MINE CLOSURE PLANNING IN IRELAND: WATER ASPECTS

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ABSTRACT

All new mines in Ireland, or significant extensions of existing mines, are subject to a rigorous process of Environmental Impact Assessment. In its Environmental Impact Statement, the mining company must submit a clear Mine Closure Plan, setting out the measures whereby the mine site will be restored and rehabilitated when the mine closes.

In many ways, the mine closure plan is the most important part of the Environmental Impact Statement; while a working mine may affect its environment for a few decades, the impact of a closed mine is unlimited in time. And yet, because the final configuration of the mine and the hydrogeological conditions at closure are only poorly known when the mine is being planned, drawing up an appropriate closure plan is a difficult exercise.

The regulatory authorities in Ireland, and their advisors, have taken considerable trouble to ensure that proper closure planning is integral to all new mining development in the country. They have taken the view that a mine closure plan is more than a document - it is a process which is pursued throughout the life of the mine. The process can be viewed as comprising:

- *Initial Closure Plan*
- *Investigations and monitoring to derive parameters needed for final closure plan*
- *Modelling and validation for final closure plan*
- *Periodic review (Interim Closure Plan)*
- *Final Closure Plan*

A mine closure plan must be:

- *Clear* • *Comprehensive*
- *Realistic* • *Flexible*
- *Robust* • *Financially achievable*
- *In accordance with BATNEEC principles*

In Irish mines the main water issues involved in mine closure are:

- *Groundwater rebound*
- *Water contamination from mine workings or waste after groundwater rebound*
- *Tailings*

The Irish approach to these issues is illustrated with reference to recent mining developments.

INTRODUCTION

Three major underground zinc-lead mines have been developed in Carboniferous Limestones in Ireland in recent years, making Ireland one of Europe's leading producers of zinc concentrate and a significant producer of lead concentrate. The three mines are at Navan, County Meath (opened in 1976), Galmoy, County Kilkenny (1995) and Lisheen, County Tipperary (scheduled to start production in 1999) (Figure 1). Since all three mines are in agricultural regions with no previous experience of mining, environmental protection is a particular concern. Special problems of dewatering and pollution control were present at Galmoy and Lisheen, where the host rocks are important limestone aquifers.

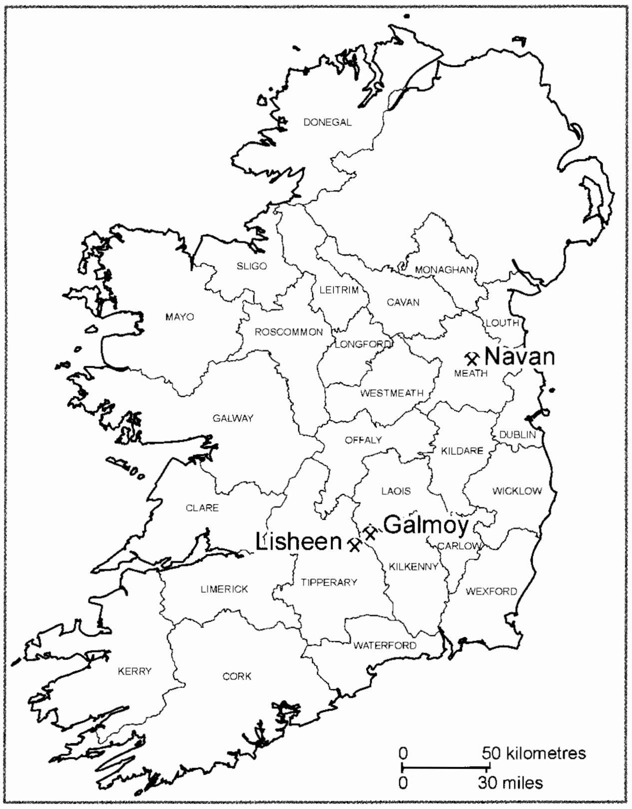

Figure 1. Locations of current mayor Zinc-Lead Mines in Ireland.

TARA MINE, NAVAN, COUNTY MEATH

Tara mine lies just outside the town of Navan, County Meath, about 40 km north of Dublin. The River Blackwater flows across the flat lying area above the deposit.

The stratiform orebody, dipping generally Southwest at about 20° and reaching depths approaching 1000 m, occurs near the local base of the Carboniferous Limestone sequence in partially dolomitised bioclastic limestones and calcareous sandstones (Ashton and others, 1986). The ore-bearing horizons pass upwards into unbedded Waulsortian micrites. A series of Northeast trending faults disrupt the succession. The area is covered by Quaternary sands, gravels and tills.

When development began, the orebody contained resources of 70 Mt, grading 10.1% zinc and 2.6% lead. The development consists of a 2.6 Mtpa room-and-pillar underground mine with backfilling. Access is by a 300 m vertical shaft and a decline. Mine water is collected in sumps and pumped to the tailings pond. Surface facilities include conventional milling and flotation.

GALMOY MINE, COUNTY KILKENNY

The Galmoy deposit, discovered in 1986, lies 110 km Southwest of Dublin in a mainly rural area, 6 km from the nearest village, Rathdowney. Several small streams cross the undulating topography of the area. There are two wetland areas of some conservation importance nearby. Many farms were served by individual wells.

The geology consists of gently dipping argillaceous bioclastic limestones (120m thick), overlain by massive Waulsortian mudbanks (160 to 200 m thick) which are intensely dolomitised in this area (Doyle and others, 1992). The two stratiform orebodies (designated 'CW' and 'G') totalling 6.12 Mt at the start of production, grading 11.5% zinc and 1.11% lead and with locally high pyrite, lie at the base of the Waulsortian, 50 to 110 m below surface and about 1.5 km apart. The main structural feature is an easterly trending normal fault dipping northwards which bounds the south of the 'G' orebody. There are numerous Northwest trending joints and minor faults, often with intense fracturing. Palaeokarst development, (probably Tertiary in age) consists of mainly sediment filled cavities but no cave systems were identified. There is no evidence of active karst. The lower parts of the area are blanketed by glacial tills and occasional interbedded sands and gravels, generally about 5 m thick.

Galmoy is a 650,000 tpa underground mine with backfilling; underground access and ore transport along crosscuts to a decline midway between the orebodies, and conventional grinding and flotation on surface. Development began in 1995, and production in 1997.

LISHEEN MINE, COUNTY TIPPERARY

The Lisheen deposit, discovered in 1990, is located 8 km Southwest of the Galmoy mine in a generally similar rural area 12 km Northeast of the nearest town, Thurles. The mine is on the edge of a raised bog (Derryville) which has been exploited for many years for milled peat. Many properties around the mine are supplied with water by a co-operative, the Moyne Group Water Scheme, rather than having their own wells. The main source well for this scheme was located close to the deposit. A County Council regional water scheme supplies the area to the north.

The geological setting is quite similar to Galmoy. Two flat-lying stratiform orebodies (the Main and Derryville zones) with total reserves of 18.9 Mt at 12.5% Zn and 2.5% Pb and about 17% Fe, occur at the base of the dolomitised Waulsortian at an average of 190m below surface. They are bounded to the south by two en echelon normal faults, downthrown 200 m to the north which bring the underlying argillaceous bioclastic limestones and oolites into contact with the ore (Hitzman and others, 1992). There is a north-south joint and fault system. Palaeokarst occurs in the area, expressed mainly as sediment-filled fissures. The most significant feature is an infilled palaeodoline, at least Tertiary in age, over 40 m in diameter and up to 80 m deep. There is no sign of active karstification at present.

The development consists of a 1.5 Mtpa underground room-and-pillar mine with backfilling, and conventional grinding and flotation on surface. Primary access is by a decline constructed to the south of the faults where the Argillaceous Bioclastic Limestone provides much better ground conditions and lower mass permeabilities than the Waulsortian. Development began in 1997, and first ore production is anticipated in September 1999.

REQUIREMENTS OF A CLOSURE PLAN

Clear: The closure plan must be clear and specific, i.e. general undertakings to clean everything up are not sufficient. The plan must set out in sufficient detail how each part of the plant and site will be cleared and restored, what monitoring and maintenance will be required, and what it will cost.

Comprehensive: All parts of the site, and all aspects of the operations, must be encompassed.

Realistic: The plan must be based on realistic assumptions, so must not assume that conditions most favourable to the developer will obtain. It should initially be prudently conservative and identify solutions which will be achievable even under somewhat adverse conditions, but should not assume worst possible circumstances, to avoid placing unreasonable burdens on the project. The plan must indicate what additional data need to be collected to substantiate the plan's assumptions, and how these data will be obtained, e.g. by specific field investigations, experimental work, or routine monitoring.

Flexible: Since the actual mine closure is likely to be some 15-20 years (perhaps longer) after submission of the Environmental Impact Statement, it must be expected that many changes may have taken place by the time it is implemented:

- The mine size and configuration may be considerably different from the original design.
- There will be much more data available on the hydrological parameters of the mine (permeability, recharge, etc.).
- There may have been considerable technological changes in mine development, processing, water and waste treatment, etc.
- Numerical modelling techniques will have improved.
- The physical and chemical characteristics of the tailings may prove to be different from those derived from preliminary laboratory trials.
- New options for the closure end points may be identified as a result of, for example, changes in preferred land use.

The final mine closure plan must take account of all such changes. Hence the initial closure plan should be flexible enough to accommodate such changes as it is periodically reviewed throughout the life of the mine. The plan must set out how the developer is committed to collecting the data which will be essential to successful mine closure.

The plan must take account of the vulnerability of mining operations to changes in commodity prices, with the consequent possibility of early closure. Thus it is not satisfactory to leave detailed closure planning to an unspecified date some fixed period before planned closure.

Robust: The closure plan should be sufficiently robust that it is not sensitive to minor changes in parameters, e.g. permeabilities or groundwater recharge estimates.

Financially achievable: The plan must be realistically costed from the beginning, and a guaranteed source of adequate funds established from the outset, and indexed against inflation. The adequacy of the fund must be reviewed periodically to ensure it takes account of technical revisions in the closure plan. Reliance on company accounting provisions is no longer an option.

BATNEEC (Best Available Technology Not Entailing Excessive Cost): The plan must be based on BATNEEC. The technologies involved should be well-proven. Technologies which are theoretical or still at experimental or 'pilot study' stage should not be included, although they may be proposed at a later date if proven by then.

GROUNDWATER REBOUND

Where mining requires substantial dewatering of an aquifer to a considerable depth, as at Galmoy and Lisheen, and mining has persisted for 10-20 years, the resultant cone of depression can be expected to take several years to reach its new equilibrium after closure. In the case of Lisheen, preliminary modelling suggests it will take about five years to equilibrate naturally. In practice, this will depend to some extent on the actual rainfall over the period of rebound, particularly the winter rainfall - a succession of abnormally wet winters would shorten the period, whereas dry winters would extend it.

At Tara Mine, groundwater rebound is not a significant issue, since the host rocks have low bulk permeabilities and the cone of dewatering is small and has not affected any significant groundwater sources.

The Galmoy cone of depression is not as extensive as was initially predicted. A perimeter dewatering programme proved largely unsuccessful, owing to the difficulty in locating major water-bearing fractures in the rock. As a consequence, the mine has depended largely on in-mine dewatering, which has minimised the lateral extent of the cone of depression. Also, bulk permeabilities have proved lower than expected. However, the cone of depression is still very substantial: as of late 1998 it extended over an area of approximately 8 km^2, as defined by the one metre drawdown contour.

The cone of depression at Lisheen is still in the early stages of development. It is expected to be bigger than that at Galmoy, and initial predictions suggested an extent of about 70 km^2 (within the 1 m drawdown contour). Preliminary monitoring to date suggests that the cone of depression will be less extensive than predicted. Further it is apparent at this early stage in drawdown that large fractures are influencing the boundary of the cone, resulting in a digitated rather than the predicted smooth cone margin. As in the Galmoy case, significant fracture controlled water strikes were made during the mine development which were not predicted. Local in-mine dewatering has been necessary at the intersection of these fractures. Numerical modelling indicates that full groundwater rebound after 20 years dewatering should occur within five years under average climatic conditions.

Where river flow augmentation is required because of the dewatering, closure plans include provision for continued augmentation, as necessary, during the rebound period. Where replacement of water supplies is necessary, this will be continued until the natural groundwater regime is re-established in terms of both quality and quantity; where the consumers so desire the replacement water supply systems will continue indefinitely under local management.

WATER CONTAMINATION FROM MINE WORKINGS OR WASTE AFTER CLOSURE

During both mining and the recovery period, sulphide minerals in the unsaturated zone, particularly in the workings, will tend to oxidise, potentially leading to sulphate and heavy metal contamination of groundwater. Therefore it is generally good practice to augment the natural groundwater rebound by artificial means, using surplus water available from local rivers (after conditioning, as necessary). This can be combined with controlled pumping from the old workings and treatment of the water before discharge so that migration of pollutants into either ground or surface water is minimised. Permits provide for all mine waters to be pumped and treated to an acceptable quality until it can be shown that this is no longer necessary.

In all three mines, pollution of the groundwater after mine closure must be prevented. In this regard, the closure plans depend quite heavily on predictive modelling of water table rebound, solute transport and particle tracking. However, it is acknowledged that the readily available models cannot represent adequately a complex fractured limestone aquifer, and it is important that the modelling be up-dated as such computer codes are improved and more data become available during mining. For this reason, model review committees have been established, comprising two representatives of the developer and two representatives of the regulators.

Since the three orebodies are hosted by carbonate rocks, ARD is expected to be quickly neutralised.

TAILINGS MANAGEMENT FACILITIES

The three developers have taken different approaches to the final end-points for their tailings dams though with the same objective of ensuring physical and chemical stability: Tara and Arcon plan a conventional dry end-point, with the tailings re-vegetated to ensure surface stability. Vegetation trials at Tara have validated their proposals. Lisheen, where the tailings are potentially acid generating, plans a wetland in which oxidation is prevented by perpetual saturation.

The Tara TMF is on a 160 ha site 5 km north of the mine. The site is relatively flat and originally required a ring dam 8 m high, constructed mainly from on-site glacial till with a central drainage chimney connected to an interceptor ditch which was intended to collect any seepage. The TMF was originally built in stages and consisted of three cells. This allowed large scale rehabilitation to be undertaken during operations so that the small scale re-vegetation trials could be validated.

By the mid-1990s Tara recognised the need for additional tailings storage capacity for the remaining reserves and resources of over 20 Mt, if the mine were to continue beyond 2000. After considering various alternatives, Tara proposed to increase capacity on the existing site by constructing a new dam 8 m high built on the existing tailings, with two internal cells.

The Galmoy TMF is on a 35 ha site 300 m from the nearest known ore, in a low valley. The facility has an engineered ring dam built from local glacial materials with chimney and finger drains of sand. The base is sealed with a double HDPE liner. On closure, it is proposed to restore the dam to amenity use, mainly for wildlife conservation but with the possibility of recreational use. The dam will be vegetated with a mixture of woodland, scrub and grassland species. A choice of suitable species will be based on trials in the intervening period, and also on experience at Tara, where tailings re-vegetation trials been conducted since 1987. It is expected that the vegetation should be self-sustaining after approximately five years. The TMF will be operated in three cells, and after the first cell is filled and decommissioned, field rehabilitation trials will begin. The dam surface will have a dished shape, with a surface gradient of 0.5º sloping towards the central drain, by which surface water will be decanted. A concrete or gabion spillway will be constructed to cope with extreme rainfall events.

Tailings disposal at Lisheen will be mainly on a worked peat bog immediately east of the plant site, 1 km from the nearest ore and south of the fault complex. The TMF is designed as a water retaining structure comprising a 3 km perimeter embankment with internal drainage on a 78 ha site. The peat has been stripped from the dam footprint but left in place as an attenuating layer under the tailings and covered by a LDPE geomembrane. This is the largest lined mine waste impoundment of its type in Europe. Unlike Tara and Galmoy, there is only a single cell so that rehabilitation plans will rely heavily on on-site and off-site trials. These have already commenced using tailings of similar mineralogy from an abandoned mine.

On closure, it is proposed to re-create a wetland on the top of the Lisheen TMF, which will effectively prevent any oxidation of the tailings beneath. This will be achieved by:

- deposition of layers of organic-enriched crushed limestone, using the tailings distribution system
- planting of reeds and other wetland vegetation
- protecting the developing vegetation from wave action by laying down lines of baled forest brash, hay or straw.
- maintaining water levels to allow a mean maximum depth of 0.5-0.7 m above the tailings surface, with annual spring drawdowns in the first three years to encourage the spread of vegetation.

It is anticipated that an ecologically self-sustainable reedmarsh, similar to the margins of many Irish calcareous marl-based lakes, will be established within 10 years of closure.

A notable feature of all three developments is that the dams have been engineered as water retaining structures, constructed of compacted fill with internal drainage, and not from tailings. In each case there is provision for independent audit of the design, construction and operation of the dam by a qualified dam engineer. These standards are to ensure that the risk of dam failure, or development of serious leaks, should be negligible. Any future TMFs in Ireland will have to meet similar standards of integrity since the EPA has indicated that it regards mine wastes as no different in principle from any other non-hazardous industrial wastes and will require the appropriate land-fill design.

It is essential for the successful operation of the proposed Lisheen wetland that it never dries out, i.e. that a sufficient depth of water is maintained at all times over the surface of the deposit. It is assumed that this will be achieved by purely natural means, i.e. by excess rainfall.

It is worth pointing out that there has been considerable sharing of information on tailings rehabilitation among the three companies, and this can only benefit all three in their efforts to produce an environmentally acceptable outcome to their operations. There has also been considerable input from university-level institutions in Ireland and U.K.

REGULATORY ENVIRONMENT

In the current regulatory environment a developer submits three applications: (i) to the planning authority for planning permission, (ii) to the Environmental Protection Agency for an Integrated Pollution Control (IPC) Licence, and (iii) to the Department of the Marine and Natural Resources for a State Mining Facility. These permits cover different aspects of the developments, but the three authorities co-ordinate closely, and with appropriate pre-consultation and simultaneous applications, even a major development can proceed quite smoothly, provided that the developer takes its environmental responsibilities seriously. The IPC licence is the principal regulatory tool for the control of day-to-day operations, including tailings management, of a mine.

IPC is a single permit approach to all emissions to all media. Therefore the individual impact on both groundwater and surface water as well as any transfer of impact from one to the other is considered. It is a highly transparent and pragmatic approach to regulation. The BATNEEC principle is a core element of this authorisation and control philosophy.

In Ireland the protection of groundwater from mine activities is principally driven by the implementation of the EU Groundwater Directive. Maintenance of a high quality environment is a national priority.

FINANCIAL PROVISIONS

Conditions imposed by the regulatory authorities aim to ensure that mine operation, monitoring and model review will produce an acceptable post-closure outcome. Critical to this process is ensuring that sufficient funds will be available either for planned or premature closure and to deal with post-closure problems requiring remediation. Solutions to this problem have been established to a large degree in co-operation with the developers who have recognised that this is now an essential part of mine development. Each has provided a substantial surety (Euro 5.7M for Galmoy, Euro 12.2M for Lisheen and Euro 3.2M for the TMF at Navan where there is a separate smaller bond for the mine established under an earlier permission). All are indexed for inflation. These consist of an independent guarantee to be replaced eventually by a fund held separately from the company. Withdrawals will require the consent of the permitting authorities.

In the case of Lisheen mine, a further Euro 1.7M has been bonded for the long term management and maintenance of the tailings. The aftercare plan includes for groundwater and surface water monitoring and reporting, insurance, etc. The enforcement of the IPC licence (and legal obligations thereunder) for the facility can be extended indefinitely, i.e. the operators of the mine and tailings facility will never be released from their licence obligations to ensure surface and groundwater is protected during operational and post-closure phases of the mine. These bonding provisions are granted to the EPA through national legislation. The activity cannot commence in the absence of these bonds being in place.

In addition to these provisions the operator is required to maintain sufficient indemnity to underwrite the clean-up or reinstatement costs resulting from an accident or unscheduled emissions. The operator is required to quantify this risk or liability and demonstrate to the satisfaction of the regulators provision for same.

PERIODIC REVIEW

The Navan and Galmoy mines are not yet subject to Integrated Pollution Control Licensing. Their Planning Permissions provide for periodical review of the closure plans. A report must be submitted every year and this may trigger a review by the Planning authority which can insist on changes, including changes to the surety. The operators may also propose changes, but these will not come into effect unless approved by the Planning Authority.

The IPC licences for mine activities require, via specifically drafted conditions, the annual review of the established closure plan. Any change in operations that have a bearing on the closure plan are required to be addressed on a minimum frequency of annually and shorter if the change is significant. The licence conditions also permit the revision of funds secured for the closure and aftercare of the mine. The licences also require the establishment of large scale field trials to validate the tailings closure solution.

Review of closure plans may also be triggered by adverse results of requisite comprehensive environmental monitoring in and around the mine site. Such monitoring embraces numerous surface water locations and networks of groundwater monitoring boreholes strategically positioned around the tailings facilities.

CONCLUSION

As far as possible, the permits provide that mine closure should lead to a "walk-away" status, and where this is not practicable, to a "passive care" status, supported by a guaranteed and substantial residual care fund.

Protection of the environment is a premier aspect of much of Ireland's recent legislation. This concern is underwritten by, and implemented through, a rigorous planning and environmental authorisation and post-authorisation control system.

The design philosophy as well as the safety and monitoring provisions required of mine operations in respect of water protection has significantly influenced the construction and closure plans for mine and mine waste facilities.

Irish regulatory authorities generally perceive metal mining wastes as representing a perpetual risk to the environment. Thus a very long term view is taken in the water protection provisions provided by mine operators.

The integrated pollution control regulatory approach to mine operations has proven to be successful and satisfactory for the general public, non-governmental organisations, and regulators, as well as mine operators and investors.

ACKNOWLEDGEMENTS

This paper has drawn heavily upon the work of the staff of the three mining companies and our respective departments, and especially of the undermentioned consultants, all of whose work is hereby acknowledged:

CAAS
Conodate
Enviroplan Services Ltd.
Golder Associates
Knight Piésold
Steffen, Robertson & Kirsten
Water Management Consultants
R.P.S. Cairns
K.T. Cullen & Co. Ltd.
Eolas
Kilborn Engineering Pacific Ltd.
Minerex Ltd.
Wardell Armstrong

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