4.27 The Tolerable Daily Intakes for the SNIFFER assessment have been obtained from the Dutch Guidance, World Health Organisation, and published data by US EPA IRIS system. They are specifically developed to be protective for long-term exposure to a compound. The risk analysis results are provided in Appendix 3.

4.28 No Tolerable Daily Intake Value are available for Diesel Range Organics covering the hydrocarbon range C4-C35. However the Total Petroleum Hydrocarbons covering the ranges C10-C30 have been used. Therefore the values attributed to aliphatic ranges of the Total Petroleum Hydrocarbon Fractions, C10-C12, C12-C16, C16-C21 and C21-C34 have been used. The range of SSAC values for these ranges are given within table 6 below. However as the hydrocarbon fractions present in Diesel Range Organics have not been assessed individually, for the purposes of this assessment the lowest SSAC value will be used.

4.29 Normally boron, zinc and copper would not be considered to be toxic to human health. However, the high levels detected warrant further assessment and therefore they have been assessed.

Table 6 SNIFFER Site Specific Risk Assessment Criteria for non-SGV contaminants found at the Galmoy Mine Site

Determinand	Range of Values mg/kg	Site Specific Assessment Criteria Value mg/kg
Boron	<5-12	40
Copper	9-392	480
Zinc	105-68,065	630
Diesel Range Organics	<1-5746	552-14,785 *

* The SSAC value is derived using the values attributed to the aliphatic TPH fractions within the US Total Petroleum Hydrocarbons Criteria Working Group'.

4.30 This risk assessment analysis demonstrates that boron and copper do not present a risk to human health within the site area therefore no mitigation measures (remedial action) is required in respect of these contaminants.

4.31 The risk assessment analysis demonstrates that further actions are required in respect of zinc and diesel range organics.

4.32 The locations of the elevated levels of zinc, and Diesel Range Organics are shown in table 7 below. The estimated lateral extent of these elevated zones are shown in Figures 4 & 5.

Table 7 Galmoy Mine Site Locations of Contaminants found exceeding the SSAC under the SNIFFER Framework

Contaminant	Location of elevated levels
Zinc	TP1 (0.0-0.3m), TP2 (0.0-0.3m & 0.3-1.2m), TP3 (0.0-0.3m), TP4 (0.0-0.3m&0.3-1.2m), TP5 (0.0-0.3m&0.3-1.2m), TP6 (0.3-1.2m&0.3-1.2m), TP7 0.0-0.3m&0.3-1.2m), TP8 (0.0-0.3m&0.3-1.2m), TP9 (0.0-0.3m&0.3-1.2m), TP10 (0.0-0.3m&0.3-1.2m), TP12 (0.0-0.3m)
Diesel Range Organics	TP12 (0.0-0.3m), TP7 (0.3-1.2m)

4.33 Based on the Site Specific Assessment Criteria Values utilised in this risk assessment, it is apparent that zinc, and diesel range organics have potential to be hazardous to human health at the locations detailed above. Consideration will need to be given to remedial actions.

Dutch Guidance

4.34 The Dutch Guidance is based on three Values. The first is the National Background Concentration which is only applicable in the Netherlands and is not therefore relevant for this assessment. The remaining two values are the Target Value and Intervention Value. The Target Value indicates a level of soil quality which has to be achieved to fully recover the functional properties of a soil for human, animal and plant life. The Intervention Value indicates when the functional properties of the soil for human, animal and plant life is seriously impaired or threatened. Intervention values represent a level of contamination above which there is a serious case of soil contamination.

4.35 Table 8 summarises the Dutch levels for those contaminants for which there are no soil guideline values or for which site specific assessment criteria cannot currently be calculated.

Table 8 Dutch Levels for contaminants identified at the Galmoy Mine Site

Determinand	Range of values (mg/kg)	Dutch List	
		Target (Optimum) Value (mg/kg)	Intervention (Action) Value (mg/kg)
Barium	17-331	200	625
Cobalt	6-243	20	240
Molybdenum	<1-8	10	200
Mineral Oil	<1-4597	50	5000

4.36 The risk assessment analysis demonstrates that, Molybdenum does not present a risk to human health within the Galmoy Mine site and no remedial actions are currently required in this area for these contaminants. Mineral oil is below the Dutch guideline value, however the high value of 4597mg/kg recorded at 0.00-0.30m at trial pit 7 is near enough the Dutch Guideline Value to be considered for treatment.

4.37 Cobalt exceeded the Dutch guideline value of 240mg/kg in one sample. The sample taken at 0.30-1.20m within trial pit 2 recorded 243 mg/kg of cobalt. The near surface sample of 0.00-0.30m recorded a level of 231 mg/kg which is near enough to the Dutch guideline value to be considered for treatment.

4.38 Based on the Dutch Intervention values utilised in this risk assessment, there is potential for cobalt and mineral oil to be hazardous to human health at trial pit 2 and trial pit 7 respectively. Consideration will need to be given to remedial actions.

Summary: Human Risk

4.39 The risk analysis carried out in accordance with CLEA guidance has shown that remedial actions are required within the Galmoy Mine Site in respect of arsenic, lead, nickel, cobalt, manganese, zinc, diesel range organics and Mineral Oil. Remedial actions are required in identified zones for each of these contaminants, the approximate extent of which are shown in Figures 4 & 5

5.0 GROUND CONTAMINATION: RISK ASSESSMENT ANIMAL AND PLANT LIFE

Risk to Animal and Plant Life

5.1 CLEA guidance is focused on risk to human health and does not assess the potential risk to plant or animal life from contaminants present in the ground. However, certain contaminants are known to be harmful to plant life (ie, phytotoxic). In addition contaminants hazardous to animals have the potential to accumulate within plants and consequently be digested by grazing animals. Contaminants that have the potential to be hazardous to plant and animal life are listed below:

- Arsenic
- Cadmium,
- Copper,
- Nickel,
- Zinc,
- Chromium,
- Boron,
- Lead
- Mercury,
- Selenium
- Mineral Oil
- Diesel Range Organics

Risk Assessment

5.2 In the absence of CLEA guidance for risk of harm to plant life and animal life, this risk assessment has utilised the following guidance.

Interdepartmental Committee on the Reclamation of Contaminated Land, Report 70/90. Notes on the Restoration and Aftercare of Metalliferous Mining Sites for Pasture and Grazing

The Code of Good Agricultural Practice for the Protection of Soil. Ministries of Agricultural Fisheries and Food. October 1998 and

Dutch Guidance (*Dutch Ministry of Public Housing Land Use and Notification Letter on Intervention for Soil and Groundwater Remediation*).

ICRCL Guidance Note

5.3 The ICRCL guidance note provides technical advice on concentrations of potentially toxic elements in soil that have been affected by mine spoil. The guidance takes into account the effects of these organic contaminants on the following:

- The risk of phytotoxicity to grasses and clover and therefore the effect on pasture production; and
- The intakes of toxic elements by grazing animals, through ingestion of herbage, soil or dust contaminated by these elements.

5.4 The guidance states that elements such as zinc and copper affect plant growth. Other elements such as cadmium, lead, arsenic and fluorine are not usually toxic to plants at the concentrations encountered in sites. However these elements may be absorbed by plants or be present in dust on leaves in amounts that could prove harmful to grazing animals.

Trigger Levels

5.5 Within the ICRCL guidelines there are two trigger levels against which the contaminant levels can be judged. These are the “threshold” trigger value and the “action” trigger value. Contaminant concentrations below the threshold value are deemed to present no significant hazard and therefore no remedial action is required. At concentrations between the threshold and action trigger value, consideration should be given as to whether remedial action is justified. Above the action trigger level, remedial action is usually required.

The Soil Code

5.6 The code of Good Agricultural Practice for the Protection of Soil concentrates on maximum permissible concentrations of potentially toxic elements in soils after sewage sludge has been applied to agricultural land. This concentrates on levels of elements at certain pH levels. The ICRCL guidance levels are considered to be more pertinent to the Galmoy Mine Site, however, the Code of Good Agricultural Practice soil concentration values have been included for information.

5.7 For the Soil Code maximum advisable concentrations values for Zinc, Copper and Nickel above a pH of 7.0 have been used. For Cadmium, Lead, Mercury, Chromium, Molybdenum, Selenium, Arsenic and Fluoride a pH of 5.0 and above is assumed. The maximum advisable concentrations apply to heavy metal concentrations in soils above which sewage sludge cannot be applied to agricultural land.

Dutch Guidance

5.8 The Dutch Guidance is based on three Values. The first is the National Background Concentration which is only applicable in the Netherlands and is not therefore relevant for this assessment. The remaining two values are the Target Value and Intervention Value. The Target Value indicates a level of soil quality which has to be achieved to fully recover the functional properties of a soil for human, animal and plant life. The Intervention Value indicates when the functional properties of the soil for human, animal and plant life is seriously impaired or threatened. Intervention values represent a level of contamination above which there is a serious case of soil contamination.

5.9 Table 9 shows the range of values recorded at the Galmoy Mine Site from the 2005 Site Investigation compared with the ICRCL maximum (action trigger) concentrations, the soil code maximum permissible concentrations of potentially toxic elements and the Dutch Guidance Values.

Table 9 Risk Assessment to Animal and Plant Life Contamination data for the Galmoy Mine Site with reference to ICRCL, the Soil Code, Dutch Levels

Contaminant	Range of Values (mg/kg)	ICRCL Maximum (Action Trigger) Concentrations (Values not to be exceeded for use as specified)		The Soil Code Maximum Permissible and Advisable Concentrations of Potentially Toxic Elements (mg/kg)	Dutch Guidance	
		For grazing livestock[(a)]	For crop growth (risk of toxicity)[(b)]		Target (Optimum) Value (mg/kg)	Intervention (Action) Value (mg/kg)
Arsenic	<5-1150	500	1000	50	29	55
Mercury	<1	-	-	1	0.3	10
Chromium	8-18	-	-	400 (provisional)	100	380
Zinc	105-68,065	3000	1000	300	140	720
Cadmium	<1-121	30	50	3	0.8	12
Lead	26-14,319	1000	-	300	85	530
Nickel	19-337	-	-	110	35	210
Boron	<5-12	-	3	-	-	-
Copper	9-392	500[(c)]	250	200	36	190
Barium	17-331	-	-	-	200	625
Molybdenum	<1-14	-	-	4	-	-
Selenium	<1	-	-	3	-	-
Fluoride	-	1000	-	500	-	-
Iron %	0.68-4.44	-	-	-	-	-

(a) For calves, sheep and horses – assuming that plant uptake is normal, the stock are continuously exposed to these concentrations and that it is proposed to manage the sward in such a way that only a relatively low level of soil contamination of herbage will occur. In such cases, soil may comprise up to about 5% of dry matter intake. Under less favourable conditions soil ingestion may be much higher. (The corresponding EDTA extractable phytotoxic limits for zn and cu are 130 & 70 mg/dm3 respectively – soil material should be considered a phytotoxic risk if either total or EDA-extractable limits are exceeded.

(b) For clover and the more productive sown grass species assuming a soil pH of at leas 6.0 metal tolerant cultivars are available, but these are intended for amenity/recreational after uses and advice should be sought before they are used in agriculture.

(c) The possibility of sub-clinical antagonistic effects on copper, metabolism cannot be ruled out if concentrations of zinc and cadmium in soils exceed 2000 and 15 mg/kg respectively.

(d) The accepted safe concentration of Molybdenum in soils is 4mg/kg. However, there are some areas in the UK where, because of local geology, the natural concentration of this element in the soils exceeds this level. In such cases there may be no additional problems as a result of applying sludge, but this should not be done except in accordance with expert advice. This advice will take account of existing soil molybdenum levels and current arrangements to provide copper supplements to livestock.

5.10 The analysis shows that arsenic, zinc, cadmium, lead, nickel and copper exceed the ICRCL maximum concentration for grazing livestock and crop growth as well as the Soil Code maximum permissible value and the Dutch Guidance intervention value. Boron exceeds the ICRCL Threshold value. Molybdenum exceeds the soil code maximum permissible value.

Summary: Risk to Animal and Plant Life

5.11 Remedial actions are required for arsenic, zinc, cadmium lead, copper, nickel, boron and molybdenum. It should be noted that the pH values for the site are likely to be alkaline and therefore the impact of metals on plant life would normally be considered to be limited. However, the extremely high lead and zinc concentrations at this site are likely to have an adverse affect on plant germination and growth.

Risk Assessment Model Animal and Plant Life: Post Assessment

5.12 Required remedial action has been identified in respect of elevated levels of arsenic, lead, zinc, cadmium, nickel, copper,. boron and molybdenum in areas of the site with respect to animal and plant life. Appropriate remedial action which could be adopted for the site are outlined in Section 7.

6.0 COMPARISON WITH THE SILVERMINES AND TYNAGH MINES

6.1 In 2004 a report entitled *'Final Report of Expert Group for Silvermines, County Tipperary. Lead and other Relevant Metals'* was published. This report gives guideline values for Human and Animal health for concentrations of Lead and Cadmium in the soils in the Silverdale Mine area. An earlier report titled' *Report of the investigation into the presence of lead and other heavy metals in he Tynagh Mines Area, County Galway'* was published in 2003. This report also details the analysis of soils for heavy metals in this area and the guideline value adopted for Lead concentration.

6.2 The guideline values presented in the above report are site specific and have been arrived at based on research of concentrations of heavy metals in the soil, water system, air, human, animal and plant receptors and their bioavailability. The overall findings were that a soil lead value of 1000mg/kg (dry weight) and below was acceptable for garden soils and agricultural soils. Values above this would require active management n the case of garden soils for the purposes of protecting human health and in the case of agricultural soils with a view to protecting animal health. In the case of Cadmium the guidance is to follow that of the Soils Guideline Values within the CLEA guidance.

6.3 No other guideline values are given in the report for other heavy metals. According to the report zinc and copper are of generally low toxicity and did not pose a significant risk to human health. The guideline values for lead and cadmium were considered sufficient to act as a trigger for active management.

6.4 Compared with the risk assessment undertaken for the purposes of the Galmoy Mine Site the soil guideline value applied is the same as that recommended by the Silvermines report for Human Health. However the Soil Guideline Value for lead applied in accordance with the CLEA guidance is 450mg/kg(lead) compared with 1000mg/kg(lead) stated in the Silvermines report. The UK ICRCL guideline value for Lead applied for grazing animals is 1000mg/kg(lead).

6.5 If research done in the Silvermines and Tynagh Mines areas has led to a site specific lead value of 1000mg/kg then a case may be made for a 'clean up' value of the same to be applied at the Galmoy Mine Site. However, the current site investigation is too limited to obtain this conclusion. A critical factor will be the bioavailability of the lead within the soils at Galmoy, as well as the leachability (ability of a contaminant to dissolve in liquid) of the contaminant. These factors are site dependant and will have to be clarified before finalising soil clean up targets for the Galmoy Site.

6.6 It should be noted that the Silvermines and Tynagh Mining areas have been affected by historical mining without adequate remediation. It is the intention of Galmoy Mines Ltd to undertake the remediation of the mine site and return the soil back to safe usage.

7.0 REMEDIAL OPTIONS FOR GROUND CONTAMINATION

7.1 The Post-Assessment CLEA Conceptual Model for the Galmoy Mine site, provided in Figure 3, highlights the contaminants present on site which require remedial action following the risk analysis assessments carried out (see Section 5). These risk assessments have specifically identified the necessity to undertake remedial action in respect of risk to human health and risk to animal and plant life.

7.2 This section briefly describes possible remedial options which could be adopted to deal with the risks to human health, animal and plant life and the water environment.

7.3 Remedial measures are required in respect of potential harm to human health from ground contamination at the site, due to arsenic, lead, nickel, cobalt, copper, zinc and mined oil contamination. With regards to animal and plant life, remedial measures are required in respect of arsenic, zinc, copper, lead, cadmium and nickel. Based on CLEA guidance, remedial action can take the following forms:

- Remove the source, and
- Break the pathway.

Removing the Source

7.4 One remedial option would be to remove these zoned areas of made ground and natural superficial material and dispose of the contaminated ground within the TMF on site. The alternative is to dispose of the material at an appropriate licensed disposal facility. Both options would remove the source of contaminants and thereby minimise risk to future users of the Galmoy Mine Site. The second option does, however, incur costs associated with disposal off-site and may give rise to increased HGV movements to/from the site.

7.5 The site investigation data has shown that at the location of the trial pits the surface soils on the site (0.00-0.30m) are contaminated at elevated levels. The analysis of material between 0.30m and 1.20m has shown two distinct ‘hotspot’ areas on the site where elevate levels of contaminants have been detected. The material in which they have been detected has been gravel (sub-base or covering material) or clay material. In addition, more localised hotspots exist from diesel range organics, mineral oil barium and cobalt.

Break the Pathway

7.6 The pathways between contaminant sources and human receptors can be effectively broken by construction of a cover layer or through immobilisation techniques. A properly constructed cover layer isolates the potential hazardous material, preventing its disposal and thus removing the likelihood of inhalation, ingestion or dermal contact.

7.7 A cover system will usually take the form of a “capping layer”. An effective capping layer could be formed as a clean soil layer, between 0.15 -1.00m deep depending on the risk identified. The clean soil layer could be a mixture of subsoil and topsoil or soil forming material. It is suggested that a marker layer comprising a geofabric/geotextile is laid at the base of the capping layer. This will provide a visible marker and will also serve to avoid intermingling of the in-situ contaminated soil materials and the imported clean soil materials in the capping layer.

7.8 As the site is proposed to be returned to agriculture or amenity (woodland) use the area required for capping could potentially be extensive and may be financially restrictive. Other concerns that the cover layer could be damaged or breached in some way through farming activities or forestry.

7.9 Immobilisation techniques involve the use of ‘E Clays’ which are tailored specifically for the contamination identified at a site. These ‘immobilise’ the contaminants and prevent leaching or contact with on site receptors. Again this technique would entail a cost for treatment of the contaminated ground.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 This report has reviewed the findings of the site investigation conducted at the Galmoy Mine site in 2005.

Risk Assessments

8.2 In the absence of specific regulations on Ireland the risk assessments have been carried out in accordance with UK CLEA Regulations and other relevant guidance on ground contamination. The pre-assessment conceptual model (Figure 2) identified the potential sources, pathways and receptors for the Galmoy Mine site.

8.3 Risk assessment analyses (Section 4 and 5) were carried out to assess potential harm to human health; animal and plant life. The outcomes of these risk assessment analyses are depicted in the post-assessment conceptual model (Figure 3) for the Galmoy Mine site.

8.4 The risk assessment analyses identified arsenic, lead, cobalt, nickel, cadmium, zinc, and mineral oil contaminants as having potential to harm human health; and arsenic, lead, copper, cadmium, nickel and zinc contaminants as having potential to harm animal and plant life. The likely area extent of these contaminants with regard to human health is shown on Figures 4 & 5. These contaminants are located within the gravel and clay strata.

Remedial Options

8.5 Outline remedial options have been proposed in Section 7 to address the identified risks to human health, animal and plant life. These remedial options concern either “removal of source” (i.e. excavate and dispose within a tailings facility or a suitably licensed waste disposal facility off site) or “breaking the pathway” (i.e. construction of a suitable capping/cover layer).

8.6 It is recommended that once the closure and demolition of the mine site has been carried out that a full and detailed contamination survey is undertaken of the site prior to remediation and returning the site to the proposed end use.

8.7 The recommendation is that the contamination assessment is carried out in accordance with the UK CLR Report No.4 ‘Sampling Strategies for Contaminated Land’ Department of Environment, Published 1994.

8.8 Based on the mining setting of the site and the elevated concentrations of contaminants identified during the site investigation it is recommended that the soils are tested for the following contaminants associated with the mining activities carried out at the site. Not all of the following contaminants were tested for as part of the current site investigation. This list is not exhaustive and when the contamination assessment is carried out at closure further potential contaminants may have come to light or will be covered by guidance.

- Arsenic
- Cadmium
- Copper
- Nickel
- Boron
- Cobalt
- Mineral Oil
- pH
- TPH Fractions
- Barium
- Zinc
- Sulphur
- Diesel Range Organics

8.9 Both bioavailability and leachate testing of the heavy metal contaminants should also be undertaken. This will assist in the application of Site Specific Clean Up Guidelines. The closure contamination assessment must be undertaken with the end use of the site in mind and in accordance with relevant guidance and legislation at that time.

8.10 During the decommissioning, clean up and early stages of aftercare of the site precautions must be taken to reduce potential effects of elevated contaminants on human health. It is recommended that the guidance within the '*Final Report of Expert Group for Silvermines, County Tipperary'.* Environmental Protection Agency, Ireland. (2004) is applied where relevant.

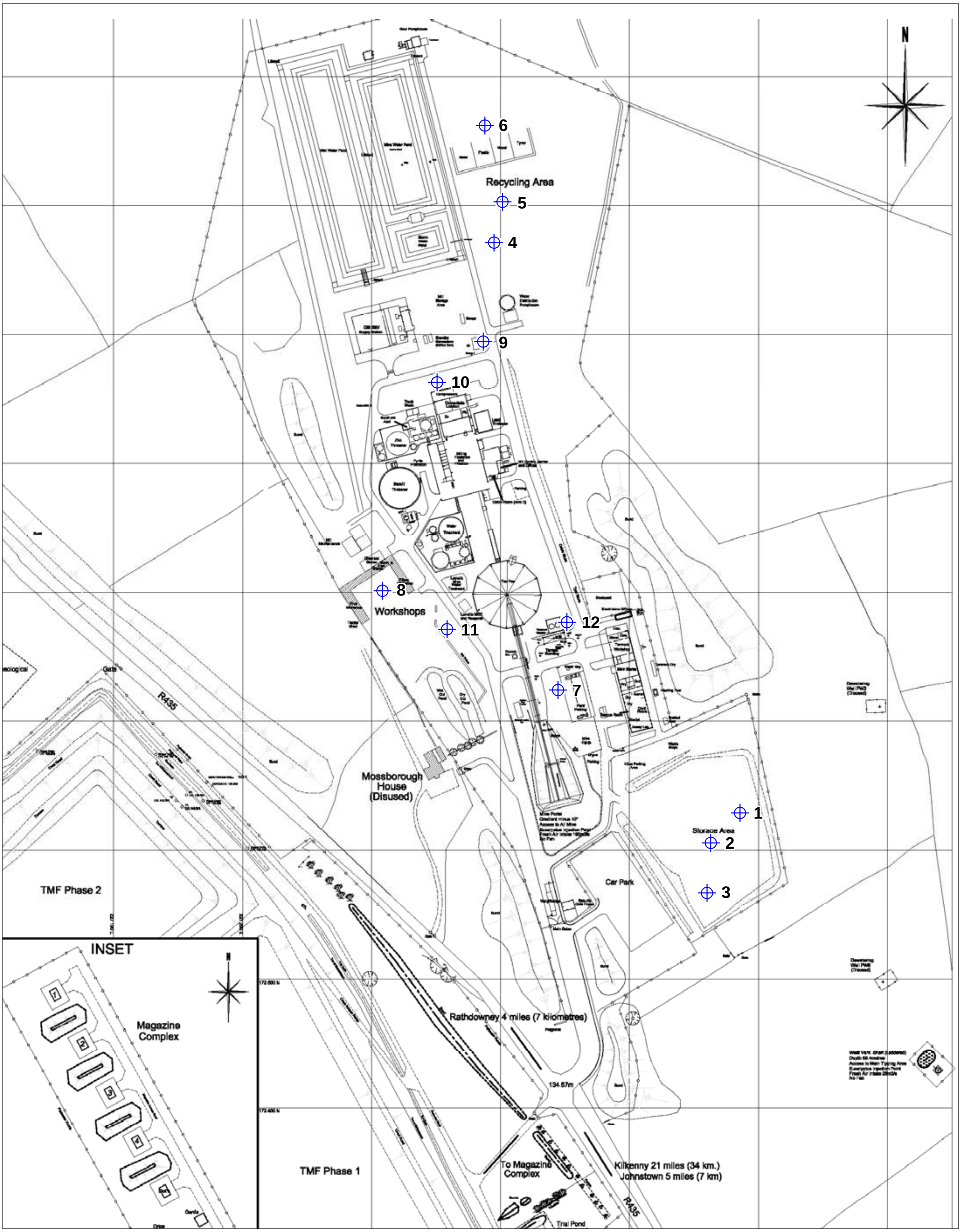
Limitations

The work undertaken to provide the basis of this report includes a study of the readily available documented information from a variety of sources. The information reviewed should not be considered exhaustive and has been accepted in good faith by Wardell Armstrong International Ltd ("WAI") as providing a true indication of the site conditions. However, no liability can be accepted for the detailed accuracy or otherwise of any of the reports or documents prepared by others for the Client or for third parties, or for any associated errors or omissions.

It should be noted that the environment and contaminated land guidance and legislation are constantly under review, with authoritative guidance documents subject to change. The conclusions presented herein are based on guidance and legislation available at the time of issuing this report, and no liability can be accepted for the retrospective effects of any changes or amendments to such guidance and/or legislation.

WAI has produced this report solely for the use of the Client and his agent. The report should not be relied upon in any way by any third party.

Figure 1 A5.1 Location of Trial Pits



Title:

Site Plan Showing Trial Pit Locations

Fig. A5.1

Project Ref No: 51-0241	DRG Ref: TP3_GALMO_510241
Drawn By: S.D. Clarke	Date: 10 NOV 2005
Checked By: J. Turner	Date: 10 NOV 2005
BNG Ref:	Map Ref:

⌖ Trial Pit Locations

Printed @ A4 : Grid = 100m & Scale = 1 :4 000

Clients:

Galmoy Mines Ltd.

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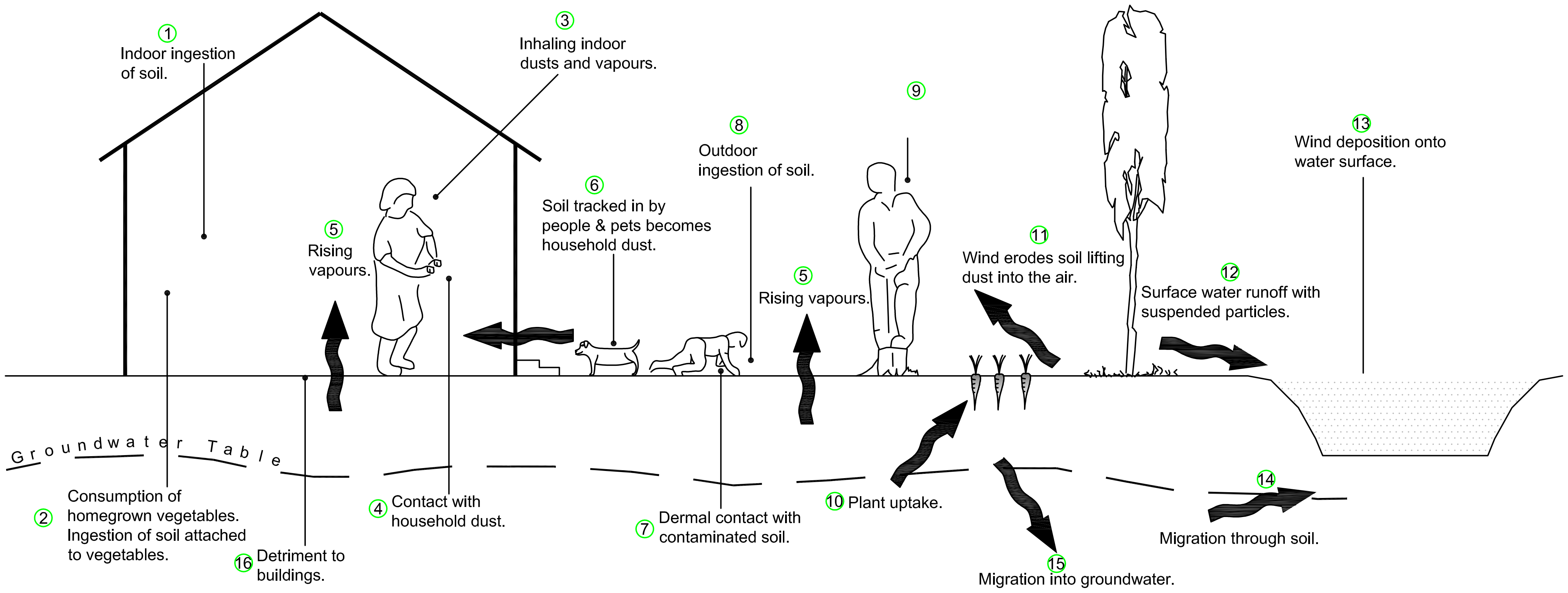
Registered Office: Wardell Armstrong International Ltd, Lancaster Building, Newcastle under Lyme, Staffs, ST5 1PQ, United Kingdom
Company number:3298668 File Location: P:\Environment\51-0241 Arcon Mine MCP\3.Maps\Layouts\TP1_GAMO_510241.wor

Figure 2 A5.2 Risk Assessment CLEA Conceptual Model (Sources – Pathways-Receptors) Pre-Assessment

CLEA : Conceptual Model for Risk to Human Health : Galmoy Mine.



CONTAMINANTS	HAZARDS	PATHWAYS
Arsenic	Toxic by ingestion, skin contact and inhalation. Water pollutant. May reduce plant growth.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Boron	Toxic by ingestion, skin contact and inhalation. Water pollutant. Phytotoxic.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Cadmium	Toxic by ingestion, skin contact and inhalation. Water pollutant.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Chromium	Toxic by ingestion and inhalation. Water pollutant. Phytotoxic.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Copper	Toxic at elevated levels by ingestion, skin contact and inhalation. Water pollutant. Phytotoxic.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Lead	Toxic by ingestion, skin contact and inhalation. Water pollutant. Phytotoxic.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Mercury	Toxic by ingestion, skin contact and inhalation. Water pollutant. Phytotoxic.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Nickel	Toxic at elevated levels by ingestion, skin contact and inhalation. Water pollutant. Phytotoxic.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.

CONTAMINANTS	HAZARDS	PATHWAYS
Selenium	Toxic by ingestion, skin contact and inhalation. Water pollutant.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Zinc	Toxic at elevated levels by ingestion, skin contact and inhalation. Water pollutant. Phytotoxic.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Diesel Range Organics	Toxic by ingestion, skin contact and inhalation. Water pollutant. May reduce plant growth. Detrimental to building materials.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Mineral Oil	Toxic by ingestion, skin contact and inhalation. Water pollutant. May reduce plant growth. Detrimental to building materials.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16.
Barium	Toxic by ingestion, skin contact and inhalation. Water pollutant. Phytotoxic at elevated levels. Detrimental to building materials.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16.
Molybdenum	In Extremely high doses can be harmful to human and animal health	1, 2, 3, 4, 6, 7, 8, 9, 11
Cobalt	Hazard by ingestion of dusts/mists, dermal contact with dusts or solutions. May have detrimental health effects on grazing animals	1, 2, 3, 4, 6, 7, 8, 9, 11

REFERENCE

FIG. A5.2

Migration of contaminants

Exposure pathways 1

CLIENT
GALMOY MINES LTD

PROJECT
GALMOY MINE
Second Interim Mine Closure and Rehabilitation Plan

DRAWING TITLE
RISK ASSESSMENT CLEA CONCEPTUAL MODEL (Sources - Pathways - Receptors) PRE ASSESSMENT

DRG No	SCALE	DATE
A5.2	NTS	NOVEMBER 2005
DRAWN BY	CHECKED BY	APPROVED BY
BOC		

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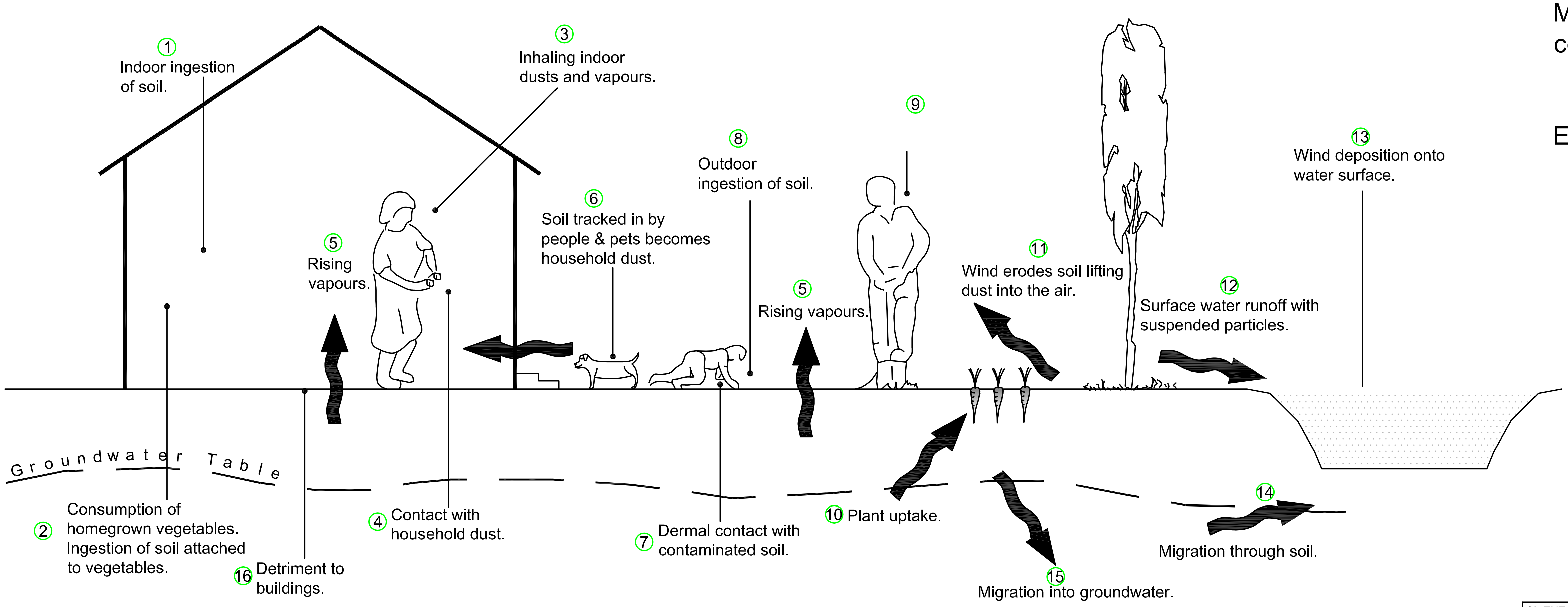
Figure 3 A5.3 Risk Assessment CLEA Conceptual Model (Sources – Pathways – Receptors) Post Assessment

FIG. A5.3

CLEA : Conceptual Model for Risk to Human Health : Galmoy Mine.



REFERENCE

Migration of contaminants

Exposure pathways

CONTAMINANTS	HAZARDS	PATHWAYS
Arsenic	Toxic by ingestion, skin contact and inhalation. Water pollutant. May reduce plant growth.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Lead	Toxic by ingestion, skin contact and inhalation. Water pollutant. Phytotoxic.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Cadmium	Toxic by ingestion, skin contact and inhalation. Water pollutant.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Nickel	Toxic at elevated levels by ingestion, skin contact and inhalation. Water pollutant. Phytotoxic.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.

CONTAMINANTS	HAZARDS	PATHWAYS
Zinc	Toxic at elevated levels by ingestion, skin contact and inhalation. Water pollutant. Phytotoxic.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Diesel Range Organics	Toxic by ingestion, skin contact and inhalation. Water pollutant. May reduce plant growth. Detrimental to building materials.	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Mineral Oil	Toxic by ingestion, skin contact and inhalation. Water pollutant. May reduce plant growth. Detrimental to building materials.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16.
Cobalt	Hazard by ingestion of dusts/mists, dermal contact with dusts or solutions. May have detrimental health effects on grazing animals	1, 2, 3, 4, 6, 7, 8, 9, 11

CLIENT

GALMOY MINES LTD

PROJECT

GALMOY MINE
Second Interim Mine Closure and Rehabilitation Plan

DRAWING TITLE

RISK ASSESSMENT CLEA CONCEPTUAL MODEL (Sources - Pathways - Receptors) POST ASSESSMENT

DRG No	SCALE	DATE
A5.3	NTS	NOVEMBER 2005
DRAWN BY	CHECKED BY	APPROVED BY
BOC		

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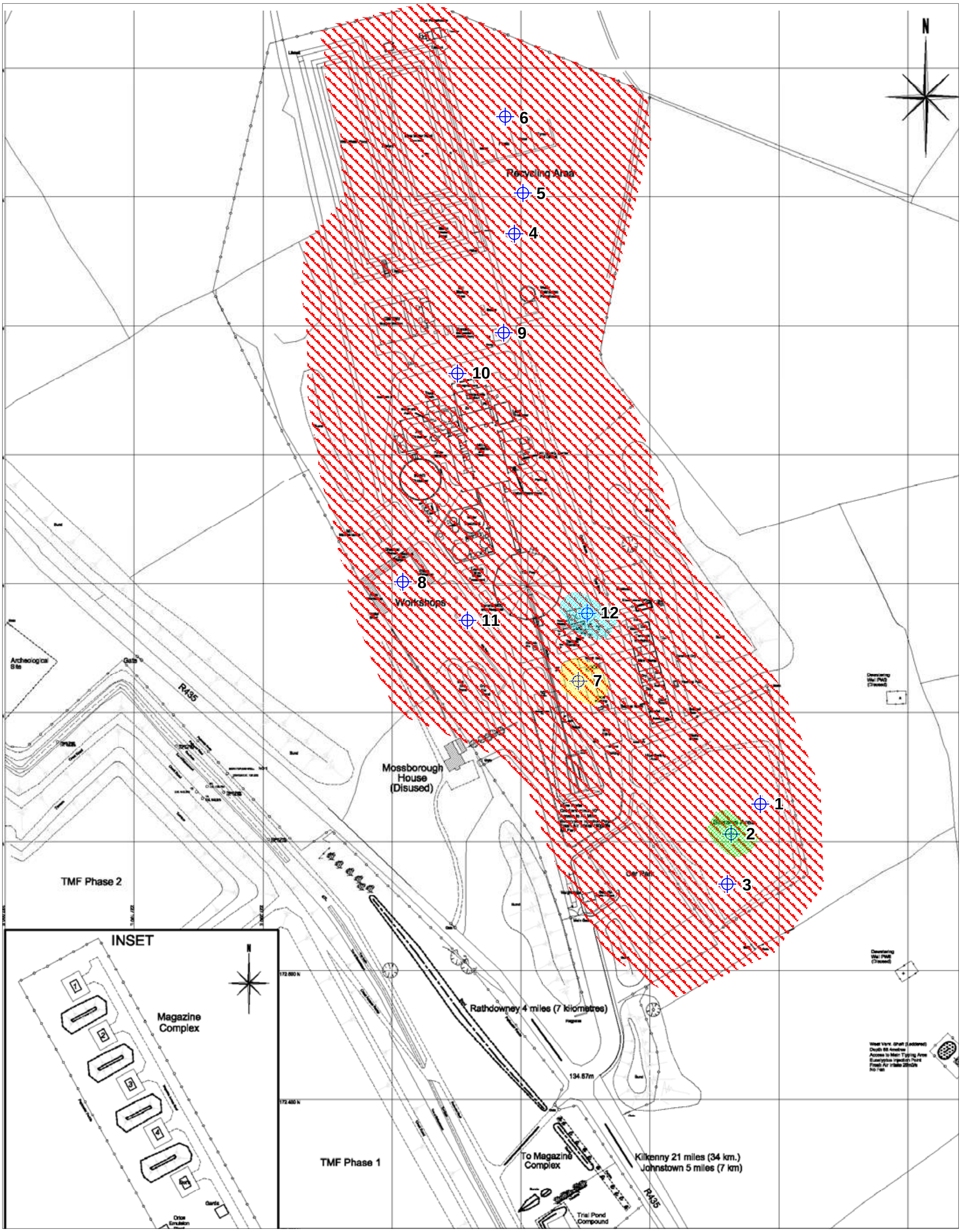
Figure 4 A5.4 Conjectured extent at near surface (0.0-0.30m) of Elevated Concentrations of Arsenic, Lead, Nickel, Zinc, Cadmium, Mineral Oils, Cobalt and Diesel Range Organics



Title: Conjected Extent @ Near Surface (0 - 0.3m) Elevated Concentrations of Arsenic, Lead, Nickel, Zinc, Cadmium, Mineral Oils & Diesel Range Organics

Fig. A5.4

Project Ref No: 51-0241		DRG Ref: TP1_GALMO_510241	
Drawn By:	S.D. Clarke	Date:	10 NOV 2005
Checked By:	J. Turner	Date:	10 NOV 2005
BNG Ref:		Map Ref:	

Diesel Range Organics

Mineral Oils and DRO's

Cobalt and Mineral Oils

Arsenic, Lead, Nickel, Zinc and Cadmium

Trial Pits

Printed @ A4 : Grid = 100m & Scale = 1 :4 000

Clients:

Galmoy Mines Ltd.

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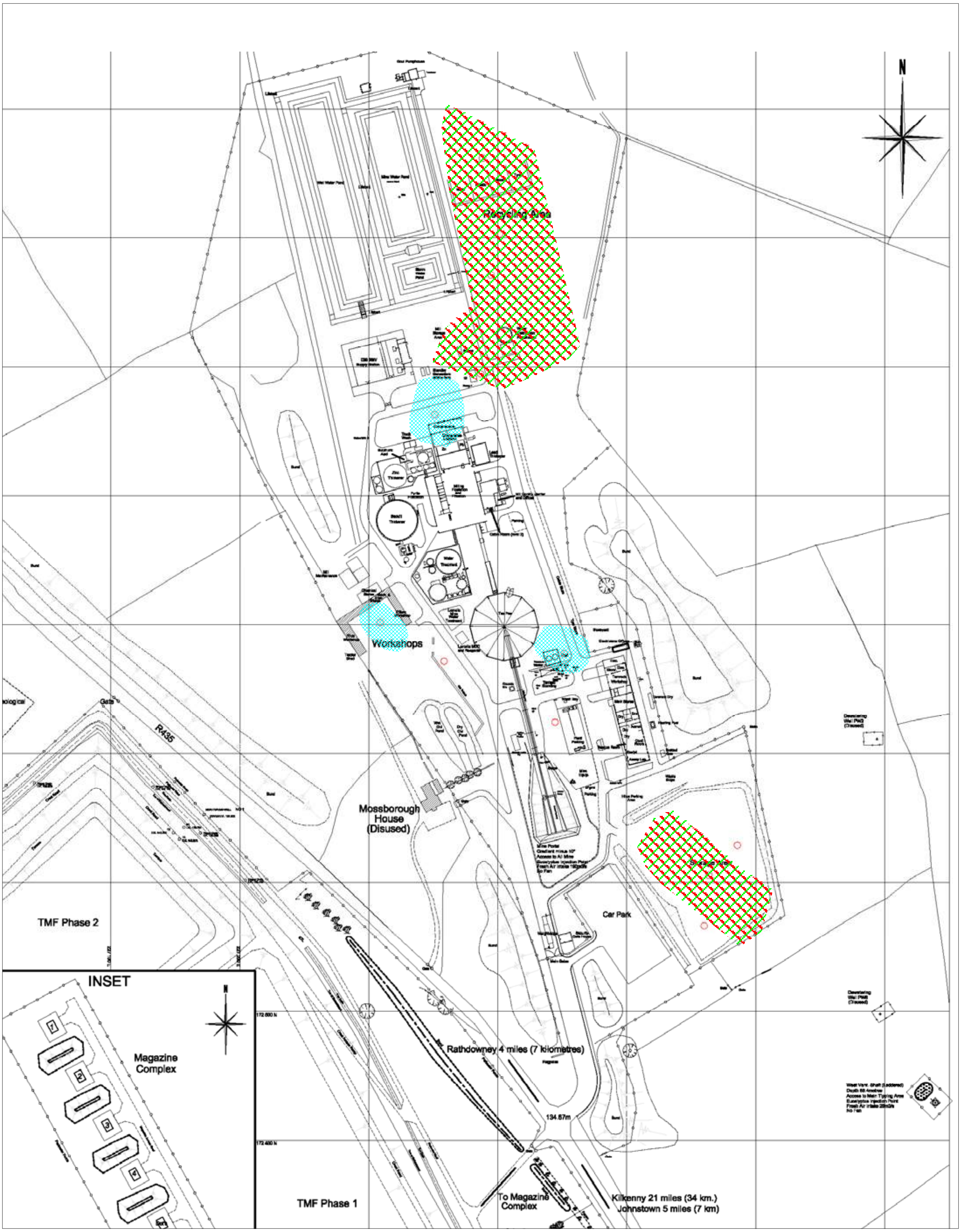
Company number:3298668 File Location: P:\Environment\51-0241 Arcon Mine MCP\3.Maps\Layouts\TP1_GAMO_510241.wor

Figure 5 A5.5 Conjectured extent at 0.3-1.2 bgl of Elevated Concentrations of Arsenic, Lead, Nickel, Zinc, Cadmium and Diesel Range Organics



Title:
Conjected Extent @ Near Surface (0.3 - 1.2m) Elevated Concentrations of Arsenic, Lead, Nickel, Zinc, Cadmium and Diesel Range Organics

Fig. A5.5

Project Ref No: 51-0241	DRG Ref: TP2_GALMO_510241	
Drawn By: S.D. Clarke	Date: 10 NOV 2005	
Checked By: J. Turner	Date: 10 NOV 2005	
BNG Ref:	Map Ref:	

Diesel Range Organics

Arsenic, Lead, Nickel, Zinc and Cadmium

Printed @ A4 : Grid = 100m & Scale = 1 :4 000

Clients:

Galmoy Mines Ltd.

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APPENDIX 1 RESULTS OF CONTAMINATION ANALYSIS

CERTIFICATE OF ANALYSIS FINAL 9/21/2005

TO: Arcon Exploration Plc. INVOICE: Same

ADDRESS Galmoy, Aqua Regia ICP
Via Thurles,
Co. Kilkenny.
Ireland Preparation
ATTN: John Stapleton P2

CODE: 1A - 18
BATCH NO. 05H116
NO. SAMPLES 24 Soil

LAB NO.	SAMPLE NO.	Arsenic ppm	Boron ppm	Barium ppm	Cadmium ppm	Cobalt ppm	Chromium ppm	Copper ppm	Mercury ppm	Molybdenum ppm	Nickel ppm	Lead ppm	Sulphur %	Selenium ppm	Zinc ppm
1	1A	233	<5	46	14	79	8	15	<1	<1	111	1590	1	<10	12355
2	1B	6	<5	17	<1	9	11	17	<1	<1	43	26	0.02	<10	262
3	2A	1150	<5	173	70	231	11	70	<1	2	315	9330	5.34	<10	57146
4	2B	1074	<5	85	62	243	11	16	<1	1	337	6104	5.7	<10	68065
5	3A	271	<5	166	48	39	8	100	<1	1	65	8824	1.86	<10	13708
6	3B	<5	<5	20	1	14	8	12	<1	<1	40	69	0.03	<10	278
7	4A	390	12	326	33	50	15	118	<1	8	78	4858	2.63	<10	17841
8	4B	854	10	51	28	85	17	24	<1	2	97	1080	2.53	<10	19333
9	5A	1014	<5	96	46	184	17	115	<1	3	262	6660	4.42	<10	43083
10	5B	528	<5	120	41	82	14	113	<1	2	123	4477	2.51	<10	23783
11	6A	637	<5	50	34	93	9	27	<1	1	145	5620	2.56	<10	33392
12	6B	80	<5	79	6	19	13	16	<1	<1	37	740	0.34	<10	3841
13	7A	333	5	331	69	40	13	120	<1	6	66	7751	2.61	<10	21800
14	7B	15	9	51	1	10	13	13	<1	<1	27	123	0.09	<10	607
15	8A	374	9	62	18	108	15	31	<1	2	201	2501	2.68	<10	20693
16	8B	7	<5	31	<1	8	10	9	<1	<1	22	48	0.04	<10	218
17	9A	600	<5	163	89	57	12	392	<1	3	99	14319	3.52	<10	22436
18	9B	49	<5	41	7	10	8	32	<1	<1	24	750	0.28	<10	1860
19	10A	260	<5	318	121	39	14	277	<1	2	71	12826	2.07	<10	29879
20	10B	12	<5	46	4	6	12	16	<1	<1	22	301	0.08	<10	999
21	11A	12	<5	65	<1	7	17	11	<1	<1	19	60	0.03	<10	259
22	11B	7	<5	27	<1	7	11	10	<1	<1	23	32	0.02	<10	105
23	12A	501	6	322	76	53	18	112	<1	14	82	7595	3.83	<10	27356
24	12B	10	9	44	<1	8	11	10	<1	<1	22	97	0.06	<10	461

	Arsenic	Boron	Barium	Cadmium	Cobalt	Chromium	Copper	Mercury	Molybdenum	Nickel	Lead	Sulphur	Selenium	Zinc
Standards														
ICP-4	1222	460	78	18	32	148	1904	99	85	374	1955	5.44	10	6126
ICP-5	635	244	394	9	17	219	974	49	44	186	982	2.48	<10	3095
Blank	<5	<5	<2	<1	<1	<2	<2	<1	<1	<1	<3	<.01	<10	3
Upper Calibration Limit	20000	500	5000	500	2500	5000	20000	500	500	2500	20000	12.5	500	20000
Assigned Values for In-house S	1260	480	100	18	33	140	1900	102	86	370	1960	5.45	13	6260
Assigned Values for In-house S	615	250	400	9	17	242	950	50	44	188	980	2.8	7	3210

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Analysis Report

Project Code : 05-03049 **Report Unique ID: 3433**
Report Date : 28-Sep-2005 **Commen. Date: 14/09/2005**

Customer: *Contact Details:*

Arcon Mines
Arcon Mines
Galway Via. Thurles
Co. Tipperary

P/O: 28945

Approved by : Cara O'Loughlin
Senior Chemist

Sample Number : 24412 Client ID: 12B Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	39	mg/kg
	Mineral Oil**	-	<1	mg/kg

Sample Number : 24413 Client ID: 12A Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	1264	mg/kg
	Mineral Oil**	-	126	mg/kg

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Analysis Report

Project Code : 05-03049 **Report Unique ID: 3433**

Sample Number : 24414 Client ID: 11B Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	<1	mg/kg
	Mineral Oil**	-	<1	mg/kg

Sample Number : 24415 Client ID: 11A Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	<1	mg/kg
	Mineral Oil**	-	<1	mg/kg

Sample Number : 24416 Client ID: 10B Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	<1	mg/kg
	Mineral Oil**	-	<1	mg/kg

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Analysis Report

Project Code : 05-03049 **Report Unique ID: 3433**

Sample Number : 24417 Client ID: 10A Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	19	mg/kg
	Mineral Oil**	-	<1	mg/kg

Sample Number : 24418 Client ID: 9B Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	<1	mg/kg
	Mineral Oil**	-	<1	mg/kg

Sample Number : 24419 Client ID: 9A Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	60	mg/kg
	Mineral Oil**	-	<1	mg/kg

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Analysis Report

Project Code : 05-03049 **Report Unique ID: 3433**

Sample Number : 24420 Client ID: 8B Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	***Component***	***Specification***	***Result***	***Units***
DRO	DRO**	-	<1	mg/kg
	Mineral Oil**	-	<1	mg/kg

Sample Number : 24421 Client ID: 8A Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	***Component***	***Specification***	***Result***	***Units***
DRO	DRO**	-	140	mg/kg
	Mineral Oil**	-	<1	mg/kg

Sample Number : 24422 Client ID: 7B Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	***Component***	***Specification***	***Result***	***Units***
DRO	DRO**	-	<1	mg/kg
	Mineral Oil**	-	<1	mg/kg

Sample Number : 24423 Client ID: 7A Sample

Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	5746	mg/kg
	Mineral Oil**	-	4597	mg/kg

Sample Number : 24424 Client ID: 6B Sample

Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	<1	mg/kg
	Mineral Oil**	-	<1	mg/kg

Sample Number : 24425 Client ID: 6A Sample

Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	<1	mg/kg
	Mineral Oil**	-	<1	mg/kg

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Analysis Report

Project Code : 05-03049

Report Unique ID: 3433

Sample Number : 24426 Client ID: 5B Sample

Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	<1	mg/kg
	Mineral Oil**	-	<1	mg/kg

Sample Number : 24427 Client ID: 5A Sample

Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	25	mg/kg
	Mineral Oil**	-	<1	mg/kg

Sample Number : 24428 Client ID: 4B Sample

Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	<1	mg/kg
	Mineral Oil**	-	<1	mg/kg

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Analysis Report

Project Code : 05-03049 **Report Unique ID: 3433**

Sample Number : 24429 Client ID: 4A Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	41	mg/kg
	Mineral Oil**	-	<1	mg/kg

Sample Number : 24430 Client ID: 3B Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	<1	mg/kg
	Mineral Oil**	-	<1	mg/kg

Sample Number : 24431 Client ID: 3A Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	<1	mg/kg
	Mineral Oil**	-	<1	mg/kg

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Analysis Report

Project Code : 05-03049 **Report Unique ID: 3433**

Sample Number : 24432 Client ID: 2B Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	<1	mg/kg
	Mineral Oil**	-	<1	mg/kg

Sample Number : 24433 Client ID: 2A Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	41	mg/kg
	Mineral Oil**	-	<1	mg/kg

Sample Number : 24434 Client ID: 1B Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	*Component*	*Specification*	*Result*	*Units*
DRO	DRO**	-	<1	mg/kg
	Mineral Oil**	-	<1	mg/kg

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Analysis Report

Project Code : 05-03049 **Report Unique ID: 3433**

Sample Number : 24435 Client ID: 1A Sample
Sample Type:Soil Received: 14/09/2005 Condition: Good

Analysis	***Component***	***Specification***	***Result***	***Units***
DRO	DRO**	-	<1	mg/kg
	Mineral Oil**	-	<1	mg/kg

Methods of Analysis

Analysis Name:	Method:
DRO	GC

Notes

* = INAB accredited test ** = subcontracted test *** = outside accredited range

Conditions

1. Reports shall not be reproduced except in full, without the expressed approval of Bord Na Mona Technical Services Analytical Laboratory
2. Results contained in this report relate only to the items tested.
3. All Comments concerning this report or its contents should be forwarded to the Laboratory Manager

APPENDIX 2 CLEA SGV CONTAMINATION ANALYSIS

Project: Galmoy Mine	**Date: 19/10/2005**	**Arsenic**	**SGV=20**

Mean Value Test - All Data

S.D = square root of $\{(x-\bar{x})^2/n$

No	Value (X)	$(x-\bar{x})$	$(x-\bar{x})^2$
1	233	-117.9167	13904.34
2	6	-344.9167	118967.5
3	1150	799.0833	638534.2
4	1074	723.0833	522849.5
5	271	-79.91667	6386.674
6	5	-345.9167	119658.3
7	390	39.08333	1527.507
8	854	503.0833	253092.8
9	1014	663.0833	439679.5
10	528	177.0833	31358.51
11	637	286.0833	81843.67
12	80	-270.9167	73395.84
13	333	-17.91667	321.0069
14	15	-335.9167	112840
15	374	23.08333	532.8403
16	7	-343.9167	118278.7
17	600	249.0833	62042.51
18	49	-301.9167	91153.67
19	260	-90.91667	8265.84
20	12	-338.9167	114864.5
21	12	-338.9167	114864.5
22	7	-343.9167	118278.7
23	501	150.0833	22525.01
24	10	-340.9167	116224.2

$\bar{x}$ = Mean	350.916667
$\{x-\bar{x}^2$	3181389.83
n	24
SD	364.085031
T (from CLR 7 page 24)	1.714
US95	$\bar{x}$ + T*S/square root n
	478.298654

US95 recalculated using T=1.2069 (from Max val test)

T=	1.2069
US95	$\bar{x}$ + T*S/square root n
	440.61172

Comment: Further Action Required. Site to be zoned

Project: Galmoy Mine	**Date: 25/10/2005**	**Arsenic**	**SGV=20**

Mean Value Test - 0.00-0.30m

S.D = square root of $\{(x-\bar{x})^2/n$

No	Value (X)	$(x-\bar{x})$	$(x-\bar{x})^2$
1	233	-248.25	61628.06
2	1150	668.75	447226.6
3	271	-210.25	44205.06
4	390	-91.25	8326.563
5	1014	532.75	283822.6
6	637	155.75	24258.06
7	333	-148.25	21978.06
8	374	-107.25	11502.56
9	600	118.75	14101.56
10	260	-221.25	48951.56
11	12	-469.25	220195.6
12	501	19.75	390.0625

$\bar{x}$ = Mean	481.25
$\{x-\bar{x}^2$	1186586.25
n	12
SD	314.455382
T (from CLR 7 page 24)	1.796
US95	$\bar{x}$ + T*S/square root n
	644.282708

US95 recalculated using
T=1.09735 (from Max val test)

T=	1.09735
US95	$\bar{x}$ + T*S/square root n
	580.86244

Comment: Further Action Required

Project: Galmoy Mine	Date: 25/10/2005	Arsenic	SGV=20

Mean Value Test - 0.30-1.20m elevated zone

S.D = square root of $\{(x-\bar{x})^2/n$

No	Value (X)	$(x-\bar{x})$	$(x-\bar{x})^2$
1	1074	557	310249
2	854	337	113569
3	528	11	121
4	80	-437	190969
5	49	-468	219024

Comment: Further Action Required

$\bar{x}$ = Mean	517	
$\{x-\bar{x}^2$	833932	
n	5	
SD	408.394907	
T (from CLR 7 page 24)	2.132	
US95		$\bar{x}$ + T*S/square root n
	906.387957	

US95 recalculated using T=1.0434
(from Max val test)

T=	1.0434	
US95		$\bar{x}$ + T*S/square root n
	707.56632	

Project: Galmoy Mine	**Date: 25/10/2005**	**Arsenic**	**SGV=20**

Mean Value Test - 0.30-1.20m remainder of area

S.D = square root of $\{(x-\bar{x})^2/n$

No	Value (X)	$(x-\bar{x})$	$(x-\bar{x})^2$
1	6	-2.857143	8.163265
2	5	-3.857143	14.87755
3	15	6.142857	37.73469
4	7		
5	12		
6	7	-1.857143	3.44898
7	10	1.142857	1.306122

Comment: No Action Required

$\bar{x}$ = Mean	8.85714286
$\{x-\bar{x}^2$	65.5306122
n	7
SD	3.05965946
T (from CLR 7 page 24)	1.943
US95	$\bar{x}$ + T*S/square root n
	11.1041108

US95 recalculated using T=1.6239
(from Max val test)

T=	1.6239
US95	$\bar{x}$ + T*S/square root n
	10.73509

Project: Galmoy Mine	**Date: 19/10/2005**	**Cadmium**	**SGV = 1**	used lowest SGV

Mean Value Test - All Data

S.D = square root of $\{(x-\bar{x})^2/n$

No	Value (X)	$(x-\bar{x})$	$(x-\bar{x})^2$
1	14	-18.20833	331.5434
2	1	-31.20833	973.9601
3	70	37.79167	1428.21
4	62	29.79167	887.5434
5	48	15.79167	249.3767
6	1	-31.20833	973.9601
7	33	0.791667	0.626736
8	28	-4.208333	17.71007
9	46	13.79167	190.2101
10	41	8.791667	77.2934
11	34	1.791667	3.210069
12	6	-26.20833	686.8767
13	69	36.79167	1353.627
14	1	-31.20833	973.9601
15	18	-14.20833	201.8767
16	1	-31.20833	973.9601
17	89	56.79167	3225.293
18	7	-25.20833	635.4601
19	121	88.79167	7883.96
20	4	-28.20833	795.7101
21	1	-31.20833	973.9601
22	1	-31.20833	973.9601
23	76	43.79167	1917.71
24	1	-31.20833	973.9601

$\bar{x}$ = Mean	32.2083333
$\{x-\bar{x}^2$	26703.9583
n	24
SD	33.3566325
T (from CLR 7 page 24)	1.714
US95	$\bar{x}$ + T*S/square root n
	43.8787778

US95 recalculated using T=1.4248 (from Max val test)

T=	1.4248
US95	$\bar{x}$ + T*S/square root n
	41.9096456

Comment - Further Action Required

Project: Galmoy Mine	**Date: 25/10/2005**	**Cadmium**	**SGV = 8**

Mean Value Test - 0.00-0.30m

S.D = square root of $\{(x-\bar{x})^2/n$

No	Value (X)	$(x-\bar{x})$	$(x-\bar{x})^2$
1	14	-37.58333	1412.507
2	70	18.41667	339.1736
3	48	-3.583333	12.84028
4	33	-18.58333	345.3403
5	46	-5.583333	31.17361
6	34	-17.58333	309.1736
7	69	17.41667	303.3403
8	18	-33.58333	1127.84
9	89	37.41667	1400.007
10	121	69.41667	4818.674
11	1	-50.58333	2558.674
12	76	24.41667	596.1736

$\bar{x}$ = Mean	51.5833333
$\{x-\bar{x}^2$	13254.9167
n	12
SD	33.235168
T (from CLR 7 page 24)	1.796
US95	$\bar{x}$ + T*S/square root n
	68.8144565

US95 recalculated using T=1.273 (from Max val test)

T=	1.273
US95	$\bar{x}$ + T*S/square root n
	63.7967074

Comment - Further Action Required

Project: Galmoy Mine	**Date: 25/10/2005**	**Cadmium**	**SGV = 8**

Mean Value Test - 0.30-1.20m Elevated Area

S.D = square root of $\{(x-\bar{x})^2/n$

No	Value (X)	$(x-\bar{x})$	$(x-\bar{x})^2$
1	62	18.33333	336.1111
2	28	-15.66667	245.4444
3	41	-2.666667	7.111111

$\bar{x}$ = Mean 43.6666667

$\{x-\bar{x}^2$ 588.666667

n 3

SD 14.0079343

T (from CLR 7 page 24) 2.92

US95 $\bar{x}$ + T*S/square root n

67.2821217

Comment - Further Action Required

US95 recalculated using T=1.2820
(from Max val test)

T= 1.282

US95 $\bar{x}$ + T*S/square root n

54.0348219

Project: Galmoy Mine	Date: 25/10/2005	Cadmium	SGV = 8

Mean Value Test - 0.30-1.20m Remainder of site

S.D = square root of {(x-$\bar{x}$)^2/n

No	Value (X)	(x-$\bar{x}$)	(x-$\bar{x}$)^2
1	1	-1.555556	2.419753
2	6	3.444444	11.8642
3	1	-1.555556	2.419753
4	1	-1.555556	2.419753
5	7	4.444444	19.75309
6	4	1.444444	2.08642
7	1	-1.555556	2.419753
8	1	-1.555556	2.419753
9	1	-1.555556	2.419753

$\bar{x}$ = Mean	2.55555556
{x-$\bar{x}$^{2}	48.2222222
n	9
SD	2.31474074
T (from CLR 7 page 24)	1.86
US95	$\bar{x}$ + T*S/square root n
	3.99069481

US95 recalculated using T=1.6857
(from Max val test)

T=	1.6857
US95	$\bar{x}$ + T*S/square root n
	3.85620838

Comment - No Action Required

Project: Galmoy Mine	Date: 19/10/2005	Chromium	SGV: 130

Mean Value Test - All Data

S.D = square root of $\{(x-\bar{x})^2/n$

No	Value (X)	$(x-\bar{x})$	$(x-\bar{x})^2$
1	8	-4.333333	18.77778
2	11	-1.333333	1.777778
3	11	-1.333333	1.777778
4	11	-1.333333	1.777778
5	8	-4.333333	18.77778
6	8	-4.333333	18.77778
7	15	2.666667	7.111111
8	17	4.666667	21.77778
9	17	4.666667	21.77778
10	14	1.666667	2.777778
11	9	-3.333333	11.11111
12	13	0.666667	0.444444
13	13	0.666667	0.444444
14	13	0.666667	0.444444
15	15	2.666667	7.111111
16	10	-2.333333	5.444444
17	12	-0.333333	0.111111
18	8	-4.333333	18.77778
19	14	1.666667	2.777778
20	12	-0.333333	0.111111
21	17	4.666667	21.77778
22	11	-1.333333	1.777778
23	18	5.666667	32.11111
24	11	-1.333333	1.777778

$\bar{x}$ = Mean	12.3333333
$\{x-\bar{x}^2$	219.333333
n	24
SD	3.02305952
T (from CLR 7 page 24)	1.714
US95	$\bar{x}$ + T*S/square root n
	13.3910075

US95 recalculated using T=1.6323 (from Max val test)

T=	1.6323
US95	$\bar{x}$ + T*S/square root n
	13.3405921

Comment: No Action Required

Project: Galmoy Mine	Date: 19/10/2005	Lead	SGV: 450

Mean Value Test - All Data

S.D = square root of {$(x-\bar{x})^2$/n

No	Value (X)	$(x-\bar{x})$	$(x-\bar{x})^2$
1	1590	-2400.875	5764201
2	26	-3964.875	15720234
3	9330	5339.125	28506256
4	6104	2113.125	4465297
5	8824	4833.125	23359097
6	69	-3921.875	15381104
7	4858	867.125	751905.8
8	1080	-2910.875	8473193
9	6660	2669.125	7124228
10	4477	486.125	236317.5
11	5620	1629.125	2654048
12	740	-3250.875	10568188
13	7751	3760.125	14138540
14	123	-3867.875	14960457
15	2501	-1489.875	2219728
16	48	-3942.875	15546263
17	14319	10328.13	1.07E+08
18	750	-3240.875	10503271
19	12826	8835.125	78059434
20	301	-3689.875	13615178
21	60	-3930.875	15451778
22	32	-3958.875	15672691
23	7595	3604.125	12989717
24	97	-3893.875	15162263

$\bar{x}$ = Mean	3990.875
{$x-\bar{x}^2$	437993555
n	24
SD	4271.97044
T (from CLR 7 page 24)	1.714
US95	$\bar{x}$ + T*S/square root n
	5485.50411

US95 recalculated using T=1.2184
(from Max val test)

T=	1.2184
US95	$\bar{x}$ + T*S/square root n
	5053.3348

Comment: Further Action Required. Site to be zoned.

Project: Galmoy Mine	Date: 25/10/2005	Lead	SGV: 450

Mean Value Test - 0.0-0.30m

S.D = square root of $\{(x-\bar{x})^2/n$

No	Value (X)	$(x-\bar{x})$	$(x-\bar{x})^2$
1	1590	-5237.833	27434898
2	9330	2502.167	6260838
3	8824	1996.167	3984681
4	4858	-1969.833	3880243
5	6660	-167.8333	28168.03
6	5620	-1207.833	1458861
7	7751	923.1667	852236.7
8	2501	-4326.833	18721487
9	14319	7491.167	56117578
10	12826	5998.167	35978003
11	60	-6767.833	45803568
12	7595	767.1667	588544.7

$\bar{x}$ = Mean	6827.83333
$\{x-\bar{x}^2$	201109108
n	12
SD	4093.78704
T (from CLR 7 page 24)	1.796
US95	$\bar{x}$ + T*S/square root n
	8950.30038

US95 recalculated using T=0.8484 (from Max val test)

T=	0.8484
US95	$\bar{x}$ + T*S/square root n
	7830.45084

Comment: Further Action Required.

Project: Galmoy Mine	Date: 25/10/2005	Lead	SGV: 450

Mean Value Test - 0.30-1.20mm Elevated Areas

S.D = square root of $\{(x-\bar{x})^2/n$

No	Value (X)	$(x-\bar{x})$	$(x-\bar{x})^2$
1	6104	3473.8	12067286
2	1080	-1550.2	2403120
3	4477	1846.8	3410670
4	740	-1890.2	3572856
5	750	-1880.2	3535152

Comment: Further Action Required.

$\bar{x}$ = Mean	2630.2
$\{x-\bar{x}^2$	24989084.8
n	5
SD	2235.57978
T (from CLR 7 page 24)	2.132
US95	$\bar{x}$ + T*S/square root n
	4761.73453

US95 recalculated using T=1.374 (from Max val test)

T=	1.374
US95	$\bar{x}$ + T*S/square root n
	4003.90002

Project: Galmoy Mine	Date: 25/10/2005	Lead	SGV: 450

Mean Value Test - 0.30-1.20mm Remainder of Area

S.D = square root of {(x-$\bar{x}$)^2/n

No	Value (X)	(x-$\bar{x}$)	(x-$\bar{x}$)^2
1	26	-77.42857	5995.184
2	69	-34.42857	1185.327
3	123	19.57143	383.0408
4	48	-55.42857	3072.327
5	301	197.5714	39034.47
6	60	-43.42857	1886.041
7	97	-6.428571	41.32653

Comment: No action required

$\bar{x}$ = Mean	103.428571
{x-$\bar{x}$^{2}	51597.7143
n	7
SD	85.8551224
T (from CLR 7 page 24)	1.943
US95	$\bar{x}$ + T*S/square root n
	166.479283

US95 recalculated using T=1.8709
(from Max val test)

T=	1.8709
US95	$\bar{x}$ + T*S/square root n
	164.139625

Project: Galmoy Mine	Date: 19/10/2005	Mercury	SGV: 8

Mean Value Test - All Data

S.D = square root of {(x-~~x~~)^2/n

No	Value (X)	(x-~~x~~)	(x-~~x~~)^2
1	1	0	0
2	1	0	0
3	1	0	0
4	1	0	0
5	1	0	0
6	1	0	0
7	1	0	0
8	1	0	0
9	1	0	0
10	1	0	0
11	1	0	0
12	1	0	0
13	1	0	0
14	1	0	0
15	1	0	0
16	1	0	0
17	1	0	0
18	1	0	0
19	1	0	0
20	1	0	0
21	1	0	0
22	1	0	0
23	1	0	0
24	1	0	0
25	1	0	0
26	1	0	0

~~x~~ = Mean	1
{x-~~x~~^{2}	0
n	26
SD	0
T (from CLR 7 page 24)	1.714
US95	~~x~~ + T*S/square root n
	1

US95 recalculated using T=0 (from Max val test)

T=	0
US95	~~x~~ + T*S/square root n
	1

Comment: No Action Required

Project: Galmoy Mine	Date: 19/10/2005	Nickel	SGV: 50

Mean Value Test - All Data

S.D = square root of {(x-x̄)^2/n

No	Value (X)	(x-x̄)	(x-x̄)^2
1	111	13.875	192.5156
2	43	-54.125	2929.516
3	315	217.875	47469.52
4	337	239.875	57540.02
5	65	-32.125	1032.016
6	40	-57.125	3263.266
7	78	-19.125	365.7656
8	97	-0.125	0.015625
9	262	164.875	27183.77
10	123	25.875	669.5156
11	145	47.875	2292.016
12	37	-60.125	3615.016
13	66	-31.125	968.7656
14	27	-70.125	4917.516
15	201	103.875	10790.02
16	22	-75.125	5643.766
17	99	1.875	3.515625
18	24	-73.125	5347.266
19	71	-26.125	682.5156
20	22	-75.125	5643.766
21	19	-78.125	6103.516
22	23	-74.125	5494.516
23	82	-15.125	228.7656
24	22	-75.125	5643.766

x̄ = Mean	97.125
{x-x̄^{2}	198020.625
n	24
SD	90.8342412
T (from CLR 7 page 24)	1.714
US95	x̄ + T*S/square root n
	128.905066

US95 recalculated using T=1.8504
(from Max val test)

T=	1.8504
US95	x̄ + T*S/square root n
	131.434121

Comment: Further Action Required. Site to be zoned

Project: Galmoy Mine	Date: 25/10/2005	Nickel	SGV: 50

Mean Value Test - 0.00-0.30m

S.D = square root of {(x-$\cancel{x}$)^2/n

No	Value (X)	(x-$\cancel{x}$)	(x-$\cancel{x}$)^2
1	111	-15.16667	230.0278
2	315	188.8333	35658.03
3	65	-61.16667	3741.361
4	78	-48.16667	2320.028
5	262	135.8333	18450.69
6	145	18.83333	354.6944
7	66	-60.16667	3620.028
8	201	74.83333	5600.028
9	99	-27.16667	738.0278
10	71	-55.16667	3043.361
11	19	-107.1667	11484.69
12	82	-44.16667	1950.694

$\cancel{x}$ = Mean	126.166667
{x-$\cancel{x}^2$	87191.6667
n	12
SD	85.2406723
T (from CLR 7 page 24)	1.796
US95	$\cancel{x}$ + T*S/square root n
	170.360592

US95 recalculated using T=1.5968
(from Max val test)

T=	1.5968
US95	$\cancel{x}$ + T*S/square root n
	165.458905

Comment: Further Action Required.

Project: Galmoy Mine	Date: 25/10/2005	Nickel	SGV: 50

Mean Value Test - 0.30-1.20m elevated zone

S.D = square root of {(x-$\bar{x}$)^2/n

No	Value (X)	(x-$\bar{x}$)	(x-$\bar{x}$)^2
1	337	151.3333	22901.78
2	97	-88.66667	7861.778
3	123	-62.66667	3927.111

$\bar{x}$ = Mean	185.666667
{x-$\bar{x}^2$	34690.6667
n	3
SD	107.533974
T (from CLR 7 page 24)	2.92

US95 $\bar{x}$ + T*S/square root n
366.954192

Comment: Further Action Required

US95 recalculated using T=1.391
(from Max val test)
T= 1.391
US95 $\bar{x}$ + T*S/square root n
272.02658

Project: Galmoy Mine	Date: 25/10/2005	Nickel	SGV: 50

Mean Value Test - 0.30-1.20m Remainder of Area

S.D = square root of $\{(x-\bar{x})^2/n$

No	Value (X)	$(x-\bar{x})$	$(x-\bar{x})^2$
1	43	14.11111	199.1235
2	40	11.11111	123.4568
3	37	8.111111	65.79012
4	27	-1.888889	3.567901
5	22	-6.888889	47.45679
6	24	-4.888889	23.90123
7	22	-6.888889	47.45679
8	23	-5.888889	34.67901
9	22	-6.888889	47.45679

$\bar{x}$ = Mean	28.8888889
$\{x-\bar{x}^2$	592.888889
n	9
SD	8.11643661
T (from CLR 7 page 24)	1.86
US95	$\bar{x}$ + T*S/square root n
	33.9210796

US95 recalculated using
T=1.64889 (from Max val test)

T=	1.64889
US95	$\bar{x}$ + T*S/square root n
	33.3499259

Comment: No Further Action

Project: Galmoy Mine	**Date: 19/10/2005**	**Selenium**	**SGV: 35**

Mean Value Test - All Data

S.D = square root of $\{(x-\bar{x})^2/n$

No	Value (X)	$(x-\bar{x})$	$(x-\bar{x})^2$
1	10	0	0
2	10	0	0
3	10	0	0
4	10	0	0
5	10	0	0
6	10	0	0
7	10	0	0
8	10	0	0
9	10	0	0
10	10	0	0
11	10	0	0
12	10	0	0
13	10	0	0
14	10	0	0
15	10	0	0
16	10	0	0
17	10	0	0
18	10	0	0
19	10	0	0
20	10	0	0
21	10	0	0
22	10	0	0
23	10	0	0
24	10	0	0

$\bar{x}$ = Mean	10
$\{x-\bar{x}^2$	0
n	24
SD	0
T (from CLR 7 page 24)	1.714
US95	$\bar{x}$ + T*S/square root n
	10

US95 recalculated using T=0 (from Max val test)

T=	0
US95	$\bar{x}$ + T*S/square root n
	10

Comment: No Action Required

APPENDIX 3 SNIFFER FRAMEWORK

RISK EVALUATION

It is considered that the Integrated Site Specific Assessment Criteria of **630 mg/kg** for **Zinc** derived using the SNIFFER Method is appropriate for this site.

The selected Relevant Health Criteria (RHC) for Zinc as a threshold substance was the Tolerable Daily Intake (TDI). Due to the absence of published DEFRA / Environment Agency R&D toxicological data for Zinc, a TDI was obtained from published guidance from the (Dutch Ministry of Public Housing Land Use and Notification Letter on Intervention for Soil and Groundwater Remediation). A value of 0.5 mg/kg body weight per day was used in the calculation.

As it is intended for the site to revert to agricultural use (crop growing or grazing) or amenity use the setting for allotment was used. By default for allotment the most sensitive critical receptor is chosen, i.e. a female child. Therefore the 0-6 years Exposure Duration, averaging period, Childhood and receptor body weight have been used.

Site specific concentration factors for the uptake of Zinc by leafy / root vegetables have been obtained using a formula from the following document:

> "A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture", Oak Ridge National Laboratory, USA.

Although the copper in the topsoil is not in a radioactive form, the behaviour of the metal in its non radioactive form will be similar. Therefore, it is considered appropriate to use this document to calculate concentration factors for Zinc. The concentration factors used to model plant uptake are as follows:

- 0.519006 μg/g dry weight plant / μg/g dry weight soil for leafy vegetables
- 0.311404 μg/g dry weight plant / μg/g dry weight soil for root vegetables

SNIFFER Method - Metals/Metalloids

Project Ref: 51-0241 **Run No: 1**

1 This worksheet may be used for metal and metalloid contaminants except for lead (Pb).

2 This worksheet has been completed by Jolene Turner on 27/10/2005

and has been checked by on

3 It relates to Zinc found at Galmoy Mine

Toxicology

4 Is the substance a non-threshold substance (Y or N) N

5 Insert the Relevant Health Criterion value for ingestion 5.00E-01 mg per kg body weight per day
For a non-threshold substance the RHC is the Index Dose (ID).
For threshold substances the RHC is the Tolerable Daily Intake (TDI).

Land Use

6 The Table below lists the default exposure durations and averaging times, used in the method for standard land uses.
Please insert Y to indicate your choice of land use and acceptance of the default assumptions.

Land Use	Exposure duration (years)		Averaging time (days)	
Residential with plant uptake	0-6		2190	
Residential without plant uptake	0-6		2190	
Allotments	0-6	Y	2190	Y
Commercial/Industrial	16-59		15695	

Background Exposure

7 Insert Mean Daily Intake (MDI) from non-soil sources
(If the contaminant is a non-threshold substance insert zero) mg per day

Is the MDI equal to or greater than 80% of the TDI or is the MDI unknown? (Y or N) y

8 Because the MDI for children is lower than that for adults, the MDI will need to be corrected by a Childhood Factor (CF) which depends on exposure duration. Insert the appropriate factor here: 0.485

Exposure duration (years)	Childhood Factor ingestion
0-6	0.485
16-59	1

Receptor Body Weight

9 Insert the Time-Averaged (female) Body Weight (TABW) depending on the chosen exposure duration

Exposure duration (years)	TABW
0-6	11.15
16-59	46.4

11.15 kg body weight

Reference Intake

10 For non-threshold substances the Reference Intake (RI) for the ingestion pathway is calculated using the formula: RI_{ingest}=ID mg per kg body weight per day

For threshold substances the Reference Intake (RI) for ingestion pathways is calculated using the formula: RI_{ingest}=(TDI-((MDI/70x46.4)xCF)/TABW)[a] mg per kg body weight per day

[a] Note - The background component is in line with the approach in CLR 9, namely that th MDI is corrected by the relevant adult body weight.

For threshold substances where the background exposure (MDI) is greater than or equal to 80% of the TDI, or the MDI is unknown, the Reference Intake (RI) for ingestion pathways is calculated using the formula: RI_{ingest}=0.2TDI 1.00E-01 mg per kg body weight per day

Intake via Soil and Dust Ingestion

11 Select a value for SEI_{ding} from this table, depending on your choice of land use

SEI_{ding} = 9.85E-06 mg per kg body weight per day

Land Use	SEI_{ding} (kg soil per kg body weight per day)
residential wth plant uptake	9.85319E-06
residential without plant uptake	9.85319E-06
allotment	9.85319E-06
commercial/industrial	5.43222E-07

12 Is site specific data on the bioaccessibility of the contaminant in soil available? (Y or N) N

if Y insert the representative fraction here (default=1)

The amended SEI_{ding} = SEI_{ding} * bioaccessibility fraction 9.85319E-06 kg soil per kg body weight per day

13 The nominal assessment sub criterion for intake via soil and dust ingestion using the formula: $ASC_{ding} = RI_{ingest}/SEI_{ding}$

ASC = 1.00000E-01 mg per kg body weight per day / 9.85319E-06 kg soil per kg body weight per day 10148.99743 mg per kg soil

Intake via Consumption of Homegrown Vegetables

14 This pathway only applies to two land uses: residential with plant uptake and allotments. For other land uses go directly to paragraph 24.
Select the basis for the Concentration Factor from **15 <u>or</u> 16** below. Select **<u>one</u>** option only.

15 For a number of metal contaminants values of CF are given in CLR10. For the contaminant of concern select the appropriate SEI_{veg} from the Table below.

Contaminant	**SEI_{veg} (kg soil/kg body weight/day)**
Arsenic	3.88743E-06
Cadmium	3.1033E-04 [b]
Chromium	1.11838E-05
Nickel	9.62006E-06
Selenium	5.29089E-05
Mercury	2.15968E-05

[b] Note –
For Cadmium the algorithms in CLR10 for calculation of CF are pH sensitive.
SEI_{veg} value given is for pH7. See main document Section 7.1.5 for further detail.

SEI_{veg}= kg soil per kg body weight per day

16 Are measured site specific Concentration Factors for leafy and root plant uptake of metals available? (Yor N) y

Measured Concentration Factor for leafy vegetables CF_{leafy} = 0.519006 ug per g (dry or fresh)[c] weight plant per ug per g dry weight so

Measured Concentration Factor for root vegetables CF_{root} = 0.311404 ug per g (dry or fresh)[c] weight plant per ug per g dry weight so

[c] Note - See 17 below

17 For calculation of the SEI_{veg} the units for CF_{leafy} and CF_{root} must be ug per g fresh weight plant over ug per g dry weight soil.
It may be necessary to use a dry weight conversion factor when using measured CF values.
Is a dry weight conversion required? (Y or N) Y

The Time Averaged Vegetable Consumption Rate for homegrown vegetables used to calculate the SEI_{veg} is given in the Table below.

Vegetable Type	TAVCR (kg FW/day)	TAVCR*HF* CF *DW	TAVCR*HF* CF
Brussel sprouts	5.04750E-03	1.57129E-04	calc not required
Cabbage	4.86885E-03	1.99243E-04	calc not required
Carrot	7.38094E-03	9.09327E-05	calc not required
Leafy salads	3.25677E-03	1.18343E-05	calc not required
Onion	3.69474E-03	1.04463E-04	calc not required
Potato	4.41616E-02	1.08343E-03	calc not required

Select a value for SEI_{veg} from this table for the contaminant of concern, depending on your choice of land use

Land Use	SEI_{veg} (kg soil/kg body weight/day)
residential with plant uptake	1.47716E-04
allotments	1.47716E-04

SEI_{veg}= 1.48E-04 kg soil per kg body weight per day

18 The nominal assessment sub criterion for intake via consumption of homegrown vegetables is calculated using the formula: $ASC_{veg} = RI_{ingest}/SEI_{veg}$

Input SEI_{veg} from question 15 or 17

ASC = 1.00000E-01 / 1.48E-04 = 676.9747353 mg per kg soil

mg per kg body weight per day

kg soil per kg body weight per day

Intake via Ingestion of Soil Attached to Vegetables

19 This pathway only applies to two land uses: residential with plant uptake and allotments. For other land uses go directly to paragraph 23.

20 Select a value for $SEI_{indirect}$ from this table, depending on your choice of land use

Land Use	$SEI_{indirect}$ kg soil/kg body weight/day
residential wth plant uptake	1.12723E-06
allotment	1.12723E-06

$SEI_{indirect}$= 1.27E-06 kg soil per kg body weight per day

21 Is site specific data on the bioaccessibility of the contaminant in soil available? (Yor N) n

Insert the representative fraction here (default=1)

The amended $SEI_{indirect}$ = $SEI_{indirect}$ * bioaccessibility fraction 1.27230E-06 kg soil per kg body weight per day

22 The nominal assessment sub criterion for intake via indirect soil ingestion using the formula: $ASC_{indirect} = RI_{indirect}/SEI_{indirect}$

$ASC_{indirect}$ = 1.00000E-01 mg per kg body weight per day / 1.2723E-06 kg soil per kg body weight per day = 78597.81498 mg per kg soil

Integrated Site Specific Assessment Criterion

		Σ(ASC)		SSAC	
23 Allotments	1/	0.001588415	=	629.558436	mg per kg soil

24 The appropriate SSAC is automatically selected for the landuse scenario chosen

25 The level 1 Site Specific Assessment Criterion for **Zinc** in the **Allotments** scenario is **630** mg per kg soil

Risk Evaluation

26 Justify your use of the defaults on the worksheet and characterise the risk associated with the site.
Include the following:

	Justification provided (Y or N)
i. Choice of Relevant Health Criteria value	Y
ii. Site use (current and intended), comment on compatibitility with land use selected	Y
iii. Critical Receptor	Y
iv. Pathways included/omitted (including bioaccessibility if used)	Y
v. Soil Parameters, e.g. pH	Y

RISK EVALUATION

It is considered that the Integrated Site Specific Assessment Criteria of **480 mg/kg** for **Copper** derived using the SNIFFER Method is appropriate for this site.

The selected Relevant Health Criteria (RHC) for Copper as a threshold substance was the Tolerable Daily Intake (TDI). Due to the absence of published DEFRA / Environment Agency R&D toxicological data for copper, a TDI was obtained from published guidance from the (Dutch Ministry of Public Housing Land Use and Notification Letter on Intervention for Soil and Groundwater Remediation). A value of 0.14 mg/kg body weight per day was used in the calculation.

As it is intended for the site to revert to agricultural use (crop growing or grazing) or amenity use the setting for allotment was used. By default for allotment the most sensitive critical receptor is chosen, i.e. a female child. Therefore the 0-6 years Exposure Duration, averaging period, Childhood and receptor body weight have been used.

Site specific concentration factors for the uptake of copper by leafy / root vegetables have been obtained using a formula from the following document:

> "A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture", Oak Ridge National Laboratory, USA.

Although the copper in the topsoil is not in a radioactive form, the behaviour of the metal in its non radioactive form will be similar. Therefore, it is considered appropriate to use this document to calculate concentration factors for copper. The concentration factors used to model plant uptake are as follows:

- 0.160587 μg/g dry weight plant / μg/g dry weight soil for leafy vegetables
- 0.10117 μg/g dry weight plant / μg/g dry weight soil for root vegetables

SNIFFER Method - Metals/Metalloids

Project Ref: 51-0241 **Run No: 1**

1 This worksheet may be used for metal and metalloid contaminants except for lead (Pb).

2 This worksheet has been completed by Jolene Turner on 27/10/2005

and has been checked by on

3 It relates to Copper found at Galmoy Mine

Toxicology

4 Is the substance a non-threshold substance (Y or N) N

5 Insert the Relevant Health Criterion value for ingestion 1.40E-01 mg per kg body weight per day
For a non-threshold substance the RHC is the Index Dose (ID).
For threshold substances the RHC is the Tolerable Daily Intake (TDI).

Land Use

6 The Table below lists the default exposure durations and averaging times, used in the method for standard land uses.
Please insert Y to indicate your choice of land use and acceptance of the default assumptions.

Land Use	Exposure duration (years)		Averaging time (days)	
Residential with plant uptake	0-6		2190	
Residential without plant uptake	0-6		2190	
Allotments	0-6	Y	2190	Y
Commercial/Industrial	16-59		15695	

Background Exposure

7 Insert Mean Daily Intake (MDI) from non-soil sources
(If the contaminant is a non-threshold substance insert zero)

mg per day

Is the MDI equal to or greater than 80% of the TDI or is the MDI unknown? (Y or N)

y

8 Because the MDI for children is lower than that for adults, the MDI will need to be corrected by a Childhood Factor (CF) which depends on exposure duration. Insert the appropriate factor here:

Exposure duration (years)	Childhood Factor ingestion
0-6	0.485
16-59	1

0.485

Receptor Body Weight

9 Insert the Time-Averaged (female) Body Weight (TABW) depending on the chosen exposure duration

Exposure duration (years)	TABW
0-6	11.15
16-59	46.4

11.15 kg body weight

Reference Intake

10 For non-threshold substances the Reference Intake (RI) for the ingestion pathway is calculated using the formula: RI_{ingest}=ID

mg per kg body weight per day

For threshold substances the Reference Intake (RI) for ingestion pathways is calculated using the formula: RI_{ingest}=(TDI-((MDI/70x46.4)xCF)/TABW)[a]

[a] Note - The background component is in line with the approach in CLR 9, namely that th MDI is corrected by the relevant adult body weight.

mg per kg body weight per day

For threshold substances where the background exposure (MDI) is greater than or equal to 80% of the TDI, or the MDI is unknown, the Reference Intake (RI) for ingestion pathways is calculated using the formula: RI_{ingest}=0.2TDI

2.80E-02 mg per kg body weight per day

Intake via Soil and Dust Ingestion

11 Select a value for SEI_{ding} from this table, depending on your choice of land use

SEI_{ding} = 9.85E-06 mg per kg body weight per day

Land Use	SEI_{ding} (kg soil per kg body weight per day)
residential wth plant uptake	9.85319E-06
residential without plant uptake	9.85319E-06
allotment	9.85319E-06
commercial/industrial	5.43222E-07

12 Is site specific data on the bioaccessibility of the contaminant in soil available? (Y or N) N

if Y insert the representative fraction here (default=1)

The amended SEI_{ding} = SEI_{ding} * bioaccessibility fraction 9.85319E-06 kg soil per kg body weight per day

13 The nominal assessment sub criterion for intake via soil and dust ingestion using the formula: $ASC_{ding} = RI_{ingest}/SEI_{ding}$

ASC = 2.80000E-02 mg per kg body weight per day / 9.85319E-06 kg soil per kg body weight per day 2841.719281 mg per kg soil

Intake via Consumption of Homegrown Vegetables

14 This pathway only applies to two land uses: residential with plant uptake and allotments. For other land uses go directly to paragraph 24.
Select the basis for the Concentration Factor from **15 <u>or</u> 16** below. Select **<u>one</u>** option only.

15 For a number of metal contaminants values of CF are given in CLR10. For the contaminant of concern select the appropriate SEI_{veg} from the Table below.

Contaminant	SEI_{veg} (kg soil/kg body weight/day)
Arsenic	3.88743E-06
Cadmium	3.1033E-04 [b]
Chromium	1.11838E-05
Nickel	9.62006E-06
Selenium	5.29089E-05
Mercury	2.15968E-05

[b] Note –
For Cadmium the algorithms in CLR10 for calculation of CF are pH sensitive.
SEI_{veg} value given is for pH7. See main document Section 7.1.5 for further detail.

SEI_{veg}= kg soil per kg body weight per day

16 Are measured site specific Concentration Factors for leafy and root plant uptake of metals available? (Yor N) y

Measured Concentration Factor for leafy vegetables CF_{leafy} = 0.160587 ug per g (dry or fresh)[c] weight plant per ug per g dry weight so

Measured Concentration Factor for root vegetables CF_{root} = 0.10117 ug per g (dry or fresh)[c] weight plant per ug per g dry weight so

[c] Note - See 17 below

17 For calculation of the SEI_{veg} the units for CF_{leafy} and CF_{root} must be ug per g fresh weight plant over ug per g dry weight soil.
It may be necessary to use a dry weight conversion factor when using measured CF values.
Is a dry weight conversion required? (Y or N) y

The Time Averaged Vegetable Consumption Rate for homegrown vegetables used to calculate the SEI_{veg} is given in the Table below.

Vegetable Type	TAVCR (kg FW/day)	TAVCR*HF* CF *DW	TAVCR*HF* CF
Brussel sprouts	5.04750E-03	4.86178E-05	calc not required
Cabbage	4.86885E-03	6.16485E-05	calc not required
Carrot	7.38094E-03	2.95425E-05	calc not required
Leafy salads	3.25677E-03	3.66169E-06	calc not required
Onion	3.69474E-03	3.39383E-05	calc not required
Potato	4.41616E-02	3.51989E-04	calc not required

Select a value for SEI_{veg} from this table for the contaminant of concern, depending on your choice of land use

Land Use	SEI_{veg} (kg soil/kg body weight/day)
residential with plant uptake	4.74796E-05
allotments	4.74796E-05

SEI_{veg}= 4.75E-05 kg soil per kg body weight per day

18 The nominal assessment sub criterion for intake via consumption of homegrown vegetables is calculated using the formula: $ASC_{veg} = RI_{ingest}/SEI_{veg}$

Input SEI_{veg} from question 15 or 17

ASC = 2.80000E-02 / 4.75E-05 = 589.7269564 mg per kg soil

mg per kg body weight per day

kg soil per kg body weight per day

Intake via Ingestion of Soil Attached to Vegetables

19 This pathway only applies to two land uses: residential with plant uptake and allotments. For other land uses go directly to paragraph 23.

20 Select a value for $SEI_{indirect}$ from this table, depending on your choice of land use

Land Use	$SEI_{indirect}$ kg soil/kg body weight/day
residential wth plant uptake	1.12723E-06
allotment	1.12723E-06

$SEI_{indirect}$= 1.27E-06 kg soil per kg body weight per day

21 Is site specific data on the bioaccessibility of the contaminant in soil available? (Yor N) n

Insert the representative fraction here (default=1)

The amended $SEI_{indirect}$ = $SEI_{indirect}$ * bioaccessibility fractior 1.27230E-06 kg soil per kg body weight per day

22 The nominal assessment sub criterion for intake via indirect soil ingestion using the formula: $ASC_{indirect} = RI_{indirect}/SEI_{indirect}$

$ASC_{indirect}$ = 2.80000E-02 mg per kg body weight per day / 1.2723E-06 kg soil per kg body weight per day = 22007.38819 mg per kg soil

Integrated Site Specific Assessment Criterion

		Σ(ASC)		SSAC	
23 Allotments	1/	0.002093039	=	477.774200	mg per kg soil

24 The appropriate SSAC is automatically selected for the landuse scenario chosen

25 The level 1 Site Specific Assessment Criterion for **Copper** in the **Allotments** scenario is **480** mg per kg soil

Risk Evaluation

26 Justify your use of the defaults on the worksheet and characterise the risk associated with the site.
Include the following:

	Justification provided (Y or N)
i. Choice of Relevant Health Criteria value	Y
ii. Site use (current and intended), comment on compatibitility with land use selected	Y
iii. Critical Receptor	Y
iv. Pathways included/omitted (including bioaccessibility if used)	Y
v. Soil Parameters, e.g. pH	N/A

RISK EVALUATION

It is considered that the Integrated Site Specific Assessment Criteria of **40 mg/kg** for **Boron** derived using the SNIFFER Method is appropriate for this site.

The selected Relevant Health Criteria (RHC) for Boron as a threshold substance was the Tolerable Daily Intake (TDI). Due to the absence of published DEFRA / Environment Agency R&D toxicological data for Boron, a TDI was obtained from published guidance from the Dutch Guidance '(Dutch Ministry of Public Housing Land Use and Notification Letter on Intervention for Soil and Groundwater Remediation). A value of 0.2 mg/kg body weight per day was used in the calculation.

As it is intended for the site to revert to agricultural use (crop growing or grazing) or amenity use the setting for allotment was used. By default for allotment the most sensitive critical receptor is chosen, i.e. a female child. Therefore the 0-6 years Exposure Duration, averaging period, Childhood and receptor body weight have been used.

Site specific concentration factors for the uptake of Boron by leafy / root vegetables have been obtained using a formula from the following document:

> "A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture", Oak Ridge National Laboratory, USA.

Although the boron in the topsoil is not in a radioactive form, the behaviour of the metal in its non radioactive form will be similar. Therefore, it is considered appropriate to use this document to calculate concentration factors for Boron. The concentration factors used to model plant uptake are as follows:

- 4.04951 μg/g dry weight plant / μg/g dry weight soil for leafy vegetables
- 2.024755 μg/g dry weight plant / μg/g dry weight soil for root vegetables

SNIFFER Method - Metals/Metalloids

Project Ref: **51-0241** **Run No:** **1**

1 This worksheet may be used for metal and metalloid contaminants except for lead (Pb).

2 This worksheet has been completed by Jolene Turner on 27/10/2005

and has been checked by on

3 It relates to Boron found at Galmoy Mine

Toxicology

4 Is the substance a non-threshold substance (Y or N) N

5 Insert the Relevant Health Criterion value for ingestion 2.00E-01 mg per kg body weight per day
For a non-threshold substance the RHC is the Index Dose (ID).
For threshold substances the RHC is the Tolerable Daily Intake (TDI).

Land Use

6 The Table below lists the default exposure durations and averaging times, used in the method for standard land uses.
Please insert Y to indicate your choice of land use and acceptance of the default assumptions.

Land Use	Exposure duration (years)		Averaging time (days)	
Residential with plant uptake	0-6		2190	
Residential without plant uptake	0-6		2190	
Allotments	0-6	Y	2190	Y
Commercial/Industrial	16-59		15695	

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Background Exposure

7 Insert Mean Daily Intake (MDI) from non-soil sources
(If the contaminant is a non-threshold substance insert zero)

mg per day

Is the MDI equal to or greater than 80% of the TDI or is the MDI unknown? (Y or N)

y

8 Because the MDI for children is lower than that for adults, the MDI will need to be corrected by a Childhood Factor (CF)
which depends on exposure duration. Insert the appropriate factor here:

Exposure duration (years)	Childhood Factor ingestion
0-6	0.485
16-59	1

0.485

Receptor Body Weight

9 Insert the Time-Averaged (female) Body Weight (TABW) depending on the chosen exposure duration

Exposure duration (years)	TABW
0-6	11.15
16-59	46.4

11.15 kg body weight

Reference Intake

10 For non-threshold substances the Reference Intake (RI) for the ingestion pathway is calculated
using the formula: RI_{ingest}=ID

mg per kg body weight per day

For threshold substances the Reference Intake (RI) for ingestion pathways is calculated
using the formula: RI_{ingest}=(TDI-((MDI/70x46.4)xCF)/TABW)[a]

mg per kg body weight per day

[a] Note - The background component is in line with the approach in CLR 9, namely that th
MDI is corrected by the relevant adult body weight.

For threshold substances where the background exposure (MDI) is greater than or equal to 80%
of the TDI, or the MDI is unknown, the Reference Intake (RI) for ingestion pathways is calculated
using the formula: RI_{ingest}=0.2TDI

4.00E-02 mg per kg body weight per day

Intake via Soil and Dust Ingestion

11 Select a value for SEI_{ding} from this table, depending on your choice of land use

SEI_{ding} = 9.85E-06 mg per kg body weight per day

Land Use	SEI_{ding} (kg soil per kg body weight per day)
residential wth plant uptake	9.85319E-06
residential without plant uptake	9.85319E-06
allotment	9.85319E-06
commercial/industrial	5.43222E-07

12 Is site specific data on the bioaccessibility of the contaminant in soil available? (Y or N) | N

if Y insert the representative fraction here (default=1)

The amended SEI_{ding} = SEI_{ding} * bioaccessibility fraction | 9.85319E-06 kg soil per kg body weight per day

13 The nominal assessment sub criterion for intake via soil and dust ingestion using the formula: $ASC_{ding} = RI_{ingest}/SEI_{ding}$

ASC = 4.00000E-02 mg per kg body weight per day / 9.85319E-06 kg soil per kg body weight per day = 4059.598973 mg per kg soil

Intake via Consumption of Homegrown Vegetables

14 This pathway only applies to two land uses: residential with plant uptake and allotments. For other land uses go directly to paragraph 24.
Select the basis for the Concentration Factor from **15 <u>or</u> 16** below. Select **<u>one</u>** option only.

15 For a number of metal contaminants values of CF are given in CLR10. For the contaminant of concern select the appropriate SEI_{veg} from the Table below.

Contaminant	SEI_{veg} (kg soil/kg body weight/day)
Arsenic	3.88743E-06
Cadmium	3.1033E-04 [b]
Chromium	1.11838E-05
Nickel	9.62006E-06
Selenium	5.29089E-05
Mercury	2.15968E-05

[b] Note –
For Cadmium the algorithms in CLR10 for calculation of CF are pH sensitive.
SEI_{veg} value given is for pH7. See main document Section 7.1.5 for further detail.

SEI_{veg}= kg soil per kg body weight per day

16 Are measured site specific Concentration Factors for leafy and root plant uptake of metals available? (Yor N) | y

Measured Concentration Factor for leafy vegetables CF_{leafy} = 4.04951 ug per g (dry or fresh)[c] weight plant per ug per g dry weight so

Measured Concentration Factor for root vegetables CF_{root} = 2.024755 ug per g (dry or fresh)[c] weight plant per ug per g dry weight so

[c] Note - See 17 below

17 For calculation of the SEI_{veg} the units for CF_{leafy} and CF_{root} must be ug per g fresh weight plant over ug per g dry weight soil.
It may be necessary to use a dry weight conversion factor when using measured CF values.
Is a dry weight conversion required? (Y or N) | y

The Time Averaged Vegetable Consumption Rate for homegrown vegetables used to calculate the SEI_{veg} is given in the Table below.

Vegetable Type	TAVCR (kg FW/day)	TAVCR*HF* CF *DW	TAVCR*HF* CF
Brussel sprouts	5.04750E-03	1.22599E-03	calc not required
Cabbage	4.86885E-03	1.55458E-03	calc not required
Carrot	7.38094E-03	5.91246E-04	calc not required
Leafy salads	3.25677E-03	9.23365E-05	calc not required
Onion	3.69474E-03	6.79221E-04	calc not required
Potato	4.41616E-02	7.04449E-03	calc not required

Select a value for SEI_{veg} from this table for the contaminant of concern, depending on your choice of land use

Land Use	SEI_{veg} (kg soil/kg body weight/day)
residential with plant uptake	1.00340E-03
allotments	1.00340E-03

SEI_{veg}= 1.00E-03 kg soil per kg body weight per day

18 The nominal assessment sub criterion for intake via consumption of homegrown vegetables is calculated using the formula: $ASC_{veg} = RI_{ingest}/SEI_{veg}$

Input SEI_{veg} from question 15 or 17

ASC = 4.00000E-02 / 1.00E-03 = 39.86446083 mg per kg soil

mg per kg body weight per day

kg soil per kg body weight per day

Intake via Ingestion of Soil Attached to Vegetables

19 This pathway only applies to two land uses: residential with plant uptake and allotments. For other land uses go directly to paragraph 23.

20 Select a value for $SEI_{indirect}$ from this table, depending on your choice of land use

Land Use	$SEI_{indirect}$ kg soil/kg body weight/day
residential wth plant uptake	1.12723E-06
allotment	1.12723E-06

$SEI_{indirect}$= 1.27E-06 kg soil per kg body weight per day

21 Is site specific data on the bioaccessibility of the contaminant in soil available? (Yor N) n

Insert the representative fraction here (default=1)

The amended $SEI_{indirect}$ = $SEI_{indirect}$ * bioaccessibility fractior 1.27230E-06 kg soil per kg body weight per day

22 The nominal assessment sub criterion for intake via indirect soil ingestion using the formula: $ASC_{indirect} = RI_{indirect}/SEI_{indirect}$

$ASC_{indirect}$ = 4.00000E-02 mg per kg body weight per day / 1.2723E-06 kg soil per kg body weight per day = 31439.12599 mg per kg soil

Integrated Site Specific Assessment Criterion

		Σ(ASC)		SSAC	
23 Allotments	1/	0.025363137	=	39.427299	mg per kg soil

24 The appropriate SSAC is automatically selected for the landuse scenario chosen

25 The level 1 Site Specific Assessment Criterion for **Boron** in the **Allotments** scenario is **40** mg per kg soil

Risk Evaluation

26 Justify your use of the defaults on the worksheet and characterise the risk associated with the site.
Include the following:

	Justification provided (Y or N)
i. Choice of Relevant Health Criteria value	Y
ii. Site use (current and intended), comment on compatibitility with land use selected	Y
iii. Critical Receptor	Y
iv. Pathways included/omitted (including bioaccessibility if used)	Y
v. Soil Parameters, e.g. pH	N/A

51-0241
Galmoy Mine Site
Details of Parameters used to calculate Site Specific Assessment Criteria (SSAC)

Diesel Range Organics
Aliphatics C10-C12, C12-C16, C16-C21, C21-C34

CAS	0-00-0
Type	Organic
Threshold / Non-threshold?	Threshold

Contaminant Properties Used	**Publication / Reference**	**Justification**
Oral Tolerable Daily Intake (TDI)	TPH Criteria Working Group	Similar approach to be adopted in UK
Oral Mean Daily Intake (MDI)	n/a	Not available
Inhalation Tolerable Daily Intake (TDI)	TPH Criteria Working Group	Similar approach to be adopted in UK
Inhalation Mean Daily Intake (MDI)	n/a	Not available
Henry's Law Constant	RBCA Model / USEPA	No available UK Data
Bioaccessibility Fraction	n/a	n/a
Octanol/water partition coefficient (K_{ow})	Derived from TPH Criteria Working Group data	Similar approach to be adopted in UK
Org carbon/water particion coefficient (K_{oc})	RBCA Model / USEPA	No available UK Data
Concentration Factor Leafy Vegetables	n/a	Calculated by model
Concentration Factor Root Vegetables	n/a	Calculated by model
Vapour Pressure	Dutch RIVM Report 711701 023	No available UK Data
Diffusion Coefficient - Water	RBCA Model / USEPA	No available UK Data
Diffusion Coefficient (Soil Air)	RBCA Model / USEPA	No available UK Data

Soil Properties Used	Publication	Source
Soil Organic Matter	n/a	Estimated based on site observations
Fraction of Organic Carbon	n/a	Calculated by model
Air Filled Porosity	SNIFFER Model Users Handbook	Default Value for granular soils
Water Filled Porosity	SNIFFER Model Users Handbook	Default Value for granular soils
Bulk Soil Density	CLR10	Default Value for granular soils
Soil / Water Content	CLR10	Default Value for granular soils
Dilution Ratio	SNIFFER Model Users Handbook	Default Value

Other	Publication	Source
Time Averaged Body Height	CLR10	Default Value
Height of Mixing Zone	CLR10	Default Value

Calculated Integrated SSAC Range :	**552-27147mg/kg**

SNIFFER Method - Organics

Project Ref: **51-0241** **Run No:** **1**

1 This worksheet may be used for organic contaminants

2 This worksheet has been completed by Jolene Turner on 31/10/2005

and has been checked by on

3 It relates to Aliphatic EC10-12 found at Galmoy Mine

INGESTION PATHWAYS

Toxicology for Ingestion Pathways

4a Is the substance a non threshold substance? (Yor N) N

5a Insert the relevant health criterion for ingestion 1.00E-01 mg per kg body weight per day
For a non threshold substance the relevant health criterion is the Index Dose (ID).
For threshold substances the relevant health criterion is the Tolerable Daily Intake (TDI).

Land Use

6a The Table below lists the default exposure durations and averaging times, used in the method for standard land uses.
Please insert Y to indicate your choice of land use and acceptance of the default assumptions.

Land Use	Exposure duration (years)		Averaging time (days)	
Residential with plant uptake	0-6		2190	
Residential without plant uptake	0-6		2190	
Allotments	0-6	Y	2190	Y
Commercial/industrial	16-59		15695	

Background Exposure for Ingestion

7a Insert Mean Daily Intake (MDI) from non-soil sources (If the contaminant is a non threshold substance insert zero) — 6.00E+00 mg per day

Is the MDI equal to or greater than 80% of the TDI or is the MDI unkown? (Y or N) — y

8a Because the MDI for children is lower than that for adults, the MDI will need to be corrected by a Childhood Factor (CF) which depends on exposure duration. Insert the appropriate factor here: — 0.485

Exposure duration (years)	Childhood Factor (ingestion)
0-6	0.485
16-59	1

Receptor Body Weight

9a Insert the Time-Averaged (female) Body Weight (TABW) depending on the chosen exposure duration — 11.15 kg body weight

Exposure duration (years)	TABW
0-6	11.15
16-59	46.4

Reference Intake for Ingestion

10a For non threshold substances the Reference Intake (RI) for the ingestion pathway is calculated using the formula: $RI_{ingest}=ID$ — mg per kg body weight per day

For threshold substances the Reference Intake (RI) for ingestion pathways is calculated using the formula: $RI_{ingest}=(TDI-((MDI/70x46.4)xCF)/TABW)$[a] — mg per kg body weight per day

[a] Note - The background component is in line with the approach in CLR 9, namely that the MDI is corrected by the relevant adult body weight.

For threshold substances where the background exposure (MDI) is greater than or equal to 80% of the TDI, or the MDI is unknown, the Reference Intake (RI) for ingestion pathways is calculated using the formula: $RI_{ingest}=0.2TDI$ — 0.02 mg per kg body weight per day

INHALATION PATHWAYS

Toxicology for Inhalation Pathways

4b Is the substance a non threshold substance. (Yor N) — N

5b Insert the relevant health criterion for inhalation — 2.86E-01 mg per kg body weight per day
For a non threshold substance the relevant health criterion is the (indicative) Index Dose (ID).
For threshold substances the relevant health criterion is the Tolerable Daily Intake (TDI).

Land Use

6b The Table below lists the default exposure durations and averaging times, used in the level 1 methodology for standard land uses.
Please insert Y to indicate your choice of land use and acceptance of the default assumptions.

Land Use	Exposure duration (years)		Averaging time (days)	
Residential with plant uptake	0-6		2190	
Residential without plant uptake	0-6		2190	
Allotments	0-6	y	2190	y
Commercial/industrial	16-59		15695	

Background Exposure for inhalation

7b Insert Mean Daily Intake (MDI) from non-soil sources
(If the contaminant is a non threshold substance insert zero) ____ mg per day

Is the MDI equal to or greater than 80% of the TDI or is the MDI unknown? (Y or N) y

8b Because the MDI for children is lower than that for adults, the MDI will need to be corrected by a Childhood Factor (CF)
which depends on exposure duration. Insert the appropriate factor here: 0.362

Exposure duration (years)	Childhood Factor (inhalation)
0-6	0.362
16-59	1

Receptor Body Weight

9b Insert the Time-Averaged (female) Body Weight (TABW) depending on the chosen exposure duration 11.15 kg body weight

Exposure duration (years)	TABW
0-6	11.15
16-59	46.4

Reference Intake for Inhalation

10b For non threshold substances the Reference Intake (RI) for the inhalation pathway is calculated using the formula: RI_{inhal}=ID | | mg per kg body weight per day

For threshold substances the Reference Intake (RI) for ingestion pathways is calculated using the formula: RI_{ingest}=(TDI-((MDI/70x46.4)xCF)/TABW)[a]

[a] Note - The background component is in line with the approach in CLR 9, namely that the MDI is corrected by the relevant adult body weight. | | mg per kg body weight per day

For threshold substances where the background exposure (MDI) is greater than or equal to 80% of the TDI the Reference Intake (RI) for inhalation pathways is calculated using the formula: RI_{inhal}=0.2TDI | 0.0572 | mg per kg body weight per day

Pathway Check

11 The relevant pathways for calculating Site Specific Assessment Criteria depend on the land-use scenarios and the relative tendency of a substance to exist as vapour molecules as opposed to being dissolved in water, as expressed in Henry's Law constant.

Is the dimensionless Henry's constant H' greater than or equal to 10^{-3}? (Yor N)
If the answer is Y, include vapour inhalation pathways. If it is N, do not. | Y

Intake via Soil and Dust Ingestion

12 Select a value for SEI_{ding} from this table, depending on your choice of land use

Land Use	SEI_{ding} (kg soil/kg body weight/day)
Residential with plant uptake	9.85319E-06
Residential without plant uptake	9.85319E-06
Allotments	9.85319E-06
Commercial/Industrial	5.43222E-07

SEI_{ding} = 9.85E-06

13 Is site specific data on the bioaccessibility of the contaminant in soil available? (Y or N) | N

If Y insert the representative fraction here (default=1) |

The amended SEI_{ding} = SEI_{ding} * bioaccessibility fraction | 9.85319E-06 | kg soil per kg body weight per day

14 The nominal assessment sub criterion for intake via soil and dust ingestion is calculated using the formula: $ASC_{ding} = RI_{ingest}/SEI_{ding}$

ASC_{ding} = 2.00000E-02 (mg per kg body weight per day) / 9.85319E-06 (kg soil per kg body weight per day) = 2029.799486 mg per kg soil

Intake via Consumption of Homegrown Vegetables

15 This pathway only applies to two land uses: residential with plant uptake and allotments. For other land uses go directly to question 25 .
Select the basis for the Concentration Factor from **16 or 17** below. Select **one** option only

16 Are measured site specific Concentration Factors for leafy and root plant uptake of organics available? (Yor N) N

Measured Concentration Factor for leafy vegetables ug per g (dry or fresh)[a] weight plant per ug per g dry weight soil

Measured Concentration Factor for root vegetables ug per g (dry or fresh)[a] weight plant per ug per g dry weight soil

[a] Note - See 18 below

17 Where measured site specific Concentration Factors are not available the following formulae can be used to calculate Concentration Factors for leafy and root vegetable uptake of organics using the Briggs and Ryan approach.

To use the formulae for plant uptake of organics the following data are required:

a representative value for K_{ow} (octanol/water partition coefficient) 3.16E+06 l water per l octanol

a representative value of ϕ (soil density) 1.6 g dry weight per cm^3

a representative value of K_{oc} (organic carbon-water partition coefficient) : 2.51E+05 cm^3 per g dry weight

a representative value of f_{oc} (fraction of organic carbon in soil) : 0.012 kg OC per kg soil

a representative value of θ (soil-water content by volume) 0.15 cm^3 per cm^3

For leafy vegetables $CF_{leafy} = (0.784*10^{-0.434*(logKow-1.78)^2/2.44}*(10^{0.95logKow-2.05}+0.82)*(\phi/(\theta+\phi K_{oc}f_{oc}))$

$CF_{leafy}=$ 0.000378503 [b] ug per g fresh weight plant per ug per g dry weight soil

For root vegetables $CF_{root}=(10^{0.77logKow-1.52}+0.82)*(\phi/(\theta+\phi K_{oc}f_{oc}))*0.01$

$CF_{root}=$ 0.010139282 [b] ug per g fresh weight plant per ug per g dry weight soil

[b] Note - If the soil correction factor ($\phi/(\theta+\phi K_{oc}f_{oc})$) is greater than 1 a default value of 1 is used.

18 For calculation of the SEI_{veg} the units for CF_{leafy} and CF_{root} must be ug per g fresh weight plant over ug per g dry weight soil.
It may be necessary to use a dry weight conversion factor when using **measured** CF values.
Is a dry weight conversion required? (Y or N) n

Calculation of SEI_{veg}
The Time Averaged Vegetable Consumption Rate for homegrown vegetables is given in the Table below.

Vegetable Type	TAVCR (kg FW/day)	TAVCR*HF*CF*DW	TAVCR*HF*CF
Brussel sprouts	5.04750E-03	calc not required	1.20623E-06
Cabbage	4.86885E-03	calc not required	1.15321E-06
Carrot	7.38094E-03	calc not required	3.05233E-05
Leafy salads	3.25677E-03	calc not required	2.15764E-07
Onion	3.69474E-03	calc not required	2.18032E-05
Potato	4.41616E-02	calc not required	1.67983E-04

19 Select a value for SEI_{veg} from this table for the contaminant of concern, depending on your choice of land use and toxicological endpoint

Landuse	SEI_{veg} (kg soil per kg body weight per day)
Residential with plant uptake	1.99896E-05
Allotments	1.99896E-05

$SEI_{veg}=$ 2.00E-05 kg soil per kg body weight per day

20 The nominal assessment sub criterion for intake via consumption of homegrown vegetables is calculated using the formula: $ASC_{veg} = RI_{ingest}/SEI_{veg}$

$ASC_{veg} =$ 2.00000E-02 mg per kg body weight per day / 1.99896E-05 kg soil per kg body weight per day = 1000.520271 mg per kg soil

Intake via Ingestion of Soil Attached to Vegetables

21 This pathway only applies to two land uses: residential with plant uptake and allotments. For other land uses go directly to paragraph 25.

22 Select a value for $SEI_{indirect}$ from this table, depending on your choice of land use

Land Use	$SEI_{indirect}$ (kg soil per kg body weight per day)
Residential with plant uptake	1.12723E-06
allotments	1.12723E-06

$SEI_{indirect}$= 1.1272E-06 kg soil per kg body weight per day

23 Is site specific data on the bioaccessibility of the contaminant in soil available? (Y or N) n

Insert the representative fraction here (default=1)

The amended $SEI_{indirect}$ = $SEI_{indirect}$ * bioaccessibility fraction 1.12723E-06 kg soil per kg body weight per day

24 The nominal assessment sub criterion for intake via indirect soil ingestion using the formula: $ASC_{indirect} = RI_{ingest}/SEI_{indirect}$

$ASC_{indirect}$ = 2.00000E-02 (mg per kg body weight per day) / 1.12723E-06 (kg soil per kg body weight per day) = 17742.60799 mg per kg soil

Intake via Inhalation of Outdoor Air

25 This pathway only applies to substances with H' greater than or equal to 10^{-3}.
To use the formulae for inhalation of outdoor air, the following site parameters are required:

Source Area

Source zone width parallel to wind direction	W=	10	metres
Depth to subsurface contamination	d_z=	0.3	metres

Soil Matrix

Soil organic matter content	SOM=	2	%	
Mass fraction of organic carbon in soil	f_{oc}=	2	/167	1.19760E-02 kg OC per kg soil
Air filled porosity	θ_{vap}=	0.31	unitless	
Water filed porosity	θ_{wat}=	0.15	unitless	
Total porosity	θ_{total}=	0.46	unitless	
Bulk soil density	ρ=	1.6	kg soil per l soil	

Contaminant

Organic carbon/water partition coefficient	K_{oc}=	2.51E+05	l water per kg OC
Dimensionless Henry's constant	H'=	1.29E+02	l water per l air
Diffusion coefficient in water	D_{wat}=	1.00E-09	m^2 per s
Diffusion coefficient in soil air	D_i=	1.00E-05	m^2 per s
Air in soil		9.52847E-02	unitless
Water in soil		8.47465E-03	unitless
Air term		9.52847E-07	m^2 per s
Water term		6.57435E-14	m^2 per s per (l water per l air)
Effective diffusion coefficient	D_{eff}=	9.52847E-07	m^2 per s
Molecular weight	MW=	160	g per mol
Saturated vapour pressure	SatVP	0.4788	mmHg

Pathway parameters

Dilution ratio	DR=	20000	unitless
Temperature	Temp=	20	°C + 273 = 293 K
Ambient air velocity in the mixing zone (default from CLEA is 3 m per s)	V_{air}=	3	m per s

Receptor characteristics

Time-averaged body height	TAH=	0.93	m		
Height of mixing zone	h=	0.93	/2 =	0.465	m

26 **Contaminant Volatilisation Factor (CVF)**

CVF= 9.68263E-07 kg soil per l air

27 **Time-Averaged Air Intake Outdoors**

Landuse	TAAIoutv m^3 air per (kg body weight per day)
Residential with plant uptake	7.27421E-02
Residental without plant uptake	7.27421E-02
Allotments	1.55763E-02
Commercial/Industrial	6.45534E-03

Insert the appropriate $TAAI_{outv}$ here 1.56E-02 m^3 air per (kg body weight per day)

28 **Soil equivalent Intake**

Calculate the soil equivalent intake for inhalation of outdoor air
using the formula: $SEI_{outv} = TAAI_{outv} \times CVF \times 1000$

1.50820E-05 kg soil per (kg body weight per day)

29 **Nominal Assessment Sub Criterion**

Calculate the nominal assessment sub-criteria for intake via outdoor air
using the formula: $ASC_{outv} = RI_{outv}/SEI_{outv}$

ASC_{outv} = 5.72000E-02 / 1.50820E-05 = 3792.612581 mg per kg soil

mg per kg body weight per day; kg soil per kg body weight per day

Intake via Inhalation of Indoor Air

30 **Indoor inhalation of vapour**

This pathway **only** applies to substances with dimensionless Henry's constant **equal to or greater than 10^{-3}** and to the following land-use scenarios:
Residential with plant uptake, Residential without plant uptake, Commercial/industrial

31 **Time-averaged air intake indoors**

Landuse	$TAAI_{inv}$ m3 air per (kg body weight per day)
Residential with plant uptake	2.78379E-01
Residential without plant uptake	2.78379E-01
Commercial/industrial	4.34795E-02

Insert the appropriate $TAAI_{inv}$ here [ ] m^{3} air per (kg body weight per day)

32 **Soil Factor**

Soil Factor is calculated using the formula $SF=K_{oc} \times f_{oc}/H'$ SF= 23.3194273 l air per kg soil

33 **Soil vapour partition coefficient**

The soil vapour partition coefficient (SVPC) is SVPC= 0.042528028 kg soil per l air

34 The soil equivalent intakes for inhalation of indoor air is calculated using the formula: $SEI_{inv} = (TAAI_{inv} \times 1000 \times SVPC)/DR$ SEI_{inv}= 0.00000E+00 kg soil/(kg body weight per day)

35 The nominal assessment sub criterion for intake via indoor air is calculated using the formula: $ASC_{inv} = RI_{inv}/SEI_{inv}$

ASC_{inv} = 5.72000E-02 (mg per kg body weight per day) / 0.00000E+00 (kg soil per kg body weight per day) = #DIV/0! mg per kg soil

36 **Saturated vapour concentration**

Saturated vapour concentration is calculated using the formula
$C_{sat} = (SatVP \times MW \times 10^{9})/(760mmHg \times R \times Temp)$ C_{sat}= 4.19239E+06 mm Hg.g per mol

37 **Equilibrium contaminant concentration in soil vapour**

Equilibrium contaminant concentration in soil vapour
is calculated using the formula $C_{sv} = ASC_{inv} \times SVPC$ C_{sv}= #DIV/0! mg per l air

38 Saturated vapour concentration compared to the equilibrium contaminant concentration in soil vapour: C_{sv} / C_{sat} C_{sv}/C_{sat}= #DIV/0! (mg per l air) per (mm Hg.g per mol)

If the ratio is greated than 1, Level 1 risk assessment is not appropriate. It should be noted for further site-specific risk assessment that a C_{sv}/C_{sat} ratio greater than 1 may indicate the presence of a free product.

Integrated site specific assessment criteria (SSAC) for substances with dimensionless Henry's constant greater than or equal to 10^{-3}

soil ingestion pathway	$1/ASC_{ding}$=	1/	2029.799486	=	4.92660E-04	kg soil per mg
homegrown vegetable consumption pathway	$1/ASC_{veg}$=	1/	1000.520271	=	9.99480E-04	kg soil per mg
ingestion of soil attached to vegetables	$1/ASC_{indirect}$=	1/	17742.60799	=	5.63615E-05	kg soil per mg
inhalation of outdoor air	$1/ASC_{outv}$=	1/	3792.612581	=	2.63670E-04	kg soil per mg
inhalation of indoor air	$1/ASC_{inv}$=	1/	#DIV/0!	=	#DIV/0!	kg soil per mg

The integrated Site Specific Assessment Criterion (SSAC)

39 For the residential with plant uptake land use the $SSAC_{rwp}$ = mg per kg soil

40 For the allotments land use the $SSAC_{alt}$ = 551.8241558 mg per kg soil

41 For the residential without plant uptake land use the $SSAC_{other}$ = mg per kg soil

For the commercial/industrial land use the $SSAC_{other}$= mg per kg soil

42 The Level 1 Site Specific Assessment Criterion for **.liphatic EC10-1** in the **Allotments** scenario is 552 mg per kg soil

Integrated site specific assessment criteria for substances with dimensionless Henry's constant less than 10^{-3}

soil ingestion pathway	$1/ASC_{ding}$=	1/		=		kg soil per mg
homegrown vegetable consumption pathway	$1/ASC_{veg}$=	1/		=		kg soil per mg
ingestion of soil attached to vegetables	$1/ASC_{indirect}$=	1/		=		kg soil per mg

The integrated Site Specific Assessment Criterion

43 For the residential with plant uptake land use the $SSAC_{rwp}$ = mg per kg soil

For the allotments land use the $SSAC_{alt}$ = mg per kg soil

For the residential without plant uptake land use the $SSAC_{other}$ = mg per kg soil

For the commercial/industrial land use the $SSAC_{other}$= mg per kg soil

The Level 1 Site Specific Assessment Criterion for **Aliphatic EC10-12** in the scenario is mg per kg soil

Risk Evaluation

44 Justify your use of the defaults on the worksheet and characterise the risk associated with the site.
Include the following:

	Justification provided (Y or N)
i. Choice of Relevant Health Criteria value	Y
ii. Site use (current and intended), comment on compatibitility with land use selected	Y
iii. Critical Receptor	Y
iv. Pathways included/omitted (including bioaccessibility if used)	Y
v. Soil Parameters, e.g. pH	N

SNIFFER Method - Organics

Project Ref: **51-0241** **Run No:** **1**

1 This worksheet may be used for organic contaminants

2 This worksheet has been completed by Jolene Turner on 12/11/2005

and has been checked by on

3 It relates to Aliphatic >C12 - C16 found at Arcon Mine

INGESTION PATHWAYS

Toxicology for Ingestion Pathways

4a Is the substance a non threshold substance? (Yor N) n

5a Insert the relevant health criterion for ingestion 1.00E-01 mg per kg body weight per day
For a non threshold substance the relevant health criterion is the Index Dose (ID).
For threshold substances the relevant health criterion is the Tolerable Daily Intake (TDI).

Land Use

6a The Table below lists the default exposure durations and averaging times, used in the method for standard land uses.
Please insert Y to indicate your choice of land use and acceptance of the default assumptions.

Land Use	Exposure duration (years)		Averaging time (days)	
Residential with plant uptake	0-6		2190	
Residential without plant uptake	0-6		2190	
Allotments	0-6	y	2190	y
Commercial/industrial	16-59		15695	

Background Exposure for Ingestion

7a Insert Mean Daily Intake (MDI) from non-soil sources
(If the contaminant is a non threshold substance insert zero) — mg per day

Is the MDI equal to or greater than 80% of the TDI or is the MDI unkown? (Y or N) — y

8a Because the MDI for children is lower than that for adults, the MDI will need to be corrected by a Childhood Factor (CF) which depends on exposure duration. Insert the appropriate factor here:

Exposure duration (years)	Childhood Factor (ingestion)
0-6	0.485
16-59	1

0.485

Receptor Body Weight

9a Insert the Time-Averaged (female) Body Weight (TABW) depending on the chosen exposure duration

Exposure duration (years)	TABW
0-6	11.15
16-59	46.4

11.15 kg body weight

Reference Intake for Ingestion

10a For non threshold substances the Reference Intake (RI) for the ingestion pathway is calculated using the formula: $RI_{ingest}=ID$ — mg per kg body weight per day

For threshold substances the Reference Intake (RI) for ingestion pathways is calculated using the formula: $RI_{ingest}=(TDI-((MDI/70x46.4)xCF)/TABW)$[a] — mg per kg body weight per day

[a] Note - The background component is in line with the approach in CLR 9, namely that the MDI is corrected by the relevant adult body weight.

For threshold substances where the background exposure (MDI) is greater than or equal to 80% of the TDI, or the MDI is unknown, the Reference Intake (RI) for ingestion pathways is calculated using the formula: $RI_{ingest}=0.2TDI$ — 0.02 mg per kg body weight per day

INHALATION PATHWAYS

Toxicology for Inhalation Pathways

4b Is the substance a non threshold substance. (Yor N) — n

5b Insert the relevant health criterion for inhalation — 2.90E-01 mg per kg body weight per day
For a non threshold substance the relevant health criterion is the (indicative) Index Dose (ID).
For threshold substances the relevant health criterion is the Tolerable Daily Intake (TDI).

Land Use

6b The Table below lists the default exposure durations and averaging times, used in the level 1 methodology for standard land uses.
Please insert Y to indicate your choice of land use and acceptance of the default assumptions.

Land Use	Exposure duration (years)		Averaging time (days)	
Residential with plant uptake	0-6		2190	
Residential without plant uptake	0-6		2190	
Allotments	0-6	y	2190	y
Commercial/industrial	16-59		15695	

Background Exposure for inhalation

7b Insert Mean Daily Intake (MDI) from non-soil sources (If the contaminant is a non threshold substance insert zero) — mg per day

Is the MDI equal to or greater than 80% of the TDI or is the MDI unknown? (Y or N) — y

8b Because the MDI for children is lower than that for adults, the MDI will need to be corrected by a Childhood Factor (CF) which depends on exposure duration. Insert the appropriate factor here: — 0.362

Exposure duration (years)	Childhood Factor (inhalation)
0-6	0.362
16-59	1

Receptor Body Weight

9b Insert the Time-Averaged (female) Body Weight (TABW) depending on the chosen exposure duration — 11.15 kg body weight

Exposure duration (years)	TABW
0-6	11.15
16-59	46.4

Reference Intake for Inhalation

10b For non threshold substances the Reference Intake (RI) for the inhalation pathway is calculated using the formula: RI_{inhal}=ID

[ ] mg per kg body weight per day

For threshold substances the Reference Intake (RI) for ingestion pathways is calculated using the formula: RI_{ingest}=(TDI-((MDI/70x46.4)xCF)/TABW)[a]

[a] Note - The background component is in line with the approach in CLR 9, namely that the MDI is corrected by the relevant adult body weight.

[ ] mg per kg body weight per day

For threshold substances where the background exposure (MDI) is greater than or equal to 80% of the TDI the Reference Intake (RI) for inhalation pathways is calculated using the formula: RI_{inhal}=0.2TDI

0.058 mg per kg body weight per day

Pathway Check

11 The relevant pathways for calculating Site Specific Assessment Criteria depend on the land-use scenarios and the relative tendency of a substance to exist as vapour molecules as opposed to being dissolved in water, as expressed in Henry's Law constant.

Is the dimensionless Henry's constant H' greater than or equal to 10^{-3}? (Yor N)
If the answer is Y, include vapour inhalation pathways. If it is N, do not.

y

Intake via Soil and Dust Ingestion

12 Select a value for SEI_{ding} from this table, depending on your choice of land use

Land Use	SEI_{ding} (kg soil/kg body weight/day)
Residential with plant uptake	9.85319E-06
Residential without plant uptake	9.85319E-06
Allotments	9.85319E-06
Commercial/Industrial	5.43222E-07

SEI_{ding} = 9.85E-06

13 Is site specific data on the bioaccessibility of the contaminant in soil available? (Y or N)

n

If Y insert the representative fraction here (default=1)

The amended SEI_{ding} = SEI_{ding} * bioaccessibility fraction

9.85319E-06 kg soil per kg body weight per day

14 The nominal assessment sub criterion for intake via soil and dust ingestion is calculated using the formula: $ASC_{ding} = RI_{ingest}/SEI_{ding}$

ASC_{ding} = 2.00000E-02 (mg per kg body weight per day) / 9.85319E-06 (kg soil per kg body weight per day) = 2029.799486 mg per kg soil

Intake via Consumption of Homegrown Vegetables

15 This pathway only applies to two land uses: residential with plant uptake and allotments. For other land uses go directly to question 25 .
Select the basis for the Concentration Factor from **16 or 17** below. Select **one** option only

16 Are measured site specific Concentration Factors for leafy and root plant uptake of organics available? (Yor N) n

Measured Concentration Factor for leafy vegetables — ug per g (dry or fresh)[a] weight plant per ug per g dry weight soil

Measured Concentration Factor for root vegetables — ug per g (dry or fresh)[a] weight plant per ug per g dry weight soil

[a] Note - See 18 below

17 Where measured site specific Concentration Factors are not available the following formulae can be used to calculate Concentration Factors for leafy and root vegetable uptake of organics using the Briggs and Ryan approach.

To use the formulae for plant uptake of organics the following data are required:

a representative value for K_{ow} (octanol/water partition coefficient): 1.00E+08 l water per l octanol

a representative value of ϕ (soil density): 1.6 g dry weight per cm^3

a representative value of K_{oc} (organic carbon-water partition coefficient) : 5.01E+06 cm^3 per g dry weight

a representative value of f_{oc} (fraction of organic carbon in soil) : 0.012 kg OC per kg soil

a representative value of θ (soil-water content by volume): 0.15 cm^3 per cm^3

For leafy vegetables $CF_{leafy} = (0.784*10^{-0.434*(logKow-1.78)^2/2.44}*(10^{0.95logKow-2.05}+0.82)*(\phi/(\theta+\phi K_{oc}f_{oc}))$

CF_{leafy}= 6.07679E-07 [b] ug per g fresh weight plant per ug per g dry weight soil

For root vegetables $CF_{root}=(10^{0.77logKow-1.52}+0.82)*(\phi/(\theta+\phi K_{oc}f_{oc}))*0.01$

CF_{root}= 0.007258158 [b] ug per g fresh weight plant per ug per g dry weight soil

[b] Note - If the soil correction factor ($\phi/(\theta+\phi K_{oc}f_{oc})$) is greater than 1 a default value of 1 is used.

18 For calculation of the SEI_{veg} the units for CF_{leafy} and CF_{root} must be ug per g fresh weight plant over ug per g dry weight soil.
It may be necessary to use a dry weight conversion factor when using **measured** CF values.
Is a dry weight conversion required? (Y or N) n

Calculation of SEI_{veg}
The Time Averaged Vegetable Consumption Rate for homegrown vegetables is given in the Table below.

Vegetable Type	TAVCR (kg FW/day)	TAVCR*HF*CF*DW	TAVCR*HF*CF
Brussel sprouts	5.04750E-03	calc not required	1.93658E-09
Cabbage	4.86885E-03	calc not required	1.85146E-09
Carrot	7.38094E-03	calc not required	2.18500E-05
Leafy salads	3.25677E-03	calc not required	3.46406E-10
Onion	3.69474E-03	calc not required	1.56077E-05
Potato	4.41616E-02	calc not required	1.20250E-04

19 Select a value for SEI_{veg} from this table for the contaminant of concern, depending on your choice of land use and toxicological endpoint

Landuse	SEI_{veg} (kg soil per kg body weight per day)
Residential with plant uptake	1.41445E-05
Allotments	1.41445E-05

SEI_{veg}= 1.41E-05 kg soil per kg body weight per day

20 The nominal assessment sub criterion for intake via consumption of homegrown vegetables is calculated using the formula: $ASC_{veg} = RI_{ingest}/SEI_{veg}$

ASC_{veg} = 2.00000E-02 mg per kg body weight per day / 1.41445E-05 kg soil per kg body weight per day = 1413.977164 mg per kg soil

Intake via Ingestion of Soil Attached to Vegetables

21 This pathway only applies to two land uses: residential with plant uptake and allotments. For other land uses go directly to paragraph 25.

22 Select a value for $SEI_{indirect}$ from this table, depending on your choice of land use

Land Use	$SEI_{indirect}$ (kg soil per kg body weight per day)
Residential with plant uptake	1.12723E-06
allotments	1.12723E-06

$SEI_{indirect}$= 1.1272E-06 kg soil per kg body weight per day

23 Is site specific data on the bioaccessibility of the contaminant in soil available? (Y or N) n

Insert the representative fraction here (default=1)

The amended $SEI_{indirect}$ = $SEI_{indirect}$ * bioaccessibility fraction 1.12723E-06 kg soil per kg body weight per day

24 The nominal assessment sub criterion for intake via indirect soil ingestion using the formula: $ASC_{indirect} = RI_{ingest}/SEI_{indirect}$

$ASC_{indirect}$ = 2.00000E-02 (mg per kg body weight per day) / 1.12723E-06 (kg soil per kg body weight per day) = 17742.60799 mg per kg soil

Intake via Inhalation of Outdoor Air

25 This pathway only applies to substances with H' greater than or equal to 10^{-3}.
To use the formulae for inhalation of outdoor air, the following site parameters are required:

Source Area

Source zone width parallel to wind direction	W=	10	metres
Depth to subsurface contamination	d_z=	0.3	metres

Soil Matrix

Soil organic matter content	SOM=	2	%
Mass fraction of organic carbon in soil	f_{oc}=	2	/167 1.19760E-02 kg OC per kg soil
Air filled porosity	θ_{vap}=	0.31	unitless
Water filed porosity	θ_{wat}=	0.15	unitless
Total porosity	θ_{total}=	0.46	unitless
Bulk soil density	ρ=	1.6	kg soil per l soil

Contaminant

Organic carbon/water partition coefficient	K_{oc}=	5.01E+06	l water per kg OC
Dimensionless Henry's constant	H'=	535.451047	l water per l air
Diffusion coefficient in water	D_{wat}=	1.00E-09	m^2 per s
Diffusion coefficient in soil air	D_i=	1.00E-05	m^2 per s
Air in soil		9.52847E-02	unitless
Water in soil		8.47465E-03	unitless
Air term		9.52847E-07	m^2 per s
Water term		1.58271E-14	m^2 per s per (l water per l air)
Effective diffusion coefficient	D_{eff}=	9.52847E-07	m^2 per s
Molecular weight	MW=	200	g per mol
Saturated vapour pressure	SatVP	0.03648	mmHg

Pathway parameters

Dilution ratio	DR=	20000	unitless
Temperature	Temp=	20	°C + 273 = 293 K
Ambient air velocity in the mixing zone (default from CLEA is 3 m per s)	V_{air}=	3	m per s

Receptor characteristics

Time-averaged body height TAH= 0.93 m

Height of mixing zone h= 0.93 /2 = 0.465 m

26 **Contaminant Volatilisation Factor (CVF)**

CVF= 2.02756E-07 kg soil per l air

27 **Time-Averaged Air Intake Outdoors**

Landuse	TAAIoutv m^3 air per (kg body weight per day)
Residential with plant uptake	7.27421E-02
Residental without plant uptake	7.27421E-02
Allotments	1.55763E-02
Commercial/Industrial	6.45534E-03

Insert the appropriate $TAAI_{outv}$ here 7.27E-02 m^3 air per (kg body weight per day)

28 **Soil equivalent Intake**

Calculate the soil equivalent intake for inhalation of outdoor air 1.47489E-05 kg soil per (kg body weight per day)

using the formula: $SEI_{outv} = TAAI_{outv} \times CVF \times 1000$

29 **Nominal Assessment Sub Criterion**

Calculate the nominal assessment sub-criteria for intake via outdoor air

using the formula: $ASC_{outv} = RI_{outv}/SEI_{outv}$

ASC_{outv} = 5.80000E-02 / 1.47489E-05 = 3932.498888 mg per kg soil

mg per kg body weight per day; kg soil per kg body weight per day

Intake via Inhalation of Indoor Air

30 **Indoor inhalation of vapour**

This pathway **only** applies to substances with dimensionless Henry's constant **equal to or greater than 10^{-3}** and to the following land-use scenarios:
Residential with plant uptake, Residential without plant uptake, Commercial/industrial

31 **Time-averaged air intake indoors**

Landuse	$TAAI_{inv}$ m3 air per (kg body weight per day)
Residential with plant uptake	2.78379E-01
Residential without plant uptake	2.78379E-01
Commercial/industrial	4.34795E-02

Insert the appropriate $TAAI_{inv}$ here [ ] m^{3} air per (kg body weight per day)

32 **Soil Factor**

Soil Factor is calculated using the formula SF=K_{oc} x f_{oc}/H'

SF= 112.0969387 l air per kg soil

33 **Soil vapour partition coefficient**

The soil vapour partition coefficient (SVPC) is

SVPC= 0.008905444 kg soil per l air

34 The soil equivalent intakes for inhalation of indoor air is calculated using the formula: SEI_{inv} = ($TAAI_{inv}$ x 1000 x SVPC)/DR

SEI_{inv}= 0.00000E+00 kg soil/(kg body weight per day)

35 The nominal assessment sub criterion for intake via indoor air is calculated using the formula: ASC_{inv} = RI_{inv}/SEI_{inv}

ASC_{inv} = 5.80000E-02 mg per kg body weight per day / 0.00000E+00 kg soil per kg body weight per day = #DIV/0! mg per kg soil

36 **Saturated vapour concentration**

Saturated vapour concentration is calculated using the formula
C_{sat} = (SatVP x MW x 10^{9})/(760mmHg x R x Temp)

C_{sat}= 3.99275E+05 mm Hg.g per mol

37 **Equilibrium contaminant concentration in soil vapour**

Equilibrium contaminant concentration in soil vapour is calculated using the formula C_{sv} = ASC_{inv} x SVPC

C_{sv}= #DIV/0! mg per l air

38 Saturated vapour concentration compared to the equilibrium contaminant concentration in soil vapour: C_{sv} / C_{sat}

C_{sv}/C_{sat}= #DIV/0! (mg per l air) per (mm Hg.g per mol)

If the ratio is greated than 1, Level 1 risk assessment is not appropriate. It should be noted for further site-specific risk assessment that a C_{sv}/C_{sat} ratio greater than 1 may indicate the presence of a free product.

Integrated site specific assessment criteria (SSAC) for substances with dimensionless Henry's constant greater than or equal to 10^{-3}

soil ingestion pathway	$1/ASC_{ding}$=	1/	2029.799486	=	4.92660E-04	kg soil per mg
homegrown vegetable consumption pathway	$1/ASC_{veg}$=	1/	1413.977164	=	7.07225E-04	kg soil per mg
ingestion of soil attached to vegetables	$1/ASC_{indirect}$=	1/	17742.60799	=	5.63615E-05	kg soil per mg
inhalation of outdoor air	$1/ASC_{outv}$=	1/	3932.498888	=	2.54291E-04	kg soil per mg
inhalation of indoor air	$1/ASC_{inv}$=	1/	#DIV/0!	=	#DIV/0!	kg soil per mg

The integrated Site Specific Assessment Criterion (SSAC)

39 For the residential with plant uptake land use the $SSAC_{rwp}$ = mg per kg soil

40 For the allotments land use the $SSAC_{alt}$ = 662.0161203 mg per kg soil

41 For the residential without plant uptake land use the $SSAC_{other}$ = mg per kg soil

For the commercial/industrial land use the $SSAC_{other}$= mg per kg soil

42 The Level 1 Site Specific Assessment Criterion for **iphatic >C12 - C** in the **Allotments** scenario is 662 mg per kg soil

Integrated site specific assessment criteria for substances with dimensionless Henry's constant less than 10^{-3}

soil ingestion pathway	$1/ASC_{ding}$=	1/		=		kg soil per mg
homegrown vegetable consumption pathway	$1/ASC_{veg}$=	1/		=		kg soil per mg
ingestion of soil attached to vegetables	$1/ASC_{indirect}$=	1/		=		kg soil per mg

The integrated Site Specific Assessment Criterion

43 For the residential with plant uptake land use the $SSAC_{rwp}$ = mg per kg soil

For the allotments land use the $SSAC_{alt}$ = mg per kg soil

For the residential without plant uptake land use the $SSAC_{other}$ = mg per kg soil

For the commercial/industrial land use the $SSAC_{other}$= mg per kg soil

The Level 1 Site Specific Assessment Criterion for **liphatic >C12 - C1** in the scenario is mg per kg soil

Risk Evaluation

44 Justify your use of the defaults on the worksheet and characterise the risk associated with the site.
Include the following:

	Justification provided (Y or N)
i. Choice of Relevant Health Criteria value	y
ii. Site use (current and intended), comment on compatibitility with land use selected	y
iii. Critical Receptor	y
iv. Pathways included/omitted (including bioaccessibility if used)	y
v. Soil Parameters, e.g. pH	N

SNIFFER Method - Organics

Project Ref: **51-0241** **Run No:** **1**

1 This worksheet may be used for organic contaminants

2 This worksheet has been completed by Jolene Turner on 12/11/2005

and has been checked by on

3 It relates to Aliphatic >C16 - C21 found at Galmoy Mine

INGESTION PATHWAYS

Toxicology for Ingestion Pathways

4a Is the substance a non threshold substance? (Yor N) n

5a Insert the relevant health criterion for ingestion 2.00E+00 mg per kg body weight per day
For a non threshold substance the relevant health criterion is the Index Dose (ID).
For threshold substances the relevant health criterion is the Tolerable Daily
Intake (TDI).

Land Use

6a The Table below lists the default exposure durations and averaging times, used in the method for standard land uses.
Please insert Y to indicate your choice of land use and acceptance of the default assumptions.

Land Use	Exposure duration (years)		Averaging time (days)	
Residential with plant uptake	0-6		2190	
Residential without plant uptake	0-6		2190	
Allotments	0-6	y	2190	y
Commercial/industrial	16-59		15695	

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Background Exposure for Ingestion

7a Insert Mean Daily Intake (MDI) from non-soil sources
(If the contaminant is a non threshold substance insert zero) | | mg per day

Is the MDI equal to or greater than 80% of the TDI or is the MDI unkown? (Y or N) | y

8a Because the MDI for children is lower than that for adults, the MDI will need to be corrected by a Childhood Factor (CF) which depends on exposure duration. Insert the appropriate factor here:

Exposure duration (years)	Childhood Factor (ingestion)
0-6	0.485
16-59	1

0.485

Receptor Body Weight

9a Insert the Time-Averaged (female) Body Weight (TABW) depending on the chosen exposure duration

Exposure duration (years)	TABW
0-6	11.15
16-59	46.4

11.15 kg body weight

Reference Intake for Ingestion

10a For non threshold substances the Reference Intake (RI) for the ingestion pathway is calculated using the formula: RI_{ingest}=ID | | mg per kg body weight per day

For threshold substances the Reference Intake (RI) for ingestion pathways is calculated using the formula: RI_{ingest}=(TDI-((MDI/70x46.4)xCF)/TABW)[a] | | mg per kg body weight per day

[a] Note - The background component is in line with the approach in CLR 9, namely that the MDI is corrected by the relevant adult body weight.

For threshold substances where the background exposure (MDI) is greater than or equal to 80% of the TDI, or the MDI is unknown, the Reference Intake (RI) for ingestion pathways is calculated using the formula: RI_{ingest}=0.2TDI | 0.4 | mg per kg body weight per day

INHALATION PATHWAYS

Toxicology for Inhalation Pathways

4b Is the substance a non threshold substance. (Yor N) | n

5b Insert the relevant health criterion for inhalation | 2.90E-01 | mg per kg body weight per day
For a non threshold substance the relevant health criterion is the (indicative) Index Dose (ID).
For threshold substances the relevant health criterion is the Tolerable Daily Intake (TDI).

Land Use

6b The Table below lists the default exposure durations and averaging times, used in the level 1 methodology for standard land uses.
Please insert Y to indicate your choice of land use and acceptance of the default assumptions.

Land Use	Exposure duration (years)		Averaging time (days)	
Residential with plant uptake	0-6		2190	
Residential without plant uptake	0-6		2190	
Allotments	0-6	y	2190	y
Commercial/industrial	16-59		15695	

Background Exposure for inhalation

7b Insert Mean Daily Intake (MDI) from non-soil sources
(If the contaminant is a non threshold substance insert zero) [ ] mg per day

Is the MDI equal to or greater than 80% of the TDI or is the MDI unknown? (Y or N) y

8b Because the MDI for children is lower than that for adults, the MDI will need to be corrected by a Childhood Factor (CF)
which depends on exposure duration. Insert the appropriate factor here: 0.362

Exposure duration (years)	Childhood Factor (inhalation)
0-6	0.362
16-59	1

Receptor Body Weight

9b Insert the Time-Averaged (female) Body Weight (TABW) depending on the chosen exposure duration 11.15 kg body weight

Exposure duration (years)	TABW
0-6	11.15
16-59	46.4

Reference Intake for Inhalation

10b For non threshold substances the Reference Intake (RI) for the inhalation pathway is calculated using the formula: RI_{inhal}=ID

	mg per kg body weight per day

For threshold substances the Reference Intake (RI) for ingestion pathways is calculated using the formula: RI_{ingest}=(TDI-((MDI/70x46.4)xCF)/TABW)[a]

[a] Note - The background component is in line with the approach in CLR 9, namely that the MDI is corrected by the relevant adult body weight.

	mg per kg body weight per day

For threshold substances where the background exposure (MDI) is greater than or equal to 80% of the TDI the Reference Intake (RI) for inhalation pathways is calculated using the formula: RI_{inhal}=0.2TDI

0.058	mg per kg body weight per day

Pathway Check

11 The relevant pathways for calculating Site Specific Assessment Criteria depend on the land-use scenarios and the relative tendency of a substance to exist as vapour molecules as opposed to being dissolved in water, as expressed in Henry's Law constant.

Is the dimensionless Henry's constant H' greater than or equal to 10^{-3}? (Yor N)
If the answer is Y, include vapour inhalation pathways. If it is N, do not.

y

Intake via Soil and Dust Ingestion

12 Select a value for SEI_{ding} from this table, depending on your choice of land use

Land Use	SEI_{ding} (kg soil/kg body weight/day)
Residential with plant uptake	9.85319E-06
Residential without plant uptake	9.85319E-06
Allotments	9.85319E-06
Commercial/Industrial	5.43222E-07

SEI_{ding} = 9.85E-06

13 Is site specific data on the bioaccessibility of the contaminant in soil available? (Y or N)

n

If Y insert the representative fraction here (default=1)

The amended SEI_{ding} = SEI_{ding} * bioaccessibility fraction

9.85319E-06 kg soil per kg body weight per day

14 The nominal assessment sub criterion for intake via soil and dust ingestion is calculated using the formula: ASC_{ding} = RI_{ingest}/SEI_{ding}

ASC_{ding} = 4.00000E-01 (mg per kg body weight per day) / 9.85319E-06 (kg soil per kg body weight per day) = 40595.98973 mg per kg soil

Intake via Consumption of Homegrown Vegetables

15 This pathway only applies to two land uses: residential with plant uptake and allotments. For other land uses go directly to question 25 .
Select the basis for the Concentration Factor from **16 or 17** below. Select **one** option only

16 Are measured site specific Concentration Factors for leafy and root plant uptake of organics available? (Yor N) n

Measured Concentration Factor for leafy vegetables ug per g (dry or fresh)[a] weight plant per ug per g dry weight soil

Measured Concentration Factor for root vegetables ug per g (dry or fresh)[a] weight plant per ug per g dry weight soil

[a] Note - See 18 below

17 Where measured site specific Concentration Factors are not available the following formulae can be used to calculate Concentration Factors for leafy and root vegetable uptake of organics using the Briggs and Ryan approach.

To use the formulae for plant uptake of organics the following data are required:

a representative value for K_{ow} (octanol/water partition coefficient) 6.20E+10 l water per l octanol

a representative value of ϕ (soil density) 1.6 g dry weight per cm^3

a representative value of K_{oc} (organic carbon-water partition coefficient) : 1.00E+09 cm^3 per g dry weight

a representative value of f_{oc} (fraction of organic carbon in soil) : 0.012 kg OC per kg soil

a representative value of θ (soil-water content by volume) 0.15 cm^3 per cm^3

For leafy vegetables $CF_{leafy} = (0.784*10^{-0.434*(logKow-1.78)^2/2.44}*(10^{0.95logKow-2.05}+0.82)*(\phi/(\theta+\phi K_{oc}f_{oc}))$

CF_{leafy}= 3.71744E-14 [b] ug per g fresh weight plant per ug per g dry weight soil

[b] Note - If the soil correction factor ($\phi/(\theta+\phi K_{oc}f_{oc})$) is greater than 1 a default value of 1 is used.

For root vegetables $CF_{root}=(10^{0.77logKow-1.52}+0.82)*(\phi/(\theta+\phi K_{oc}f_{oc}))*0.01$

CF_{root}= 0.00514233 [b] ug per g fresh weight plant per ug per g dry weight soil

18 For calculation of the SEI_{veg} the units for CF_{leafy} and CF_{root} must be ug per g fresh weight plant over ug per g dry weight soil.
It may be necessary to use a dry weight conversion factor when using **measured** CF values.
Is a dry weight conversion required? (Y or N) n

Calculation of SEI_{veg}
The Time Averaged Vegetable Consumption Rate for homegrown vegetables is given in the Table below.

Vegetable Type	TAVCR (kg FW/day)	TAVCR*HF*CF*DW	TAVCR*HF*CF
Brussel sprouts	5.04750E-03	calc not required	1.18469E-16
Cabbage	4.86885E-03	calc not required	1.13262E-16
Carrot	7.38094E-03	calc not required	1.54805E-05
Leafy salads	3.25677E-03	calc not required	2.11912E-17
Onion	3.69474E-03	calc not required	1.10579E-05
Potato	4.41616E-02	calc not required	8.51957E-05

19 Select a value for SEI_{veg} from this table for the contaminant of concern, depending on your choice of land use and toxicological endpoint

Landuse	SEI_{veg} (kg soil per kg body weight per day)
Residential with plant uptake	1.00210E-05
Allotments	1.00210E-05

SEI_{veg}= 1.00E-05 kg soil per kg body weight per day

20 The nominal assessment sub criterion for intake via consumption of homegrown vegetables is calculated using the formula: $ASC_{veg} = RI_{ingest}/SEI_{veg}$

ASC_{veg} = 4.00000E-01 (mg per kg body weight per day) / 1.00210E-05 (kg soil per kg body weight per day) = 39916.17603 mg per kg soil

Intake via Ingestion of Soil Attached to Vegetables

21 This pathway only applies to two land uses: residential with plant uptake and allotments. For other land uses go directly to paragraph 25.

22 Select a value for $SEI_{indirect}$ from this table, depending on your choice of land use

Land Use	$SEI_{indirect}$ (kg soil per kg body weight per day)
Residential with plant uptake	1.12723E-06
allotments	1.12723E-06

$SEI_{indirect}$= 1.1272E-06 kg soil per kg body weight per day

23 Is site specific data on the bioaccessibility of the contaminant in soil available? (Y or N) — n

Insert the representative fraction here (default=1)

The amended $SEI_{indirect}$ = $SEI_{indirect}$ * bioaccessibility fraction — 1.12723E-06 kg soil per kg body weight per day

24 The nominal assessment sub criterion for intake via indirect soil ingestion using the formula: $ASC_{indirect} = RI_{ingest}/SEI_{indirect}$

$ASC_{indirect}$ = 4.00000E-01 (mg per kg body weight per day) / 1.12723E-06 (kg soil per kg body weight per day) = 354852.1597 mg per kg soil

Intake via Inhalation of Outdoor Air

25 This pathway only applies to substances with H' greater than or equal to 10^{-3}.
To use the formulae for inhalation of outdoor air, the following site parameters are required:

Source Area

Source zone width parallel to wind direction	W=	10	metres
Depth to subsurface contamination	d_z=	0.3	metres

Soil Matrix

Soil organic matter content	SOM=	2	%
Mass fraction of organic carbon in soil	f_{oc}=	2	/167 = 1.19760E-02 kg OC per kg soil
Air filled porosity	θ_{vap}=	0.31	unitless
Water filed porosity	θ_{wat}=	0.15	unitless
Total porosity	θ_{total}=	0.46	unitless
Bulk soil density	ρ=	1.6	kg soil per l soil

Contaminant

Organic carbon/water partition coefficient	K_{oc}=	1.00E+09	l water per kg OC
Dimensionless Henry's constant	H'=	6346.08649	l water per l air
Diffusion coefficient in water	D_{wat}=	1.00E-09	m^2 per s
Diffusion coefficient in soil air	D_i=	1.00E-05	m^2 per s
Air in soil		9.52847E-02	unitless
Water in soil		8.47465E-03	unitless
Air term		9.52847E-07	m^2 per s
Water term		1.33541E-15	m^2 per s per (l water per l air)
Effective diffusion coefficient	D_{eff}=	9.52847E-07	m^2 per s
Molecular weight	MW=	270	g per mol
Saturated vapour pressure	SatVP	0.000836	mmHg

Pathway parameters

Dilution ratio	DR=	20000	unitless
Temperature	Temp=	20	°C + 273 = 293 K
Ambient air velocity in the mixing zone (default from CLEA is 3 m per s)	V_{air}=	3	m per s

Receptor characteristics

Time-averaged body height TAH= 0.93 m

Height of mixing zone h= 0.93 /2 = 0.465 m

26 **Contaminant Volatilisation Factor (CVF)**

CVF= 1.20633E-08 kg soil per l air

27 **Time-Averaged Air Intake Outdoors**

Landuse	TAAIoutv m^3 air per (kg body weight per day)
Residential with plant uptake	7.27421E-02
Residental without plant uptake	7.27421E-02
Allotments	1.55763E-02
Commercial/Industrial	6.45534E-03

Insert the appropriate $TAAI_{outv}$ here 7.27E-02 m^3 air per (kg body weight per day)

28 **Soil equivalent Intake**

Calculate the soil equivalent intake for inhalation of outdoor air
using the formula: $SEI_{outv} = TAAI_{outv} \times CVF \times 1000$

8.77509E-07 kg soil per (kg body weight per day)

29 **Nominal Assessment Sub Criterion**

Calculate the nominal assessment sub-criteria for intake via outdoor air
using the formula: $ASC_{outv} = RI_{outv}/SEI_{outv}$

ASC_{outv} = 5.80000E-02 / 8.77509E-07 = 66096.17378 mg per kg soil

mg per kg body weight per day; kg soil per kg body weight per day

Intake via Inhalation of Indoor Air

30 **Indoor inhalation of vapour**

This pathway **only** applies to substances with dimensionless Henry's constant **equal to or greater than 10^{-3}** and to the following land-use scenarios:
Residential with plant uptake, Residential without plant uptake, Commercial/industrial

31 **Time-averaged air intake indoors**

Landuse	$TAAI_{inv}$ m3 air per (kg body weight per day)
Residential with plant uptake	2.78379E-01
Residential without plant uptake	2.78379E-01
Commercial/industrial	4.34795E-02

Insert the appropriate $TAAI_{inv}$ here [ ] m^3 air per (kg body weight per day)

32 **Soil Factor**

Soil Factor is calculated using the formula $SF=K_{oc} \times f_{oc}/H'$ — SF= 1887.154851 l air per kg soil

33 **Soil vapour partition coefficient**

The soil vapour partition coefficient (SVPC) is — SVPC= 0.000529844 kg soil per l air

34 The soil equivalent intakes for inhalation of indoor air is calculated
using the formula: $SEI_{inv} = (TAAI_{inv} \times 1000 \times SVPC)/DR$ — SEI_{inv}= 0.00000E+00 kg soil/(kg body weight per day)

35 The nominal assessment sub criterion for intake via indoor air is calculated
using the formula: $ASC_{inv} = RI_{inv}/SEI_{inv}$

ASC_{inv} = 5.80000E-02 (mg per kg body weight per day) / 0.00000E+00 (kg soil per kg body weight per day) = #DIV/0! mg per kg soil

36 **Saturated vapour concentration**

Saturated vapour concentration is calculated using the formula
$C_{sat} = (SatVP \times MW \times 10^9)/(760mmHg \times R \times Temp)$ — C_{sat}= 1.23526E+04 mm Hg.g per mol

37 **Equilibrium contaminant concentration in soil vapour**

Equilibrium contaminant concentration in soil vapour
is calculated using the formula $C_{sv} = ASC_{inv} \times SVPC$ — C_{sv}= #DIV/0! mg per l air

38 Saturated vapour concentration compared to the equilibrium
contaminant concentration in soil vapour: C_{sv} / C_{sat} — C_{sv}/C_{sat}= #DIV/0! (mg per l air) per (mm Hg.g per mol)

If the ratio is greated than 1, Level 1 risk assessment is not appropriate. It should be noted for further
site-specific risk assessment that a C_{sv}/C_{sat} ratio greater than 1 may indicate the presence of a free product.

Integrated site specific assessment criteria (SSAC) for substances with dimensionless Henry's constant greater than or equal to 10^{-3}

soil ingestion pathway	$1/ASC_{ding}$=	1/ 40595.98973	=	2.46330E-05	kg soil per mg
homegrown vegetable consumption pathway	$1/ASC_{veg}$=	1/ 39916.17603	=	2.50525E-05	kg soil per mg
ingestion of soil attached to vegetables	$1/ASC_{indirect}$=	1/ 354852.1597	=	2.81808E-06	kg soil per mg
inhalation of outdoor air	$1/ASC_{outv}$=	1/ 66096.17378	=	1.51295E-05	kg soil per mg
inhalation of indoor air	$1/ASC_{inv}$=	1/ #DIV/0!	=	#DIV/0!	kg soil per mg

The integrated Site Specific Assessment Criterion (SSAC)

39 For the residential with plant uptake land use the $SSAC_{rwp}$ = mg per kg soil

40 For the allotments land use the $SSAC_{alt}$ = 14785.67743 mg per kg soil

41 For the residential without plant uptake land use the $SSAC_{other}$ = mg per kg soil

For the commercial/industrial land use the $SSAC_{other}$= mg per kg soil

42 The Level 1 Site Specific Assessment Criterion for **iphatic >C16 - C** in the **Allotments** scenario is 14785 mg per kg soil

Integrated site specific assessment criteria for substances with dimensionless Henry's constant less than 10^{-3}

soil ingestion pathway	$1/ASC_{ding}$=	1/	=		kg soil per mg
homegrown vegetable consumption pathway	$1/ASC_{veg}$=	1/	=		kg soil per mg
ingestion of soil attached to vegetables	$1/ASC_{indirect}$=	1/	=		kg soil per mg

The integrated Site Specific Assessment Criterion

43 For the residential with plant uptake land use the $SSAC_{rwp}$ = mg per kg soil

For the allotments land use the $SSAC_{alt}$ = mg per kg soil

For the residential without plant uptake land use the $SSAC_{other}$ = mg per kg soil

For the commercial/industrial land use the $SSAC_{other}$= mg per kg soil

The Level 1 Site Specific Assessment Criterion for **liphatic >C16 - C2** in the scenario is mg per kg soil

Risk Evaluation

44 Justify your use of the defaults on the worksheet and characterise the risk associated with the site.
Include the following:

	Justification provided (Y or N)
i. Choice of Relevant Health Criteria value	
ii. Site use (current and intended), comment on compatibitility with land use selected	
iii. Critical Receptor	
iv. Pathways included/omitted (including bioaccessibility if used)	
v. Soil Parameters, e.g. pH	

SNIFFER Method - Organics

Project Ref: 51-241 **Run No: 1**

1 This worksheet may be used for organic contaminants

2 This worksheet has been completed by Jolene Turner on 12/11/2005

and has been checked by on

3 It relates to Aliphatic >C21 - C34 found at Galmoy Mine

INGESTION PATHWAYS

Toxicology for Ingestion Pathways

4a Is the substance a non threshold substance? (Yor N) n

5a Insert the relevant health criterion for ingestion 2.00E+00 mg per kg body weight per day
For a non threshold substance the relevant health criterion is the Index Dose (ID).
For threshold substances the relevant health criterion is the Tolerable Daily
Intake (TDI).

Land Use

6a The Table below lists the default exposure durations and averaging times, used in the method for standard land uses.
Please insert Y to indicate your choice of land use and acceptance of the default assumptions.

Land Use	Exposure duration (years)		Averaging time (days)	
Residential with plant uptake	0-6		2190	
Residential without plant uptake	0-6		2190	
Allotments	0-6	y	2190	y
Commercial/industrial	16-59		15695	

Background Exposure for Ingestion

7a Insert Mean Daily Intake (MDI) from non-soil sources
(If the contaminant is a non threshold substance insert zero) | [ ] mg per day

Is the MDI equal to or greater than 80% of the TDI or is the MDI unkown? (Y or N) | y

8a Because the MDI for children is lower than that for adults, the MDI will need to be corrected by a Childhood Factor (CF)
which depends on exposure duration. Insert the appropriate factor here:

Exposure duration (years)	Childhood Factor (ingestion)
0-6	0.485
16-59	1

0.485

Receptor Body Weight

9a Insert the Time-Averaged (female) Body Weight (TABW) depending on the chosen exposure duration

Exposure duration (years)	TABW
0-6	11.15
16-59	46.4

11.15 kg body weight

Reference Intake for Ingestion

10a For non threshold substances the Reference Intake (RI) for the ingestion pathway is calculated
using the formula: RI_{ingest}=ID | [ ] mg per kg body weight per day

For threshold substances the Reference Intake (RI) for ingestion pathways is calculated
using the formula: RI_{ingest}=(TDI-((MDI/70x46.4)xCF)/TABW)[a] | [ ] mg per kg body weight per day

[a] Note - The background component is in line with the approach in CLR 9, namely that the MDI is corrected by the relevant adult body weight.

For threshold substances where the background exposure (MDI) is greater than or equal to 80%
of the TDI, or the MDI is unknown, the Reference Intake (RI) for ingestion pathways is calculated
using the formula: RI_{ingest}=0.2TDI | 0.4 mg per kg body weight per day

INHALATION PATHWAYS

Toxicology for Inhalation Pathways

4b Is the substance a non threshold substance. (Yor N) | n

5b Insert the relevant health criterion for inhalation | 2.90E-01 mg per kg body weight per day
For a non threshold substance the relevant health criterion is the (indicative) Index Dose (ID).
For threshold substances the relevant health criterion is the Tolerable Daily
Intake (TDI).

Land Use

6b The Table below lists the default exposure durations and averaging times, used in the level 1 methodology for standard land uses.
Please insert Y to indicate your choice of land use and acceptance of the default assumptions.

Land Use	Exposure duration (years)		Averaging time (days)	
Residential with plant uptake	0-6		2190	
Residential without plant uptake	0-6		2190	
Allotments	0-6	y	2190	y
Commercial/industrial	16-59		15695	

Background Exposure for inhalation

7b Insert Mean Daily Intake (MDI) from non-soil sources
(If the contaminant is a non threshold substance insert zero)

[ ] mg per day

Is the MDI equal to or greater than 80% of the TDI or is the MDI unknown? (Y or N)

y

8b Because the MDI for children is lower than that for adults, the MDI will need to be corrected by a Childhood Factor (CF)
which depends on exposure duration. Insert the appropriate factor here:

Exposure duration (years)	Childhood Factor (inhalation)
0-6	0.362
16-59	1

0.362

Receptor Body Weight

9b Insert the Time-Averaged (female) Body Weight (TABW) depending on the chosen exposure duration

Exposure duration (years)	TABW
0-6	11.15
16-59	46.4

11.15 kg body weight

Reference Intake for Inhalation

10b For non threshold substances the Reference Intake (RI) for the inhalation pathway is calculated using the formula: RI_{inhal}=ID — [ ] mg per kg body weight per day

For threshold substances the Reference Intake (RI) for ingestion pathways is calculated using the formula: RI_{ingest}=(TDI-((MDI/70x46.4)xCF)/TABW)[a]

[a] Note - The background component is in line with the approach in CLR 9, namely that the MDI is corrected by the relevant adult body weight. — [ ] mg per kg body weight per day

For threshold substances where the background exposure (MDI) is greater than or equal to 80% of the TDI the Reference Intake (RI) for inhalation pathways is calculated using the formula: RI_{inhal}=0.2TDI — 0.058 mg per kg body weight per day

Pathway Check

11 The relevant pathways for calculating Site Specific Assessment Criteria depend on the land-use scenarios and the relative tendency of a substance to exist as vapour molecules as opposed to being dissolved in water, as expressed in Henry's Law constant.

Is the dimensionless Henry's constant H' greater than or equal to 10^{-3}? (Yor N)
If the answer is Y, include vapour inhalation pathways. If it is N, do not. — y

Intake via Soil and Dust Ingestion

12 Select a value for SEI_{ding} from this table, depending on your choice of land use

Land Use	SEI_{ding} (kg soil/kg body weight/day)
Residential with plant uptake	9.85319E-06
Residential without plant uptake	9.85319E-06
Allotments	9.85319E-06
Commercial/Industrial	5.43222E-07

SEI_{ding} = 9.85E-06

13 Is site specific data on the bioaccessibility of the contaminant in soil available? (Y or N) — n

If Y insert the representative fraction here (default=1) — [ ]

The amended SEI_{ding} = SEI_{ding} * bioaccessibility fraction — 9.85319E-06 kg soil per kg body weight per day

14 The nominal assessment sub criterion for intake via soil and dust ingestion is calculated using the formula: $ASC_{ding} = RI_{ingest}/SEI_{ding}$

ASC_{ding} = 4.00000E-01 mg per kg body weight per day / 9.85319E-06 kg soil per kg body weight per day = 40595.98973 mg per kg soil

Intake via Consumption of Homegrown Vegetables

15 This pathway only applies to two land uses: residential with plant uptake and allotments. For other land uses go directly to question 25 .
Select the basis for the Concentration Factor from **16 or 17** below. Select **one** option only

16 Are measured site specific Concentration Factors for leafy and root plant uptake of organics available? (Yor N) n

Measured Concentration Factor for leafy vegetables ug per g (dry or fresh)[a] weight plant per ug per g dry weight soil

Measured Concentration Factor for root vegetables ug per g (dry or fresh)[a] weight plant per ug per g dry weight soil

[a] Note - See 18 below

17 Where measured site specific Concentration Factors are not available the following formulae can be used to calculate Concentration Factors for leafy and root vegetable uptake of organics using the Briggs and Ryan approach.

To use the formulae for plant uptake of organics the following data are required:

a representative value for K_{ow} (octanol/water partition coefficient) 1.00E+10 l water per l octanol

a representative value of ϕ (soil density) 1.6 g dry weight per cm^3

a representative value of K_{oc} (organic carbon-water partition coefficient) : 1.00E+09 cm^3 per g dry weight

a representative value of f_{oc} (fraction of organic carbon in soil) : 0.012 kg OC per kg soil

a representative value of θ (soil-water content by volume) 0.1 cm^3 per cm^3

For leafy vegetables $CF_{leafy} = (0.784*10^{-0.434*(logKow-1.78)^{\wedge}2/2.44}*(10^{0.95logKow-2.05}+0.82)*(\phi/(\theta+\phi K_{oc}f_{oc}))$

CF_{leafy}= 1.76531E-12 [b] ug per g fresh weight plant per ug per g dry weight soil

For root vegetables $CF_{root}=(10^{0.77logKow-1.52}+0.82)*(\phi/(\theta+\phi K_{oc}f_{oc}))*0.01$

CF_{root}= 0.001261302 [b] ug per g fresh weight plant per ug per g dry weight soil

[b] Note - If the soil correction factor ($\phi/(\theta+\phi K_{oc}f_{oc})$) is greater than 1 a default value of 1 is used.

18 For calculation of the SEI_{veg} the units for CF_{leafy} and CF_{root} must be ug per g fresh weight plant over ug per g dry weight soil.
It may be necessary to use a dry weight conversion factor when using **measured** CF values.
Is a dry weight conversion required? (Y or N) n

Calculation of SEI_{veg}
The Time Averaged Vegetable Consumption Rate for homegrown vegetables is given in the Table below.

Vegetable Type	TAVCR (kg FW/day)	TAVCR*HF*CF*DW	TAVCR*HF*CF
Brussel sprouts	5.04750E-03	calc not required	5.62578E-15
Cabbage	4.86885E-03	calc not required	5.37851E-15
Carrot	7.38094E-03	calc not required	3.79702E-06
Leafy salads	3.25677E-03	calc not required	1.00631E-15
Onion	3.69474E-03	calc not required	2.71227E-06
Potato	4.41616E-02	calc not required	2.08966E-05

19 Select a value for SEI_{veg} from this table for the contaminant of concern, depending on your choice of land use and toxicological endpoint

Landuse	SEI_{veg} (kg soil per kg body weight per day)
Residential with plant uptake	2.45793E-06
Allotments	2.45793E-06

SEI_{veg}= 2.46E-06 kg soil per kg body weight per day

20 The nominal assessment sub criterion for intake via consumption of homegrown vegetables is calculated using the formula: $ASC_{veg} = RI_{ingest}/SEI_{veg}$

ASC_{veg} = 4.00000E-01 (mg per kg body weight per day) / 2.45793E-06 (kg soil per kg body weight per day) = 162738.5646 mg per kg soil

Intake via Ingestion of Soil Attached to Vegetables

21 This pathway only applies to two land uses: residential with plant uptake and allotments. For other land uses go directly to paragraph 25.

22 Select a value for $SEI_{indirect}$ from this table, depending on your choice of land use

Land Use	$SEI_{indirect}$ (kg soil per kg body weight per day)
Residential with plant uptake	1.12723E-06
allotments	1.12723E-06

$SEI_{indirect}$= 1.1272E-06 kg soil per kg body weight per day

23 Is site specific data on the bioaccessibility of the contaminant in soil available? (Y or N) n

Insert the representative fraction here (default=1)

The amended $SEI_{indirect}$ = $SEI_{indirect}$ * bioaccessibility fraction 1.12723E-06 kg soil per kg body weight per day

24 The nominal assessment sub criterion for intake via indirect soil ingestion using the formula: $ASC_{indirect} = RI_{ingest}/SEI_{indirect}$

$ASC_{indirect}$ = 4.00000E-01 (mg per kg body weight per day) / 1.12723E-06 (kg soil per kg body weight per day) = 354852.1597 mg per kg soil

Intake via Inhalation of Outdoor Air

25 This pathway only applies to substances with H' greater than or equal to 10^{-3}.
To use the formulae for inhalation of outdoor air, the following site parameters are required:

Source Area

Source zone width parallel to wind direction	W=	10	metres	
Depth to subsurface contamination	d_z=	0.3	metres	

Soil Matrix

Soil organic matter content	SOM=	2	%	
Mass fraction of organic carbon in soil	f_{oc}=	2	/167	1.19760E-02 kg OC per kg soil
Air filled porosity	θ_{vap}=	0.31	unitless	
Water filed porosity	θ_{wat}=	0.15	unitless	
Total porosity	θ_{total}=	0.46	unitless	
Bulk soil density	ρ=	1.6	kg soil per l soil	

Contaminant

Organic carbon/water partition coefficient	K_{oc}=	1.00E+09	l water per kg OC
Dimensionless Henry's constant	H'=	6346.08649	l water per l air
Diffusion coefficient in water	D_{wat}=	1.00E-09	m^2 per s
Diffusion coefficient in soil air	D_i=	1.00E-05	m^2 per s
Air in soil		9.52847E-02	unitless
Water in soil		8.47465E-03	unitless
Air term		9.52847E-07	m^2 per s
Water term		1.33541E-15	m^2 per s per (l water per l air)
Effective diffusion coefficient	D_{eff}=	9.52847E-07	m^2 per s
Molecular weight	MW=	270	g per mol
Saturated vapour pressure	SatVP	0.000836	mmHg

Pathway parameters

Dilution ratio	DR=	20000	unitless	
Temperature	Temp=	20	°C + 273 =	293 K
Ambient air velocity in the mixing zone (default from CLEA is 3 m per s)	V_{air}=	3	m per s	

Receptor characteristics

Time-averaged body height	TAH=	0.93	m		
Height of mixing zone	h=	0.93	/2 =	0.465	m

26 **Contaminant Volatilisation Factor (CVF)**

CVF= 1.20633E-08 kg soil per l air

27 **Time-Averaged Air Intake Outdoors**

Landuse	TAAIoutv m^3 air per (kg body weight per day)
Residential with plant uptake	7.27421E-02
Residental without plant uptake	7.27421E-02
Allotments	1.55763E-02
Commercial/Industrial	6.45534E-03

Insert the appropriate $TAAI_{outv}$ here 1.56E-02 m^3 air per (kg body weight per day)

28 **Soil equivalent Intake**

Calculate the soil equivalent intake for inhalation of outdoor air
using the formula: $SEI_{outv} = TAAI_{outv} \times CVF \times 1000$

1.87901E-07 kg soil per (kg body weight per day)

29 **Nominal Assessment Sub Criterion**

Calculate the nominal assessment sub-criteria for intake via outdoor air
using the formula: $ASC_{outv} = RI_{outv}/SEI_{outv}$

ASC_{outv} =	5.80000E-02	/	1.87901E-07	=	308672.4372	mg per kg soil
	mg per kg body weight per day		kg soil per kg body weight per day			

Intake via Inhalation of Indoor Air

30 **Indoor inhalation of vapour**

This pathway **only** applies to substances with dimensionless Henry's constant **equal to or greater than 10^{-3}** and to the following land-use scenarios:
Residential with plant uptake, Residential without plant uptake, Commercial/industrial

31 **Time-averaged air intake indoors**

Landuse	$TAAI_{inv}$ m3 air per (kg body weight per day)
Residential with plant uptake	2.78379E-01
Residential without plant uptake	2.78379E-01
Commercial/industrial	4.34795E-02

Insert the appropriate $TAAI_{inv}$ here [ ] m^3 air per (kg body weight per day)

32 **Soil Factor**

Soil Factor is calculated using the formula $SF=K_{oc} \times f_{oc}/H'$ — SF= 1887.154851 l air per kg soil

33 **Soil vapour partition coefficient**

The soil vapour partition coefficient (SVPC) is — SVPC= 0.000529844 kg soil per l air

34 The soil equivalent intakes for inhalation of indoor air is calculated using the formula: $SEI_{inv} = (TAAI_{inv} \times 1000 \times SVPC)/DR$ — SEI_{inv}= 0.00000E+00 kg soil/(kg body weight per day)

35 The nominal assessment sub criterion for intake via indoor air is calculated using the formula: $ASC_{inv} = RI_{inv}/SEI_{inv}$

ASC_{inv} = 5.80000E-02 (mg per kg body weight per day) / 0.00000E+00 (kg soil per kg body weight per day) = #DIV/0! mg per kg soil

36 **Saturated vapour concentration**

Saturated vapour concentration is calculated using the formula
$C_{sat} = (SatVP \times MW \times 10^9)/(760mmHg \times R \times Temp)$ — C_{sat}= 1.23526E+04 mm Hg.g per mol

37 **Equilibrium contaminant concentration in soil vapour**

Equilibrium contaminant concentration in soil vapour is calculated using the formula $C_{sv} = ASC_{inv} \times SVPC$ — C_{sv}= #DIV/0! mg per l air

38 Saturated vapour concentration compared to the equilibrium contaminant concentration in soil vapour: C_{sv} / C_{sat} — C_{sv}/C_{sat}= #DIV/0! (mg per l air) per (mm Hg.g per mol)

If the ratio is greated than 1, Level 1 risk assessment is not appropriate. It should be noted for further site-specific risk assessment that a C_{sv}/C_{sat} ratio greater than 1 may indicate the presence of a free product.

Integrated site specific assessment criteria (SSAC) for substances with dimensionless Henry's constant greater than or equal to 10^{-3}

soil ingestion pathway	$1/ASC_{ding}$=	1/ 40595.98973	=	2.46330E-05	kg soil per mg
homegrown vegetable consumption pathway	$1/ASC_{veg}$=	1/ 162738.5646	=	6.14483E-06	kg soil per mg
ingestion of soil attached to vegetables	$1/ASC_{indirect}$=	1/ 354852.1597	=	2.81808E-06	kg soil per mg
inhalation of outdoor air	$1/ASC_{outv}$=	1/ 308672.4372	=	3.23968E-06	kg soil per mg
inhalation of indoor air	$1/ASC_{inv}$=	1/ #DIV/0!	=	#DIV/0!	kg soil per mg

The integrated Site Specific Assessment Criterion (SSAC)

39 For the residential with plant uptake land use the $SSAC_{rwp}$ = mg per kg soil

40 For the allotments land use the $SSAC_{alt}$ = 27147.68362 mg per kg soil

41 For the residential without plant uptake land use the $SSAC_{other}$ = mg per kg soil

For the commercial/industrial land use the $SSAC_{other}$= mg per kg soil

42 The Level 1 Site Specific Assessment Criterion for **iphatic >C21 - C** in the **Allotments** scenario is 27147 mg per kg soil

Integrated site specific assessment criteria for substances with dimensionless Henry's constant less than 10^{-3}

soil ingestion pathway	$1/ASC_{ding}$=	1/	=		kg soil per mg
homegrown vegetable consumption pathway	$1/ASC_{veg}$=	1/	=		kg soil per mg
ingestion of soil attached to vegetables	$1/ASC_{indirect}$=	1/	=		kg soil per mg

The integrated Site Specific Assessment Criterion

43 For the residential with plant uptake land use the $SSAC_{rwp}$ = mg per kg soil

For the allotments land use the $SSAC_{alt}$ = mg per kg soil

For the residential without plant uptake land use the $SSAC_{other}$ = mg per kg soil

For the commercial/industrial land use the $SSAC_{other}$= mg per kg soil

The Level 1 Site Specific Assessment Criterion for **liphatic >C21 - C3** in the scenario is mg per kg soil

Risk Evaluation

44 Justify your use of the defaults on the worksheet and characterise the risk associated with the site.
Include the following:

	Justification provided (Y or N)
i. Choice of Relevant Health Criteria value	y
ii. Site use (current and intended), comment on compatibitility with land use selected	y
iii. Critical Receptor	y
iv. Pathways included/omitted (including bioaccessibility if used)	y
v. Soil Parameters, e.g. pH	n

APPENDIX 6 : REVIEW OF TAILINGS MANAGEMENT FACILITY RESTORATION

Client: Galmoy Mines Ltd

REVIEW OF TAILINGS MANAGEMENT FACILITY RESTORATION

Prepared by:

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December 2005

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1.0 INTRODUCTION

EAEC Ltd has been commissioned by Arcon Mines Ltd to review, from an agronomic perspective, the rehabilitation, re-vegetation and subsequent management of the tailings management facility at Arcon's lead and zinc mine at Galmoy.

The assessment is part of an overall review of the mine closure and rehabilitation plan. The original plan was presented by Wardell Armstrong, Mining, Minerals, Engineering and Environmental Consultants in November 1992. It was updated in 2002/04 and is being updated further in 2005 as required by the terms of the IPC licence from the EPA.

EAEC Ltd is a multidisciplinary environmental and agricultural consultancy firm based in Portlaoise. The firm is established for more than ten years and has been involved in a wide range of projects in Ireland in that period.

2.0 BACKGROUND

Arcon Mines Ltd started production in 1997. Lead and zinc ore from underground workings is partially crushed underground and brought to the surface via a series of conveyors. The ore is milled and the lead and zinc is extracted separately in the mill by a floatation process. The crushed and extracted host rock ('tails'), namely calcium and magnesium carbonates, is pumped as a slurry to the tailings management facility (TMF) or mixed with cement and placed underground as backfill in mined stopes.

There are two tailings cells on the site. These are shown on map 1. The combined surface area of the cells is 23.5 ha. At this stage one cell is filled and the second one is at c.75% of capacity.

The mine closure plan referred to above, sets out a variety of afteruse options for the tailings cells. These are outlined in table 8.1 of that document. This table is appended as appendix 1. All options presented envisaged the establishment of a vegetative cover of some type on the tailings cells.

In the circumstances at the time the preferred rehabilitation option was described in section 8.3 of the document. An amenity/wildlife end use with the gradual establishment of woodland, scrub and open grassland outlines that option. In this scenario stockpiled topsoil would be spread on areas to be sown with trees while grassland would be established on the bare tailing surface, compound artificial fertiliser and or organic matter having first being applied to provide the N, P and K essential for grass growth.

The mine closure plan qualified this option with a comment to the effect that future technology and availability of materials, particularly soil forming materials, could offer other options for afteruse. In addition the closure plan advised that on site rehabilitation trials recommended in the document could alter afteruse proposals.

3.0 RATIONALE

Untreated bare tails as the raw growing medium presented to germinating seeds at the Galmoy tailings facility are a difficult environment. The moisture regime is subject to extremes of wetness and drought and the pH will cause difficulties for some plant species. There are macro nutrient deficiencies and there are high levels of some micro nutrients including lead and zinc.

Similar situations occur in nature; in for example, landscapes post glacial retreat and post volcanic activity. Natural processes such as weathering, oxidation and leaching initially permit pioneer vegetation, including lower plants and ruderal higher plants, to function in such hostile sites. These life forms initiate nutrient fixation, nutrient cycling and the gradual accumulation of organic matter. Eventually an embryonic soil develops on the site and successional species establish. The soil further develops ultimately permitting the establishment of a climax vegetation type (normally woodland) which is stable and very efficient in nutrient utilisation.

All terrestrial ecotypes are formed in this manner. Variables such as moisture, temperature and available nutrients will determine whether an ecotype is woodland or desert. Activity such as grazing by herbivores will prevent normal seral* progression to woodland and will retain the area as grassland.

A key factor in the soil formation process is time. The time period for the development of soil to a stage where it can sustain a vegetative cover will vary greatly depending on the nature of the parent material. In the case of the Galmoy tailings cells a non intervention rehabilitation strategy would result in an uncertain time period to full vegetative cover and consequent surface stability. It is therefore necessary to intervene to some degree to ensure environmental stability.

The grant of planning required and the mine closure plan recommended that on site rehabilitation trials be carried out in a pilot tailings cell prior to commencement of large scale rehabilitation work. This trial work has served to inform opinion on tailings rehabilitation and is outlined below.

**sere – one of a sequence of plant communities.*

4.0 REHABILITATION TRIALS

A number of case studies of successful re-vegetation of bare lead/zinc tailings are detailed in the mine closure plan. Considerable expertise has been accumulated particularly relating to grass species selection, seeding and sward management. Notwithstanding this corpus of knowledge, Arcon carried out on site re-vegetation trials in 2001 before undertaking any large scale re-vegetation of its tailings cells. These were carried out in a specially constructed pilot tailings cell which was constructed as a requirement of the parent planning permission.

Photo 1 - Pilot tailings Rehabilitation Cell

The availability of large volumes of soil forming material at that time influenced the focus of the trials from establishing grass on bare tailings to the establishment of grass on a soil/soil forming material overlying the tailings surface.

The trial work carried out is detailed in the Tailings Management Facility Trials Report produced by Arcon as part of its AER submission to the EPA. This report is appended in appendix 2. Briefly, 14, 5m x 2.5m plots were set out each with a tailings substrate in the autumn of 2001. One was permitted to dry in the open atmosphere and the remainder had the tailings covered with 100 to 150 mm of topsoil or topsoil/compost mixture.

Nine grass varieties with known tolerance characteristics appropriate to the particular tailings were selected and sown variously as mixtures or pure stands in the plots. The characteristics included: hardiness, ground cover and tillering* capacity, tolerance to heavy metals and tolerance to slightly acidic conditions. No fertiliser was applied to any of the trial plots.

All plots germinated but grass establishment was very poor on the bare tails plot. Complete failure was evident on the bare tails plot in spring 2002. It is important to note that this failure was to be expected given that no nutrient supplementation of the tails occurred. Establishment was good to excellent on all other plots.

Spring and autumn forage analyses of the plots have been carried out annually. Using comparative data from Teagasc and IAS it was found that nitrogen, phosphorous and potassium levels are generally within normal ranges. Lead levels have exceeded the expected normal range in one set of analyses but have otherwise fallen to within the normal range. Zinc levels in one set of analyses also exceeded the normal range in some of the plots. These data are included in full in appendix 3 of this report.

The trial plots are retained. Grass cover remains well established with no evidence of vegetation die-back on plots where soil was added. No natural regeneration has taken place on the bare, un-supplemented tails. The plots continue to be monitored and the vegetation is subject to spring and autumn sampling. The herbage is analysed for lead, zinc, nitrogen, potassium and phosphorus.

On the basis of this on site trial work Arcon established that:

- A soil /compost medium of at least 100 mm depth was required for establishment and maintenance of a grass sward of any agricultural merit,

- A grass mixture of red fescue - *festuca rubra* var. Merlin, and two bents - *agrostis tenuis*, var. Heriot, and *agrostis castellana* var. Highland, together with White Clover *trifolium repens* var. Aran is the optimum selection in terms of establishment, ground cover and heavy metal tolerance, and

- Establishment/natural regeneration of vegetative cover on un-supplemented bare tails is a long term process.

**tillering – the ability of grass to produce many shoots from the base of the original stalk*

5.0 REHABILITATION TO DATE

Having established from on site trial work the relative ease of establishment of a permanent, stable grass sward on tails covered with a minimum depth of soil/compost, Arcon considered the feasibility of treating phase 1 of the TMF in a similar manner.

Key criteria in assessing the feasibility were:

- The success of the method in the trials
- The success of the method at other similar sites
- The relatively straight forward methodology involved
- The availability of large volumes of soil and soil forming material
- The long term stability of a grass sward
- The low management requirement when established and
- The compatibility of grassland with the surrounding landscape and land use

Significant volumes of topsoil were stockpiled on site from the construction phase of the mining project. In addition large volumes of Black Spent Grains (BSGs) became available from the brewing industry as soil forming material. BSGs are essentially the carbon shell remaining of the malting barley grains after the malting process is completed. In the past disposal of the BSGs was by incorporation into agricultural soils as a soil conditioner.

The treatment of the BSGs in the malting process renders particular suitability for the use as a soil forming agent. The malting barley is heated to 240°C during the brewing process. The grain is essentially caramelised at this temperature and offers a very slow release of it's nutrients in the soil medium as a consequence.

Importation of BSGs onto the Arcon site for rehabilitation purposes was approved by the EPA. To date approximately 60,000 tonnes of the material have been utilised.

A number of other materials were used at minor volumes as soil formers. These were topsoil associated with BSG storage and lime treated sewage sludge.

In August 2003 Arcon commenced spreading soil and soil forming material on a completed section of phase 1 of the TMF. The soil medium was levelled, tilled and sown with the grass/clover mixture described on the previous page. These operations were carried out using light plant and conventional farm equipment. Germination and subsequent establishment of the sward has been excellent and on a par with germination and establishment in good agricultural soils. The photograph below shows the initial rehabilitation work on phase 1 of the TMF in May 2003. The grass mixture was sown the previous September. A light application of compound fertiliser was applied to the seedbed. Lush regrowth after cutting with excellent vegetation coverage is apparent in the photo.

Photo 2 – Initial grass establishment on the TMF – May 2003

To date almost 80% of the phase 1 of the TMF is covered with soil forming material. Approximately 2 hectares of the total area was seeded in July 2003. A further 3 hectares was sown in July 2005. Grass has germinated and is well established. The photograph below shows grass seeding in July 2005 with the established grass sown in 2003 in the background to the left of the picture.

An agronomic end use is envisaged for the grassed over tailings cells. Essentially this proposal amounts to light grazing with sheep in the period April to October annually. This end use effectively introduces the grass into the human food chain. Notwithstanding the small land area and the small volume of forage involved together with the dilution effect in the wider food supply, Arcon will initially establish that the nutrient value of the grass is safe and that the heavy metal values particularly in relation to cadmium, arsenic, lead and zinc fall within acceptable concentrations. Once established an ongoing monitoring programme will be put in place to ensure continued safety and sustainability.

Photo 3 – Grass seeding on the TMF – July 2005

6.0 SOIL AND FORAGE ANALYSIS

The fundamental approach taken to the analysis programme is to establish that:

- There are adequate nutrients to sustain a grass sward
- The pH is appropriate for grass growth
- The nutrients are available at safe levels
- Heavy metals known to occur in the tailings, specifically cadmium, arsenic, zinc and lead, are available at safe levels, and
- Changes over time are noted and addressed

Analysis of both soil and forage must be carried out to ascertain the levels of the various macro and micro nutrients in both. This is a critical point because a high level of a particular element in soil does not always follow to a similar high level in the plant tissue growing on that soil. This is because quite often elements are held in insoluble forms in the soil only becoming available to the plant root very slowly over time.

In addition to addressing nutrient availability, forage analysis needs to be carried out in spring and autumn to account for seasonal variation.

Spring and autumn forage analyses are available for the trial plots since summer of 2002. Forage data commencing in November 2003 are also available from part of the rehabilitated tailings area in Phase 1 of the TMF. These data are appended in appendix 4 and will be discussed below.

A further key consideration to be noted is ability of grazing animals to absorb materials from consumed forage and soil material ingested during grazing. To illustrate this point, the EPA in its Silvermines report states that only 1% of ingested cadmium is actually retained in the body tissues.

Physical and chemical analysis of the soil medium in selected trial plots and rehabilitated tailings area in Phase 1 of the TMF has recently been carried out.

The physical analysis comprised measurement of the soil medium depth, root activity and recording of colour/colour change in the profile. The specific details of each of the 17 profiles collected including a photographic record are included in appendix 5. The location of each profile collected on Phase 1 is noted on map 1.

In both the trial plots and rehabilitated tailings area a vigourous grass growth is evident on a sound, dry surface. Tillering and root activity are normal and invertebrate activity is apparent in the root zone. In essence the re-vegetated portion of the tailings of phase 1 looks like and produces as agricultural grassland.

A total of 14 soil cores were collected in the rehabilitated tailings. A further 3 soil cores were collected from 3 plots in the pilot tailings rehabilitation cell. All cores were collected in August 2005. The cores were extracted using a standard soil corer with a soil augur used to collect the bottom section. The depth of the core extracted varied between 55 and 80 cm but in most cases a significant depth of undisturbed tailings material underlying the soil forming material was collected.

It should be noted that the intensity of sampling carried out here is considerably greater than that carried out in conventional agricultural soil fertility assessment. Normal agronomic practice is to collect 30 to 40 separate soil cores in the root zone over an area of 3 to 5 ha, to amalgamate these and to analyse as one sample. This is considered the most practical approach to deal with localised variation.

In this situation each separate soil core (except the first one) was separated into 3 fractions. The A fraction corresponds to the root zone and ranged from 8 cm to 25 cm in depth. The B fraction is the interface zone between the soil medium and underlying tailings material. The

C fraction is the underlying and undisturbed tailings material.

There is considerable variation in the composition of the B layer primarily due to the uneven depth of cover of soil forming material. In some cases the B layer is entirely soil forming material, in other cases it is virtually all tailings material. Chemical analysis was carried out on cores with tailings dominated B layers.

In order to address the issue of nutrient availability to plant roots, as against total nutrient content, different analytical techniques were employed. To estimate the plant available nutrient status of the soil the A fraction and B fraction samples were analysed using the electro ultra filtration method (EUF).This process consists of extracting the nutrient with hot water and applying an electric current to the extraction cell. It is the standard method used for establishing available nutrient levels in agricultural soils.

The B and C fractions were subjected to acid digestion which determines the total metal content. The B and C fractions were also extracted with water to determine the solubility of nutrients in water.

The soil parameters analysed were: pH, organic nitrogen, nitrate, calcium, phosphorous, potassium, magnesium, manganese, zinc, molybdenum, arsenic, cadmium and lead. The ratio of organic nitrogen to nitrate was calculated.

The EUF extraction process was employed for all parameters including lead, zinc, molybdenum, arsenic and cadmium. These parameters are not normally considered limiting to plant growth.

All analyses to date have been carried out by IAS Ltd in Bagnalstown, Co Carlow. IAS Ltd is a Department of Agriculture and Food approved soils and forages analytical facility. It holds ISO 9002 quality approved status.

7.0 RESULTS

All results are presented as certificates of analysis in appendix 6.

From an agronomic perspective a standardised index system is utilised to evaluate the amount of available nutrient in the sample. At index 1 the amount of available nutrient is very low and the particular crop growing on the medium would benefit greatly from a defined high level of supplementation. At index 2 the available nutrient is low and a defined level of supplementation would benefit the crop. Index 3 levels indicate that a maintenance level of supplementation only is required to keep the nutrient level optimum. Index 4 indicates a high level of available nutrient with no supplementation required and index 5 points to a very high level of available nutrient.

It is important to note that intensive cropping and off-takes, in terms of meat and milk, deplete available soil nutrient levels over time. In agricultural systems this loss is counterbalanced by the application of organic and/or chemical fertiliser, by nutrient cycling, by nutrient fixation by soil micro organisms and by the slow release of nutrients from the soil organic matter.

Significant and localised variation in nutrient levels is found in soils. The practical manner in which this is addressed in conventional soil analysis is noted above. Similar localised variation can be expected in this situation. For this reason it is considered that mean parameter values are appropriate assessment values.

A very important criterion in the analysis of the 3 layers is to examine the relationship between each layer in terms of the possible upward migration of metals from fraction C, to fraction B, to fraction A. A brief summary of each fraction is set out below followed by an overview of the relationship between the 3 layers.

7.1 A Samples – Root Zone

The analytical results for each parameter measured in each soil sample are given in the Appendix 6. The results are outlined in summary form in Table 1 below. The mean is calculated for each parameter.

Table 1 – Summary of ‘A ‘Sample Results

Parameter Dry Matter Basis	Units	1a	2a	3a	4a	5a	6a	7a	8a	9a	10a	11a	12a	13a	14a	Mean
EUF																
Organic N (N Org)	mg/l	24	40	23	41	33	16	22	25	27	36	33	27	40	28	30
Nitrate (NO3)	mg/l	30	4	30	85	80	6	27	41	5	7	20	26	5	27	28
Ratio N(Org)/ NO3	Calc	0.8	9.3	0.8	0.5	0.4	2.8	0.8	0.6	4.9	5.3	1.6	1.1	7.4	1.0	2.7
Ca	mg/l	638	895	920	1639	1268	745	1376	1034	1053	1447	1324	1263	747	1134	1106
P	mg/l	35.9	38.5	31.7	25.6	48.2	25.6	22.2	39.6	31.0	29.5	24.5	20.2	24.8	31.3	30.6
P. (Morgans Eq.)	mg/l	23.0	24.6	20.5	16.8	30.4	16.8	14.8	25.3	20.1	19.2	16.2	13.6	16.4	20.3	19.9
K	mg/l	214	483	210	130	373	46	81	190	319	242	198	159	454	330	245
Mg	mg/l	146	242	206	222	320	305	453	343	185	204	272	361	240	350	275
Na	mg/l															
Mn	mg/l	4.2	19.0	5.5	0.7	1.1	1.6	2.0	6.2	18.1	8.0	4.6	5.6	6.4	6.4	6.4
Cu	ug/l															
Zn*	ug/l	313	1118	594	4473	587	6017	1538	1065	777	392	736	1120	635	682	1432
B	mg/l															
Mo*	ug/l	33	220	54	76	85	27	28	90	54	77	90	59	68	91	75
Organic Matter	%															
pH	pH Units	6.8	6.6	6.6	6.6	6.1	5.4	6.1	6.5	6.7	6.9	6.8	6.6	7.0	6.7	6.5
As	mg/l	0.44	0.54	1.28	3.34	0.88	2.23	2.19	2.38	0.91	0.86	1.82	2.54	1.46	2.80	1.69
Cd	ug/l	11	13	9	22	<10	21	<10	<10	<10	<10	<10	<10	<10	<10	
Pb	ug/l	52	70	77	2160	68	317	171	129	151	95	263	401	86	201	303

The mean pH is 6.5 with a range of 5.4 to 7.0. The major plant nutrients N, P and K have mean values at index 4 and index 5 levels. Similarly the mean values for the minor plant nutrients calcium, magnesium, manganese are found at index 4 and index 5 levels.

The results indicate a high state of fertility and demonstrate that the soil medium can readily sustain a grass sward.
The parameters analysed included four specifically associated with the mining activity at Galmoy. These are the metals: zinc, arsenic, cadmium and lead.

Table 2 below is derived from table 8.2 of the mine closure plan, soil guidance values from the CLEA 2002 publication and table 2.2 of the final report of the export group for Silvermines. It outlines the total concentrations of the various parameters for reclaimed mine spoil, guidance values for contaminants in residential land and average heavy metal concentrations in Irish pasture soils.

Table 2 – Guidance values for lead, zinc, cadmium and arsenic

Parameter	Reclaimed Mine Spoil Threshold mg/kg	CLEA soil guidance values mg/kg	Mean metal conc. in Irish pasture soils mg/kg
Lead	300	450	30
Zinc	1000		73
Arsenic	50	20	15.7
Cadmium		5 (at pH 7)	0.52

7.1.1 Lead

The average lead concentration available to plants is 303 ug/l by the EUF method. Based on the sample weight and the volume of extract used, the concentration of lead can be extrapolated into units of mg/kg. This corresponding value is 10.9 mg/kg. This value is considerably lower than any of the reference values above. It is noted that the total soil lead concentration threshold value set by the EPA in its Silvermines report below which no intervention is deemed necessary is 1000 mg/kg.

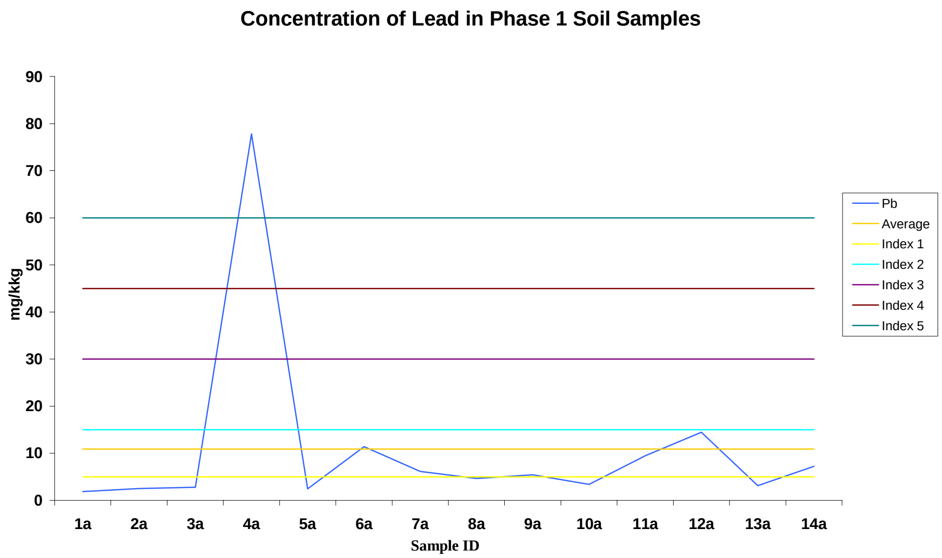

Figure 1 – Concentration of Lead in Phase 1 Soil Samples

7.1.2 Zinc

The mean plant available zinc is 1432ug/l by the EUF method which is index 4. By extrapolation this corresponds to 51.5 mg/kg of soil. This value is quite close to the Irish average value for pasture soils. It should be noted that the EPA considers that no intervention was required where total zinc levels of 8500 mg/kg were found in soils in the Silvermines. The reason stated for non intervention was that grazing animals have a very high tolerance to zinc.

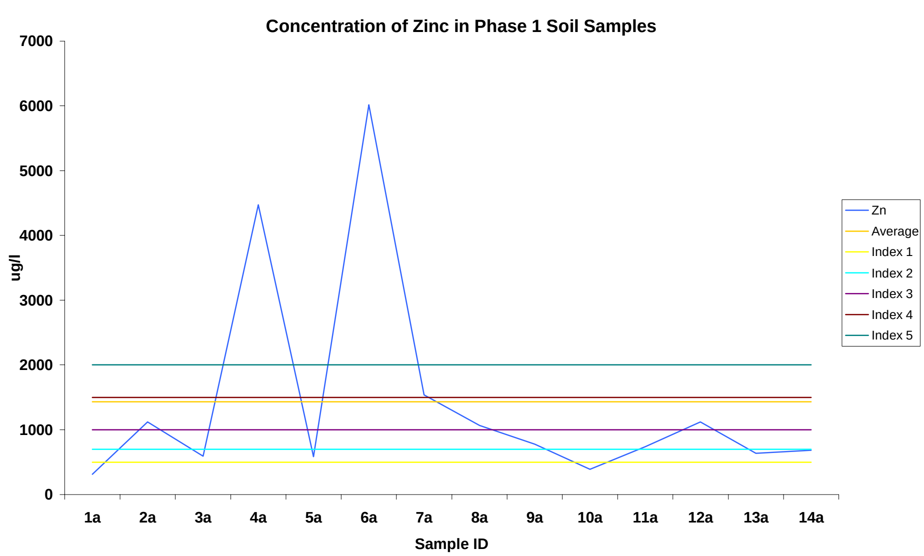

Figure 2 – Concentration of Zinc in Phase 1 Soil Samples

7.1.3 Arsenic

The mean plant available arsenic is 1.69 mg/l. This corresponds to a soil value of 60.8 mg/kg. This value exceeds the guidance values given in table 2 above. The value is not readily explained and requires further investigation. However the EPA Silvermines report, using an arsenic value of 100 mg/kg, estimates that such a level would contribute less than a 1% toxic arsenic dose. The report further notes that animals develop a tolerance to arsenic over time. It concludes that adverse impacts on animal health due to arsenic levels of this degree are unlikely.

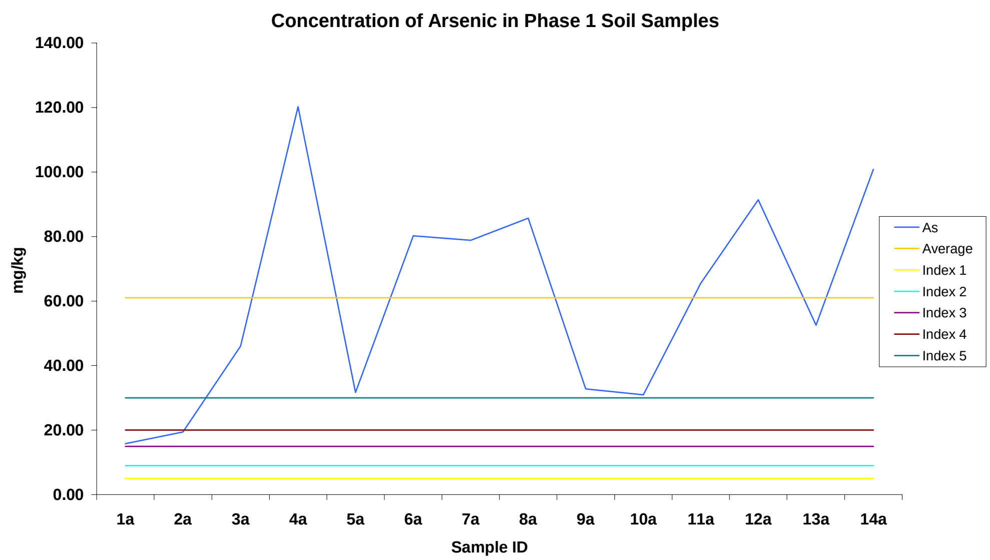

Figure 3 – Concentration of Arsenic in Phase 1 Soil Samples

7.1.4 Cadmium

The majority of cadmium values are below the level of detection. The maximum value obtained was 22ug/l which corresponds to 0.79 mg/kg. This value is above the average Irish pasture value but significantly below the CLEA value. The values are graphically illustrated below.

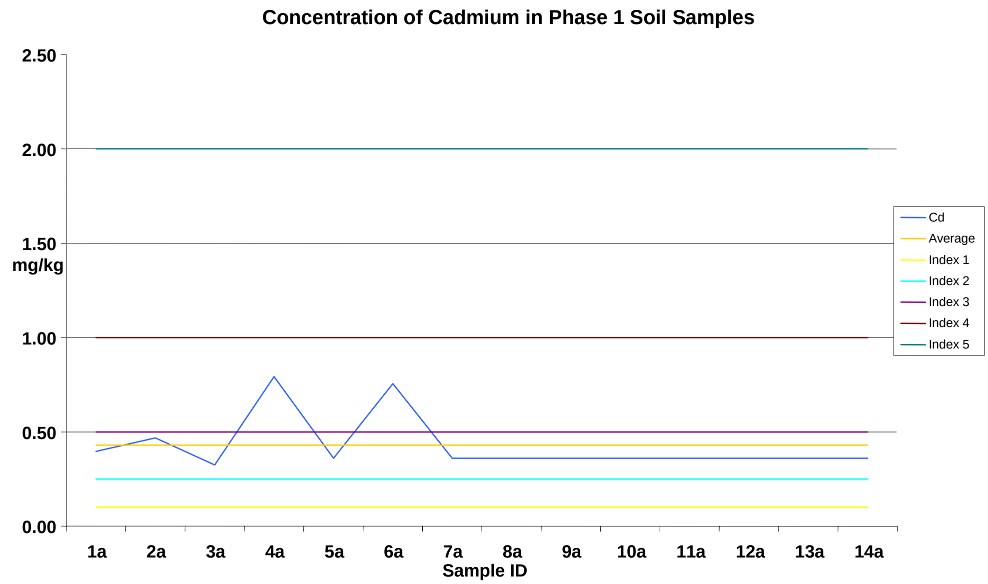

Figure 4 – Concentration of Cadmium in Phase 1 Soil Samples

7.2 B Samples – Second Layer

Because of the variability in depth of the soil forming material the composition of the second layer is not uniform. Samples 6, 7 and 8 comprised tails. Where the dominant component was soil forming material an EUF extraction was carried out. Where tailings material occurred as the main sample component as in the case of samples 6, 7 and 8 an acid digestion was used. Acid digestion establishes the total amount of a particular metal present.

In some cases there was some mixing of the soil forming material and the tailings leading to exceptional results for some parameters. The determination of the extraction methodology employed for a particular sample was made by the laboratory based on visual/physical appearances. The results are set out in summary in table 3 below.

The average pH in the soil forming material was 5.8 with a range of 4.9 to 7.0. The major plant nutrients N, P and K mean values occur at index 4 and index 5 levels. Similarly the minor plant nutrients calcium, magnesium, manganese mean values are found at index 4 and index 5.

In the samples where soil forming material occurs pH is somewhat lower but adequate and a high state of fertility is generally noted across the major and minor nutrients.

Zinc is elevated above the A sample levels but at a mean value of 241.6 mg/kg it is within the guidance value. The elevation occurs because of possible tailings contamination.

Lead values are well below the guidance value.

Arsenic occurs at the same mean value as the A sample mean.

Cadmium is found at levels significantly below the guidance value.

Table 3 - Summary of B Sample Results

Parameter Dry Matter Basis	Unit	1b	2b	3b	4b	5b	9b	10b	11b	12b	13b	14b	Mean
EUF													
Organic N (N Org)	mg/l	98	38	41	19	14	77	74	85	28	90	75	58.1
Nitrate (NO3)	mg/l	4	5	4	58	53	1	1	1	2	2	2	12.1
Ratio N(Org)/ NO3	Calc	24.6	8.1	11.4	0.3	0.3	53.5	68.3	77	15.6	50	33.8	31.2
Ca	mg/l	1294	876	1485	2688	1399	1137	1249	1234	1590	1438	1128	1410.7
P	mg/l	37.4	11.9	42.5	3.6	13	19.8	17.3	56.9	25.2	16.2	44.9	26.2
P. (Morgans Eq.)	mg/l	23.9	8.6	27.0	3.7	9.3	13.4	11.9	35.7	16.6	11.2	28.4	17.2
K	mg/l	167	383	168	79	101	307	176	106	110	441	332	215.5
Mg	mg/l	209	338	236	343	244	161	256	320	259	381	422	288.1
Na	mg/l												
Mn	mg/l	16.8	23.8	7.0	2.4	4.8	34.3	8.5	18	4.6	21.8	6.3	13.5
Cu	ug/l												
Zn*	ug/l	8345	3686	635	26371	4744	4472	1287	11600	1656	10499	605	6718.2
B	mg/l												
Mo*	ug/l	69	108	211	112	43	82	86	88	112	73	93	97.9
Organic Matter	%												
pH	pH Units	5.2	4.9	6.5	7.0	6.0	4.9	5.5	5.5	6.5	5.3	6.9	5.8
As	mg/l	0.91	0.32	1.36	6.38	0.81	0.33	0.63	1.27	2.26	1.32	3.01	1.7
Cd	ug/l	24	21	<10	52	<10	18	12	20	11	36	<10	24.3
Pb	ug/l	676	221	149	8890	285	153	313	538	367	685	263	1140.0

Table 4 - Summary of C Sample Results

Sample ID	As	Ca	Cd	Cr	Fe	Hg	Mg	Ni	Pb	S	Zn
	mg/kg	%	mg/kg	mg/kg	%	mg/kg	%	mg/kg	mg/kg	%	%
3C	2195	19.71	30.9	60.6	5.46	<28.0	7.1	364	1111	11.72	2.53
4C	2524	19.44	20.3	68.4	7.65	<28.0	7.91	330	1219	15.34	1.79
5C	3289	19.73	30.5	82.4	8.2	<28.0	7.64	407	1163	17.39	2.65
6B	4294	17.33	44.8	74.7	10.14	<28.0	7.45	478	2090	16.29	3.83
6C	3569	20.87	41.8	75.3	8.28	<28.0	7.3	444	1383	16.29	3.92
7B	1940	20.79	23.9	54.7	4.78	<28.0	7.45	359	1478	10.47	1.64
7C	2695	18.48	32.7	69.7	6.47	<28.0	7.54	384	1518	12.17	2.66
8B	2401	20.75	54.8	59.2	5.5	<28.0	7.89	383	1677	13.1	4.75
8C	2711	19.52	53.2	62.1	6.22	<28.0	7.09	427	1933	12.64	4.73
11C	1956	14.38	53.3	73.6	6.72	<28.0	4.93	169	4671	13.47	1.91
12C	2281	18.77	50.8	60.4	5.62	<28.0	7.42	314	2388	12.93	3.95
13C	3888	18.26	36.7	72	8.3	<28.0	7.01	486	1467	17.17	3.45
14C	3852	17.73	53.7	72.3	8.91	<28.0	6.45	545	2314	15.94	4.61
15B	937	11.43	14.8	55	3.49	<28.0	2.88	188	920	9.03	0.81
15C	3132	19.01	30.7	63.1	5.74	<28.0	8.63	436	1585	15.04	2.73
16B	2584	19.22	36.6	64.5	7.3	<28.0	6.78	362	1368	13.22	2.84
6C	1834	20.04	29.1	57.1	5.05	<28.0	7.22	288	991	11.66	2.38
17B	1280	13.4	15.8	57.6	4.42	<28.0	4.14	232	1002	10.57	0.93
17C	2939	19.3	30.4	60.5	6.22	<28.0	7.95	413	1697	14.37	2.51
Av	**2647.42**	**18.32**	**36.04**	**65.43**	**6.55**		**6.88**	**368.89**	**1682.89**	**13.62**	**2.87**

7.2.1 C Samples – Tailings

A summary of results for the C samples are presented in table 4 below.

Generally plant nutrients are lacking and are inadequate to permit establishment of a grass crop. As is to be expected the various metals occur at concentrations consistent with tailings. However the high pH (usually in excess of 8.0) of the tailings material is expected to maintain the metals in insoluble forms. In addition rainfall at Galmoy exceeds evaporation making the likelihood of upward mobility of metals low.

7.2.2 A, B and C Sample Overview

The analytical results of the root zone (A layer) demonstrates that this medium is of high fertility and sufficient to maintain a grass sward.

The B layer exhibits similar fertility in most cases.

The C layer was confirmed as tails.

Heavy metals were not found to occur in the A layer at concentrations considered to pose a risk to animal health. Neither is upward movement of metals through the profile noted.

This assessment is validated by the analytical results of samples 15, 16 and 17 taken from the trial plots which were established in 2001. Despite a relatively shallow soil cover on the trial plots the results are broadly similar with no upward migration of heavy metals noted. In addition a healthy and vigourous grass sward is apparent on these plots.

7.2.3 Forage/Grass Analysis

Analysis of fresh and conserved forage grown on trial plots and the rehabilitated tailings cell has been carried out on an ongoing basis initially commencing on the trial plots in July 2002 and on the tailings cell in November 2003.

Plant levels of nitrogen, phosphorous and potassium together with lead and zinc were evaluated. The following table details the results of the aforementioned parameters in the grass from trial cell and from the grassed over portion of phase 1 of the tailing management facility.

Table 5 - Trial Cells & TMF Grass Sample Forage Analyses Results					
Analysis					
Lead					
units mg/kg dry matter					
Sampling date	**Trial Cell 5**	**Trial Cell 8**	**Trial Cell 11**	**TMF Phase 1a**	**TMF Phase 1b**
Jul-02	4.9	4.9	3.5		
Early - 03	13.7	37.1	35.5		
Nov-03	4.1	11.4	7.4	15.6	16.3
Apr-04	13.4	29.3	28.2	26.3	14.8
Oct-04	7	8.9	15.8	6.1	3.8
Apr-05	12.5	23.2	36.4	6.2	3.9
Oct-05	7.7	8.7	10.6	6.3	9.4
Zinc					
units mg/kg dry matter					
Sampling date	**Trial Cell 5**	**Trial Cell 8**	**Trial Cell 11**	**TMF Phase 1a**	**TMF Phase 1b**
Jul-02	44	115.7	75.2		
Early - 03	97.9	783.2	450.9		
Nov-03	46.1	359.4	146.4	190	257.6
Apr-04	93.1	485.6	357.6	249.2	100.4
Oct-04	35.2	126.6	119.1	69.2	89.7
Apr-05	66.1	226.6	211.6	275.4	64.7
Oct-05	32.4	80.6	79.3	177.3	106.5
Total Nitrogen (%)					
	Trial Cell 5	**Trial Cell 8**	**Trial Cell 11**	**TMF Phase 1a**	**TMF Phase 1b**
Jul-02	2	1.2	2		
Early - 03	1.6	1.5	1.7		
Nov-03	2.7	2.4	2.2	2.4	2.7
Apr-04	2.7	2.4	2.8	3.2	2.3
Oct-04	1.5	1.7	1.5	3.1	3.1
Apr-05	2.3	1.8	1.7	3.2	2.6
Oct-05	1.9	1.8	1.9	3.5	3.4
Phosphorous (mg/kg)					
	Trial Cell 5	**Trial Cell 8**	**Trial Cell 11**	**TMF Phase 1a**	**TMF Phase 1b**
Jul-02	2647	1654	2235		
Early - 03	2589	2555	2602		

Nov-03	5309	5286	5123	6354	4988
Apr-04	4041	4276	4447	4062	3532
Oct-04	1836	3712	3270	3118	3921
Apr-05	3123	3941	3590	4685	3132
Oct-05	4734	6480	7147	5794	5495
Potassium (mg/kg)					
	Trial Cell 5	**Trial Cell 8**	**Trial Cell 11**	**TMF Phase 1a**	**TMF Phase 1b**
Jul-02	25094	11742	20276		
Early - 03	20428	13785	12131		
Nov-03	24062	19566	19792	21201	18154
Apr-04	21950	22356	24187	14684	22667
Oct-04	15874	15427	13772	28184	24124
Apr-05	15872	15033	18324	16916	18988
Oct-05	18745	24089	18927	26553	29977

The following points are noted in respect of these analyses.

- Some variation is to be expected through out the year reflecting plant growth rate.
- The results for nitrogen, phosphorous and potassium are in line with normal grass forage levels.
- Lead levels vary with plant growth activity but in all cases do not exceed the threshold of 40 ppm set in EU Directive 466/2001 on maximum levels for certain contaminants in animal feedstuffs.
- Zinc levels vary from 35.5 mg/kg to 783.2 mg/kg. High tolerances to zinc in animal diets are noted in the Silvermines report and problems are not anticipated there. Given the similar background levels at both locations a similar conclusion can be drawn here.

8.0 CONCLUSION AND RECOMMENDATIONS

Having observed the rehabilitation process, examined the grass sward and the soil forming material and having reviewed the chemical analyses generated from the soil and forage, a number of general points can be made in summary.

1. Grassland of agronomic merit has been established on trial plots and rehabilitated tailings at this location.

2. This grassland can be managed and maintained.

3. Low risks to grazing animals are apparent from the soil and forage analyses collected to date.

It is concluded that it is readily possible to establish and maintain a permanent grass sward on the Tailings Management Facility at Arcon Mines, Galmoy.

It is further concluded that low intensity (c.1.0 LU per Ha) grazing with sheep in the period April to October annually is a suitable and safe management practice. A grazing management system incorporating regular rotation of the sheep to non-tailings grazing during this period is advised.

These conclusions are made subject to the following recommendations:

1. All importation of soil forming materials/soil conditioners is subject to prior approval for that specific purpose by the EPA and is subject to compliance with national legislation.

2. A minimum soil forming material depth of 12.5 cm to be achieved at all locations.

3. The analysis programme to include arsenic and cadmium testing in the herbage.

4. Grass and clover mixtures of the following varieties to be used: *festuca rubra* var. Merlin, *agrostis tenuis* var. Heriot, *agrostis castellana* var. Highland and *trifolium repens* var. Aran. Change is varietal selection should only take place after an appropriate approved on site trial.

5. The preparation of a concise grassland management plan to address such issues as sustainable grazing levels, grazing periods, control of noxious weeds, fertilisation, repair of damaged areas, site management and responsible parties in the post mining phase.

6. The ongoing annual chemical and physical monitoring of the grass and grassland by an agronomist. This monitoring should include 2 annual physical inspections – one summer and one winter, annual soil analysis of the rooting layer at the rate of one composite sample per ha and biannual forage analyses – late spring and winter at the same rate. In addition a minimum 2% of grazed sheep should be subject to post mortem investigation for lead, zinc and arsenic accumulation in selected tissues. This annual monitoring should be reported to the local authority and the EPA.

7. It is not certain that a sufficient supply of soil forming material will be available to complete re-vegetation of the entire tailings management facility in the

manner reviewed. A series of site specific trials should be initiated as soon as possible to investigate re-vegetation of nutrient supplemented bare tailings. These trials should be independently reviewed and reported.

Signed: ________________

Andy Dunne M. Sc (Agr)

Date: 30th November 2005

References

Report of the Investigation into the Presence and Influence of Lead in the Silvermines area of Tipperary

Galmoy Mine Project, Co. Kilkenny, Ireland. *Mine Closure and Rehabilitation Plan Technical Report 10*

The Environmental Protection Agency. *Final report of Expert Group for Silvermines, County Tipperary. Lead and Other Relevant Metals*

An Foras Talúntais. National Soil Survey of Ireland*. Soils of Co. Laois*

APPENDIX 7 : LIFE OF MINE PLAN

GALMOY MINE LTD

Life of Mine Plan Updated 2005

		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	LOM
Mine/Mill																
Tonnes Milled	t 000s	410	371	579	543	548	660	660	641	680	720	720	720	720	713	8,685
Zinc	%Zn	10.43	11.31	11.34	10.37	10.27	10.05	11.27	12.90	13.40	13.68	13.68	13.68	13.68	13.68	12.31
Lead	%Pb	0.73	0.66	0.75	0.77	0.57	2.82	2.66	5.41	3.96	4.05	4.05	4.05	4.05	4.05	3.00
Concentrate																
Zinc	dmt 000s	61	66	104	90	88	102	119	134	149	167	167	167	167	165	1,744
Lead	dmt 000s	3	2	3	3	0	3	0	26	29	30	30	30	30	30	219
Total	dmt 000s	64	68	107	92	89	105	119	160	178	197	197	197	197	195	1,963
Total Tails	dmt 000s	347	303	472	450	459	555	542	482	502	523	523	523	523	518	6,722
Cumulative Tails	dmt 000s	347	649	1,121	1,571	2,031	2,586	3,127	3,609	4,111	4,634	5,157	5,681	6,204	6,722	
Backfill																
Backfill	dmt 000s				38	80	207	250	297	361	445	445	445	445	466	3,479
Cumulative Backfill	dmt 000s				38	118	325	575	872	1,233	1,678	2,123	2,568	3,013	3,479	
% Tails to Backfill Annual	%	0%	0%	0%	8%	17%	37%	46%	62%	72%	85%	85%	85%	85%	90%	52%
% Tails to Backfill Cumulative	%	0%	0%	0%	2%	6%	13%	18%	24%	30%	36%	41%	45%	49%	52%	
Underground																
Void Created	m3 000s	121	109	170	160	161	194	194	183	194	206	206	206	206	204	2,513
Cumulative Void	m3 000s	121	230	400	560	721	915	1,109	1,292	1,487	1,692	1,898	2,104	2,309	2,513	
Void Filled	m3 000s				23	49	128	154	183	223	275	275	275	275	288	2,148
Cumulative Void Filled	m3 000s				23	73	201	355	538	761	1,036	1,310	1,585	1,860	2,148	
% Void Filled Annual	%	0%	0%	0%	15%	31%	66%	79%	100%	115%	133%	133%	133%	133%	141%	85%
% Void Filled Cumulative	%	0%	0%	0%	4%	10%	22%	32%	42%	51%	61%	69%	75%	81%	85%	
Tailings Dams																
Tails to TMF	dmt 000s	347	303	472	412	379	348	292	185	140	79	79	79	79	52	3,243
	dmt 000s	347	649	1,121	1,533	1,913	2,261	2,552	2,737	2,877	2,956	3,034	3,113	3,191	3,243	
Phase 1	dmt 000s	347	303	472	204											1,325
Cumulative Tails to Phase 1	dmt 000s	347	649	1,121	1,325	Capacity 880m3 ~ 1320kt										
Phase 2	dmt 000s				208	379	348	292	185	140	79					1,631
Cumulative Tails to Phase 2	dmt 000s	Capacity 1170m3 ~ 1750kt			208	587	936	1,227	1,412	1,552	1,631					
Phase 3	dmt 000s											79	79	79	52	287
Cumulative Tails to Phase 3	dmt 000s	Capacity 777m3 ~ 1150t										79	157	236	287	
Phase 3 level	mAOD	Base 131.1mAOD, crest 143.0mAOD, average area 70,665m2										131.8	132.6	133.3	133.8	

APPENDIX 8 : FINANCIAL DETAILS AND ESTIMATES

GALMOY MINE PROJECT

1. ESTIMATED COST OF PLANNED CLOSURE : STAGE 1 MINE SITE CLOSURE & DEMOLITION

All costs in Є, excluding VAT

FACILITY DEMOLITION WORKS	Quantity	unit	Rate	Total Cost
STAGE 1: SURFACE				
Coarse Ore Stockpile Building & Drive Tower				
- Superstructure	1	item	45000	
- Substructure	1	item	9000	
- Conveyor from Mine Portal to Stockpile Building	1	item	25000	
- Associated M & E works	1	item	5000	
- Disposal of materials arising (excl concrete)	1	item	16000	100000
Concentrator / Mill Building				
- Concrete vats and plant	1	item	86000	
- Superstructure	1	item	29240	
- Substructure	1	item	8600	
- Associated M & E works	1	item	5160	
- Disposal of materials arising (excl concrete)	1	item	43000	172000
Backfill Thickener				
- 3.6m high concrete tank	1	item	9250	
- External exposed pipework and supports	1	item	4810	
- Gantries	1	item	5550	
- Substructures	1	item	8880	
- Associated M & E works	1	item	1110	
- Disposal of materials arising (excl concrete)	1	item	7400	37000
Lead Thickener Tank				
- Concrete Bund walls	1	item	7650	
- External exposed pipework and supports	1	item	10200	
- Steel tanks, vessels and gantries	1	item	17850	
- Substructures	1	item	5100	
- Associated M & E works	1	item	2550	
- Disposal of materials arising (excl concrete)	1	item	7650	51000
Pyrite Floatation				
- External exposed pipework and supports	1	item	5800	
- Steel tanks, vessels and gantries	1	item	11600	
- Substructures	1	item	2900	
- Associated M & E works	1	item	1450	
- Disposal of materials arising (excl concrete)	1	item	7250	29000
Zinc Thickener				
- Concrete Bund walls	1	item	5100	
- External exposed pipework and supports	1	item	6800	
- Steel tanks, vessels and gantries	1	item	12920	
- Substructures	1	item	3400	
- Associated M & E works	1	item	1700	
- Disposal of materials arising (excl concrete)	1	item	4080	34000
Leech Circuit				
- Concrete Bund walls	1	item	3000	
- External exposed pipework and supports	1	item	10500	
- Steel tanks and vessels	1	item	7500	
- Substructures	1	item	3000	
- Associated M & E works	1	item	1500	
- Disposal of materials arising (excl concrete)	1	item	4500	30000
Compressor Building				
- Superstructure	1	item	6500	
- Substructures	1	item	3250	
- Associated M & E works	1	item	650	
- Disposal of materials arising (excl concrete)	1	item	2600	13000
Metallurgy Lab				
- Superstructure	1	item	6500	
- Substructures	1	item	3250	
- Associated M & E works	1	item	650	
- Disposal of materials arising (excl concrete)	1	item	2600	13000
Reagent Buildings				
- Superstructure	1	item	15000	
- Substructures	1	item	7500	
- Associated M & E works	1	item	1500	
- Disposal of materials arising (excl concrete)	1	item	6000	30000
Explosives Storage	5	no		
- Concrete superstructures	1	item	37500	
- Substructures	1	item	10000	
- Associated M & E works	1	item	2500	50000
Fuel Tank	1	item	5000	5000
Surface Finishes (Disposal on Site)				
- Asphalt Surfacing 75mm Thick	684	m^3	11	7526
- Gravel/Crushed Stone Layers	5792	m^3	9	52131
- Hardstanding Area / Footpaths	989	m^3	16	15816
Removal and Disposal				
- Removal of reinforcement from concrete	1	item	30080	30080

FACILITY DEMOLITION WORKS	Quantity	unit	Rate	Total Cost
- Crushing of concrete and stockpiling	3174	m^3	8	26340
- Disposal of reinforcement from site	47	t	150	7050
REMOVAL OF ANCILLARY ITEMS AND SERVICES				
Pipework				
- Fresh Water Distribution	384	m	8	3072
- Fire Water Distribution	300	m	8	2400
- Potable Water Distribution	496	m	8	3968
- Sewage	100	m	8	800
- Storm Water from main buildings	280	m	8	2240
- Storm Water / foul water around mine site	3454	m	8	27632
- Manholes & gullies	70	No.	100	7000
- Mine Water	350	m	8	2800
- Discharge Water	590	m	18	10325
Electrical Power Distribution				
- Explosives Storage	450	m	8	3600
Security Fencing & Disposal				
- Explosives Storage Area	200	m	35	7000
- Well Dewatering Pump Station	261	m	35	9135
- Ventilation Shafts	60	m	35	2100
- Security compound	50	m	35	1750
Mobile Plant				
- Decommissioning plant & Services (Prov)	1	item	20000	10000
Disposal Of Material Off Site				
- Industrial Waste (Prov)	4000	litres	30000	30000
- Removal of Nuclear Sources (Prov)	1	item	30000	30000
STAGE 1 SURFACE TOTAL				**856764**
Splint into 2 years				428382

STAGE 1 UNDEGROUND	Quantity	unit	Rate	Total Cost
Mobile Plant				
- Decommissioning plant & Services (Prov)	0.5	item	20000	10,000
Conveyors below ground	794	m		
- Support structure	1	item	31760	
- Conveyor mechanism	1	item	31760	
- Associated M & E works	1	item	2382	
- Disposal of materials arising (excl concrete)	1	item	13498	79400
Electrical Power Distribution				
- Mining	350	m	15	5250
Mine Portal/Access Decline				
- Infill of portal and decline	17500	m3	8	136500
- Concrete plug, including rockbolts	135	m3	198	26730
- Concrete wall	27	m3	177	4770
- Demolition and removal of portal and entrance	1	no	30000	30000
Ventilation Raises				
- Cap	5	No.	34838	174190
- Fill and cap	1	No.	51057	51057
SUBSIDENCE MEASURES				
Subsidence Monitoring	1	item	67380	67380
Rehabilitation of Subsidence Areas (Prov)	1	item	20000	20000
- Shotcreting for pillar stabalisation (Prov)	1	item	10000	10000
ELECTRICAL POWER CONSUMPTION (1500W)				
- Ventilation Raises	9	wks	3706	33354
- Well Dewatering Pump Stations	9	wks	14825	133425
STAGE 1 UNDERGROUND TOTAL				**782056**
Splint into 2 years				391028

LANDSCAPING	Quantity	unit	Rate	Total Cost
Run contaminated material through plant	40000	m^3	2.00	80000
Excavate contamiated material & haul to Phase 3	37000	m^3	4.55	168350
Recontouring And Topsoiling	1	item	58000	58000
Landscaping	1	item	169000	169000
LANDSCAPING TOTAL				**592350**

AFTERCARE	Quantity	unit	Rate	Total Cost
Active care	5	years	12000	60000
Monitoring	5	years	5000	25000
Well dewatering for groundwater control	3	years		100000
AFTERCARE TOTAL				**185000**

STAGE 1 TOTAL	**2416170**

GALMOY MINE PROJECT

2. ESTIMATED COST OF PLANNED CLOSURE : STAGE 2 MINE SITE CLOSURE & DEMOLITION (2011)

All costs in Є, excluding VAT FACILITY	NB:2005 3rd QTR COSTS Quantity	unit	Rate cost	Total Cost
STAGE 2 DEMOLITION WORKS				
Services Building				104,000
- Superstructure	1	item	55120	
- Substructure	1	item	20800	
- Associated M & E works	1	item	2080	
- Disposal of materials arising (excl concrete)	1	item	26000	
Lamella Mine Water Treatment				33,000
- Concrete Bund walls	1	item	3300	
- External exposed pipework and supports	1	item	6600	
- Steel tanks and vessels	1	item	9900	
- Substructures	1	item	4290	
- Associated M & E works	1	item	2310	
- Disposal of materials arising (excl concrete)	1	item	6600	
Lamella MCC and Reagents				10,000
- Superstructure	1	item	5000	
- Substructure	1	item	1000	
- Associated M & E works	1	item	2000	
- Disposal of materials arising (excl concrete)	1	item	2000	
Main Water Treatment Plant				70,000
- Concrete Bund walls	1	item	7000	
- External exposed pipework and supports	1	item	10500	
- Steel tanks, vessels and gantries	1	item	17500	
- Substructures	1	item	14000	
- Associated M & E works	1	item	3500	
- Disposal of materials arising (excl concrete)	1	item	17500	
Sewage Treatment Plant	1	item		5,000
Main Electrical Substation (Decomissioning by ESB)	1	item		
Old transformer & standby generator	1	item		3,000
Gatehouse & Weighbridge	1	item		10,000
Fuelling Depot	1	item		20,000
- Concrete Bund walls	1	item	3000	
- Steel tanks, vessels and gantries	1	item	8000	
- Substructures	1	item	4000	
- Disposal of materials arising (excl concrete)	1	item	5000	
Water Distribution Pumphouse	1	item		10,000
Goul pumphouse	1	item		23,000
- Concrete walls, plinths & stairs	1	item	7000	59,500
- Superstructure	1	item	17500	
- Substructures	1	item	14000	
- Associated M & E works	1	item	3500	
- Disposal of materials arising	1	item	17500	
Stream Augmentation	1	item		2,000
Well Dewatering Pumpstations (5 no)	1	item		2,500
Settlement Holding Pond	9500	m^2	2.5	23,750
Well Conditioning Pond	9000	m^2	2.5	22,500
Surface Finishes (Disposal on Site)				
- Asphalt Surfacing 75mm thick	1625	m3	11	17,875
- Gravel/Crushed stone layers (Compacted)	2726	m3	9	24,534
- Hardstanding Areas	8760	m3	14	122,640
Removal and Disposal				
- Removal of reinforcement from concrete (Prov)	1	item	15,000	15,000
- Crushing of concrete and stockpiling (Prov)	1	item	12000	12,000
- Disposal of reinforcement from site (Prov)	1	item	5000	5,000

All costs in Є, excluding VAT FACILITY	NB:2005 3rd QTR COSTS Quantity	unit	Rate cost	Total Cost
REMOVAL OF ANCILLARY ITEMS AND SERVICES				
Pipework & Disposal				
- Freshwater Supply	1270	m	8	10,160
- Freshwater Distribution	1536	m	8	12,288
- Firewater Distribution	1200	m	8	9,600
- Potable water Distribution	584	m	8	4,672
- Sewage	470	m	8	3,760
- Storm Water	1346	m	8	10,768
- Manholes & gullies	30	No.	100	3,000
- Mine Water	1200	m	8	9,600
- Tailings	1200	m	8	9,600
- Reclaim Water	740	m	8	5,920
- Process Effluent	130	m	8	1,040
- Treated Effluent	370	m	8	2,960
- Discharge Water	300	m	17.5	5,250
Electrical Power Distribution				
- Concentrator/Mill Buildings	1560	m	8	12,480
- Services Building	1150	m	8	9,200
- Well Dewatering Pump Stations	850	m	8	6,800
- Site Lighting	2400	m	8	19,200
Telephone & Comunication (Prov)	1	item	5000	5,000
Security Fencing				
- Plant Site & Roads	5000	m	28	140,000
- Electrical & Mechanical Building	90	m	35	3,150
- Well Dewatering Pump Stations	174	m	35	6,090
STAGE 2 DEMOLITION TOTAL				**885,837**

LANDSCAPING **RETURN TO GREEN FIELD STATUS**	Quantity	unit	Rate cost	Total Cost
Recontouring & Topsoiling	1	item	50000	50,000
Landscaping	1	item	65000	65,000
Disposal of Materials Offsite				
- Idustrial Waste (Prov)	1	Item	33000	33,000
- Contaminated Material (Prov)	1	item	17000	17,000
LANDSCAPING TOTAL				**165,000**

AFTERCARE	Quantity	unit	Rate cost	Total Cost
Monitoring	5	years	5000	**25,000**

STAGE 2 TOTAL	**1,075,837**

GALMOY MINE PROJECT

3. ESTIMATED COST OF PLANNED CLOSURE : MINE SITE AND UNDERGROUND ANNUAL COST BY YEAR

Mine Site Phasing: General	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	NET TOTALS	GROSS TOTALS
Mine operation and progressive Rehabilitation of Tailings Impoundment																		
Stage 1 decommissioning and demolition Surface						428,382	428,382										856764	1001639
Stage 1 decommissioning and demolition Underground						391,028	391,028										782056	914298
Landscape							592,350										592350	692514
Active Care							50,333	50,333	50,334	17,000	17,000						185000	213305
Stage 2 demolition												595,299					595299	695961
Stage 2 Remove services												290,538					290538	339667
Stage 2 Landscaping												165,000					165000	192901
Passive care												5000	5000	5000	5000	5000	25000	26250
Sub Total						819410	1462093	50333	50334	17000	17000	1055837	5000	5000	5000	5000	**3492007**	**4076534**
CONTINGENCIES 5%						40971	73105	2517	2517	850	850	52792	250	250	250	250	174600	
INSURANCES* 1%						8948	15911	495	495	131	131	11475	0	0	0	0	37587	
SUB - TOTAL						903744	1612307	55249	55250	18485	18485	1164239	5250	5250	5250	5250	3848759	
ENGINEERING CONST. MANAGEMENT 6%						54225	96423	3000	3000	794	794	69539	0	0	0	0	227776	
TOTAL						957968	1708731	58249	58250	19279	19279	1233778	5250	5250	5250	5250	4076534	
CUMULATIVE TOTALS	0	0	0	0	0	957968	2666699	2724948	2783197	2802477	2821756	4055534	4060784	4066034	4071284	4076534		

MONITORING and LONG TERM MANAGEMENT are not included in the costs for PRELIMINARY AND GENERAL ITEMS, INSURANCES and ENGINEERING CONSTRUCTION MANAGEMENT.

MONITORING and LONG TERM MANAGEMENT (passive care) continues in perpetuity at the same annual cost as 2021

GALMOY MINE PROJECT

4 PLANNED CLOSURE ESTIMATED ANNUAL COSTS: TAILINGS IMPOUNDMENT OPERATION AND REHABILITATION (2006 - 2021)

ITEM NO.	ITEM	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	NET COST	GROUP GROSS COSTS
	LANDSCAPING																		
1	Lower outer cell walls Phase 3peel back liner and spread material over surface							399475										399475	
2	Excavate attenuation pond							273000										273000	
3	Interim seeding on dam surface Phase 3							20182										20182	
4	Final seeding on dam surface, soil and bare tailings;							40364										40364	
5	Aftercare of areas of grass.		Excluded															0	856972
	INTERIM DRAINAGE																		
6	Construct temp. sections of pipeline & tie in with existing pipeline (inc. 2 new pumps); Phases 2 & 3; Provisional Sum	Phase 2 in operation / Phase 3 construction				27000		27000										54000	
7	Operation and maintenance of pumps, water treatment works & sampling & analysis; *						90312	90312	90312	90312	90312	90312						541874	
8	Installation of monitoring standpipes; *						50713											50713	755922
	FINAL DRAINAGE																		
9	Modifications to decant structures; Provisinal Sum										5000	5000						10000	
10	Construct 3 new outfalls and cascade in Phase 2 , Phase 3; Provisional Sum										15000	30000						45000	
11	Construction of new drainage ditches & re-trimming existing ditches;										37800	540						38340	
12	Prepare attenuation pond area & lining; construct outlet weir.										341800							341800	508720
	MONITORING																		
12	Effluent & stream sampling & analysis; *											12409	12409	12409	12409	12409	12409	74451	
14	Ground water sampling & analysis; *											8632	8632	8632	8632	8632	8632	51792	
15	Soils / vegetation sampling & analysis; *											9495	3237	9495	3237	9495	3237	38196	
16	Dust sampling & analysis; *											13488	13488	13488	13488	13488	13488	80925	257632
	LONG TERM MANAGEMENT																		
17	Maintenance of fences, access roads, drains, etc;												1511	1511	1511	1511	1511	7553	
18	Monitoring of soils, vegetation and waters;												9064	9064	9064	9064	9064	45318	
19	Gorse cutting													2000		2000		4000	59715
	SUB - TOTAL	0	0	0	0	27000	141025	850334	90312	90312	489912	169876	48339	56597	48339	56597	48339	2116983	2438960
	CONTINGENCIES 5%	0	0	0	0	1350	7051	42517	4516	4516	24496	8494	2417	2830	2417	2830	2417	105849	
	PRELIMINARY & GENERAL ITEMS* 4%	0	0	0	0	1134	5923	35714	3793	3793	20576	5286	0	0	0	0	0	76219	
	INSURANCES* 1%	0	0	0	0	295	1540	9286	986	986	5350	1374	0	0	0	0	0	19817	
	SUB - TOTAL	0	0	0	0	29779	155540	937850	99607	99607	540334	185029	50756	59427	50756	59427	50756	2318869	
	ENGINEERING CONST. MANAGEMENT 6%	0	0	0	0	1787	9332	56271	5976	5976	32420	8328	0	0	0	0	0	120091	
	TOTAL @ end 2005 prices	0	0	0	0	31566	164872	994121	105584	105584	572754	193358	50756	59427	50756	59427	50756	2438960	
	CUMULATIVE @ end 2005 prices	0	0	0	0	31566	196438	1190558	1296142	1401726	1974480	2167838	2218594	2278021	2328777	2388204	2438960		

MONITORING and LONG TERM MANAGEMENT are not included in the costs for PRELIMINARY AND GENERAL ITEMS, INSURANCES and ENGINEERING CONSTRUCTION MANAGEMENT.

MONITORING and LONG TERM MANAGEMENT (passive care) continues in perpetuity at the same annual cost as 2021

Group Gross costs include PRELIMINARY AND GENERAL ITEMS, INSURANCES and ENGINEERING CONSTRUCTION MANAGEMENt, where appropriate

5 **TOTAL EXPENDITURE FOR EARLY CLOSURE at end 2006**

		Price	Volume	Cost	Unit	
TMF	Phase 2		**Level**			
	Taillings elevation		141		m	
	Crest elevation		143		m	
	Freeboard		2		m	
		Price	**Volume**	**Cost**	**Unit**	Total Volume m^3
	to lower cell walls to 2m freeboard		0.0		m	
	volume of excavtion		0.0		m^3/m run	0
	cost of excavation	€2.49		0.00	€/m run	
	Peel liner etc	€9.11		0.00	€/m run	
	Spreading excavated material	€4.32		0.00	€/m run	
	Total cost/m run			0.00	€/m run	
	Length of perimeter		1,370		m	
	Total cost			**0**	**€**	
	Excavate till from attenuation pond and stockpile within 100m radius	€4.55	60,000	273,000	**€**	
	soil on inner slopes		0.6		m^3/m	
	cost @	€3.50	984	**3,444**	**€**	
	Interim seeding over 50%		70,000		m^2	
	Cost	€0.39		**27,300**	**€**	
	Final seeding on dam surface		140,000		m^2	
	Final seeding on outer walls		20,000		m^2	
	Final seeding		160,000		m^2	
	Cost of final seeding	€0.39		**54,600**	**€**	
				Net Total		
	total			**303,744**		
	CONTINGENCIES	5%		15,187		
	PRELIMINARY & GENERAL ITEMS*	4%		12,757		
	INSURANCES*	1%		3,317		
	SUB - TOTAL			**335,005**		
	ENGINEERING CONST. MANAGEMENT 6%			20,100	**Gross Totals**	

		Gross Totals
	Remedial Works & Landscaping TOTAL	355,106
	Interim drainage	755,922
	Final drainage	508,720
	Monitoring	257,632
	Long term management	59,715
	TMF SUB TOTAL	**1,937,094**
ADMINISTRATION		**250,000**
STAGE 1	DECOMMISSIONING & DEMOLITION: Surface	1,001,639
	DECOMMISSIONING & DEMOLITION: Underground	914,298
	Landscaping	692,514
	Active care	213,305
	STAGE 1 SUB TOTAL	**2,821,756**
STAGE 2	DECOMMISSIONING & DEMOLITION	695,961
	Remove Services	339,667
	Landscaping	192,901
	Passive Care	26,250
	STAGE 2 SUB TOTAL	**1,254,778**
STOPE BACKFILLING		**884,128**
	TOTAL EXPENDITURE	**7,147,757**

6 **TOTAL EXPENDITURE FOR EARLY CLOSURE at end 2007**

		Price	Volume	Cost	Unit	
TMF	Phase 3		**Level**			
	Taillings elevation		132.29		m	
	Crest elevation		143		m	
	Freeboard		10.71		m	
		Price	**Volume**	**Cost**	**Unit**	Total Volume m ^{3}
	to lower cell walls to 2m freeboard		8.7		m	
	volume of excavtion		204.0		m^3/m run	107,543
	cost of excavation	€2.49		507.93	€/m run	
	Peel liner etc	€9.11		9.11	€/m run	
	Spreading excavated material	€4.32	204.00	881.28	€/m run	
	Total cost/m run			1398.32	€/m run	
	Length of perimeter		527		m	
	Total cost			**737,195**	**€**	
	Excavate till from attenuation pond and stockpile within 100m radius	€4.55	60,000	273,000	**€**	
	soil on inner slopes		1.5		m^3/m	
	cost @	€0.00	1,196	**0**	**€**	Not applicable
	area of outer walls		3902			
	area of internal cell		96,405			
	total area for seeding		100307			
	Interim seeding over 50%		50,153		m^2	
	Cost	€0.39		**19,560**	**€**	
	Final seeding		100307		m^2	
	Cost of final seeding	0.39		**39,120**	**€**	
				Net Total		
	total			**1,068,874**		
	CONTINGENCIES	5%		53,444		
	PRELIMINARY & GENERAL ITEMS*	4%		44,893		
	INSURANCES*	1%		11,672		
	SUB - TOTAL			**1,178,883**		
	ENGINEERING CONST. MANAGEMENT 6%			70,733	**Gross Totals**	

	Remedial Works & Landscaping TOTAL	1,249,616
	Interim drainage	755,922
	Final drainage	508,720
	Monitoring	257,632
	Long term management	59,715
	TMF SUB TOTAL	**2,831,604**
ADMINISTRATION		**250,000**
STAGE 1	DECOMMISSIONING & DEMOLITION: Surface	1,001,639
	DECOMMISSIONING & DEMOLITION: Underground	914,298
	Landscaping	692,514
	Active care	213,305
	STAGE 1 SUB TOTAL	**2,821,756**
STAGE 2	DECOMMISSIONING & DEMOLITION	695,961
	Remove Services	339,667
	Landscaping	192,901
	Passive Care	26,250
	STAGE 2 SUB TOTAL	**1,254,778**
STOPE BACKFILLING		**884,128**
	TOTAL EXPENDITURE	**8,042,267**

7 TOTAL EXPENDITURE FOR EARLY CLOSURE at end 2008

		Price	Volume	Cost	Unit	Total Volume m^3
TMF	Phase 3		**Level**			
	Taillings elevation		132.29		m	
	Crest elevation		143		m	
	Freeboard		10.71		m	
	to lower cell walls to 2m freeboard		8.7		m	
	volume of excavtion		204.0		m^3/m run	107,543
	cost of excavation	€2.49		507.93	€/m run	
	Peel liner etc	€9.11		9.11	€/m run	
	Spreading excavated material	€4.32	204.00	881.28	€/m run	
	Total cost/m run			1398.32	€/m run	
	Length of perimeter		527		m	
	Total cost			**737,195**	**€**	
	Excavate till from attenuation pond and stockpile within 100m radius	€4.55	60,000	273,000	**€**	
	soil on inner slopes		1.5		m^3/m	
	cost @	€0.00	1,196	**0**	**€**	not applicable
	Area of outer walls		3902		m^2	
	Area of internal cell		96,405		m^2	
	total area for seeding		100307			
	Interim seeding over 50% internal		50,153		m^2	
	Cost	0.39		19560	€	
	Final seeding		100307		m^2	
	Cost of final seeding	0.39		39120	€	
				Net Total		
	Total			1,068,874		
	CONTINGENCIES	5%		53,444		
	PRELIMINARY & GENERAL ITEMS*	4%		**44,893**		
	INSURANCES*	1%		11,672		
	SUB - TOTAL			1,178,883		
	ENGINEERING CONST. MANAGEMENT 6%			70,733	**Gross Totals**	
	Remedial Works & Landscaping TOTAL				1,249,616	
	Interim drainage				755,922	
	Final drainage				508,720	
	Monitoring				**257,632**	
	Long term management				59,715	
	TMF SUB TOTAL				**2,831,604**	
ADMINISTRATION					**250000**	
STAGE 1	DECOMMISSIONING & DEMOLITION: Surface				1,001,639	
	DECOMMISSIONING & DEMOLITION: Underground				914,298	
	Landscaping				692,514	
	Active care				213,305	
	STAGE 1 SUB TOTAL				2,821,756	
STAGE 2	DECOMMISSIONING & DEMOLITION				695,961	
	Remove Services				339,667	
	Landscaping				192,901	
	Passive Care				26,250	
	STAGE 2 SUB TOTAL				**1,254,778**	
STOPE BACKFILLING					**877,698**	
	TOTAL EXPENDITURE				**8,035,837**	

8 TOTAL EXPENDITURE FOR EARLY CLOSURE at end 2009

		Price	Volume	Cost	Unit	
TMF	Phase 3		**Level**			
	Taillings elevation		133.66		m	
	Crest elevation		143		m	
	Freeboard		9.34		m	
		Price	**Volume**	**Cost**	**Unit**	Total Volume
	to lower cell walls to 2m freeboard		7.3		m	
	volume of excavtion		151.8		m^3/m run	80,024
	cost of excavation	€2.49		377.96	€/m run	
	Peel liner etc	€9.11		9.11	€/m run	
	Spreading excavated material	€4.32	152.00	656.64	m^3/m run	
	Total cost/m run			1043.71	€/m run	
	Length of perimeter		527		m	
	Total cost			**550,244**	**€**	
	Excavate till from attenuation pond and stockpile within 100m radius	€4.55	60,000	273,000	**€**	
	soil on inner slopes		1.5		m^3/m	
	cost @	€0.00	791	**0**	**€**	Not applicabe
	Area of outer walls		5,577		m^2	
	Area of internal cell		97,517		m^2	
	total area for seeding		103,095			
	Interim seeding over 50% internal		51,547		m^2	
	Cost	€0.39		20,103	€	
	Final seeding		103,095		m^2	
	Cost of final seeding	€0.39		40,207	€	
				Net Total		
	Total			**883,554**		
	CONTINGENCIES	5%		44,178		
	PRELIMINARY & GENERAL ITEMS*	4%		37,109		
	INSURANCES*	1%		9,648		
	SUB - TOTAL			974,490		
	ENGINEERING CONST. MANAGEMENT 6%			58,469	**Gross Totals**	

	Remedial Works & Landscaping TOTAL	1,032,959
	Interim drainage	755,922
	Final drainage	508,720
	Monitoring	257,632
	Long term management	59,715
	TMF SUB TOTAL	**2,614,948**
ADMINISTRATION		**250,000**
STAGE 1	DECOMMISSIONING & DEMOLITION: Surface	1,001,639
	DECOMMISSIONING & DEMOLITION: Underground	914,298
	Landscaping	692,514
	Active care	213,305
	STAGE 1 SUB TOTAL	2,821,756
STAGE 2	DECOMMISSIONING & DEMOLITION	695,961
	Remove Services	339,667
	Landscaping	192,901
	Passive Care	26,250
	STAGE 2 SUB TOTAL	**1,254,778**
STOPE BACKFILLING		**286,136**
	TOTAL EXPENDITURE	**7,227,618**

9 TOTAL EXPENDITURE FOR PLANNED CLOSURE at end 2010

TMF		Level			
Taillings elevation		134.94		m	
Crest elevation		143		m	
Freeboard		8.06		m	
	Price	**Volume**	**Cost**	**Unit**	Total Volume
to lower cell walls to 2m freeboard		6.1		m	
volume of excavtion		109.8		m^3/m run	57,890
cost of excavation	€2.49		273.42	€/m run	
Peel liner etc	€9.11		9.11	€/m run	
Spreading excavated material	€4.32	110.00	475.20	m^3/m run	
Total cost/m run			757.73	€/m run	
Length of perimeter		527		m	
Total cost			**399,475**	**€**	
Excavate till from attenuation pond and stockpile within 100m radius	€4.55	60,000	273,000	**€**	
soil on inner slopes		1.5		m^3/m	
cost @	€0.00	791	**0**	**€**	not applicable
Area of outer walls		7,143		m^2	
Area of internal cell		96,354		m^2	
total area for seeding		103,497		**m^2**	
Interim seeding over 50% internal		51,749		m^2	
Cost	€0.39		20,182	€	
Final seeding		103,497		m^2	
Cost of final seeding	€0.39		40,364	€	
Total			**733,021**	€	
CONTINGENCIES	5%		36,651		
PRELIMINARY & GENERAL ITEMS*	4%		30,787		
INSURANCES*	1%		8,005		
SUB - TOTAL			808,464		
ENGINEERING CONST. MANAGEMENT 6%			48,508	**Gross Totals**	

	Remedial Works & Landscaping TOTAL	856,972
	Interim drainage	755,922
	Final drainage	508,720
	Monitoring	257,632
	Long term management	59,715
	TMF SUB TOTAL	**2,438,960**
ADMINISTRATION		**250,000**
STAGE 1	DECOMMISSIONING & DEMOLITION: Surface	1,001,639
	DECOMMISSIONING & DEMOLITION: Underground	914,298
	Landscaping	692,514
	Active care	213,305
	STAGE 1 SUB TOTAL	2,821,756
STAGE 2	DECOMMISSIONING & DEMOLITION	695,961
	Remove Services	339,667
	Landscaping	192,901
	Passive Care	26,250
	STAGE 2 SUB TOTAL	**1,254,778** 4,076,534
STOPE BACKFILLING		**0**
	TOTAL EXPENDITURE	**6,765,494**

Backfill costs

		2006	2007	2008	2009	2010
total tonnage		275000	275000	273000	89000	0
Minimum cement content (%)	50	137500	137500	136500	44500	0
Higher cement content (%)	50	137500	137500	136500	44500	0
Minimum cement content Cost (€)	1.4	192500	192500	191100	62300	0
Higher cement content Cost (€)	4.1	563750	563750	559650	182450	0
Total (€)		**756250**	**756250**	**750750**	**244750**	**0**
Contingencies	0	794063	794063	788288	256988	0
P&G	0	825825	825825	819819	267267	0
Insurances	0	834083	834083	828017	269940	0
Total (incl ECM) (€)	0	**884128**	**884128**	**877698**	**286136**	**0**