Developing the Mine Environment Life Cycle Guide for epithermal gold mines

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Abstract

A Ministry of Business, Innovation and Employment (MBIE) funded research programme led by CRL Energy, collaborating with Landcare Research, Otago University, Canterbury University and O'Kane Consultants, as well as key mining companies, iwi, regional councils and Department of Conservation is improving processes for planning and operations of mine developments to minimise environmental impacts. A particular focus is ensuring that post-mining outcomes (e.g., site rehabilitation; revegetation; legacy water quality) are appropriately identified and can be achieved in the most cost-effective manner. To do this, environmental information is being considered in the framework of a conventional mine lifecycle, taking account of the current mine permitting regime, including land access arrangements, now operating in New Zealand, and resource consents required under the Resource Management Act. This information is integrated into a Mine Environment Lifecycle Guide, which draws on and extends previous research on rock geochemistry, aquatic chemistry, freshwater ecology, aquatic toxicity, and management, treatment and rehabilitation techniques for mining, as well as undertaking new research to integrate economics and cultural values into the decision-making process.

Keywords: aquatic toxicology, geochemistry, mine rehabilitation, economics, life-cycle.

Introduction

Coal and gold mining are important economic activities in New Zealand, and the West Coast of the South Island, Otago, Southland and the Coromandel Peninsula, for example, have long and extensive histories of mining. The process of mineral extraction inevitably results in environmental impacts, but few tools exist to help mining companies and regulators assess, predict and minimise environmental impacts of mining operations. This collaborative research programme is working with key partners including mining companies, regional councils, Department of Conservation and iwi to assist with planning and operations of mine developments, in particular to ensure that post-mining outcomes (e.g., site rehabilitation;

revegetation; legacy water quality) are appropriately identified and can be achieved in the most cost-effective manner. To do this requires on-going engagement with stakeholders and appropriate environmental management throughout the life cycle of a mine. This programme draws on and extends previous research on rock geochemistry, aquatic chemistry, freshwater ecology, aquatic toxicity, and management, treatment and rehabilitation techniques for mining, and undertakes new research to integrate economics and cultural values into the decision-making process.

Developing the Mine Environment Lifecycle Guide (MELG)

The Mine Environment Lifecycle Guide (MELG) considers environment information in the framework of a conventional mine lifecycle, taking account of the current mine permitting regime, including land access arrangements, now operating in New Zealand and resource consents required under the Resource Management Act. The key stages are outlined in Table 1.

Table 1 Summary of a conventional mine life cycle, and the mine permitting/consenting operating in New Zealand.

Mine Life Cycle	Permitting/Consenting regime
Exploration	Prospecting (land access)
	Exploration (land access)
Mine planning	Mine Permit – requires pre-feasibility study Resource Consent
Operations (including commissioning and construction)	Annual reporting
Decommissioning (Closure)	Permit relinquishment
Post Closure	Agreement with regulators

A change in the mine permitting regime places greater emphasis on cost analyses at the mine permit stage, requiring a more in-depth consideration and quantification of the costs associated with environmental management throughout the project and the (general) final closure objectives. However, it is recognised that uncertainty will remain for quantification during the prefeasibility stage (mine permit application) and that only general post-mining outcomes, e.g. type of native ecosystem, and non-negotiable outcomes (e.g. removal of ridgeline) should be identified and agreed at this point. For mine permitting, it is expected that best estimates will be used to ensure the closure objectives can reasonably be achieved and the related uncertainty is managed with the bond. The MELG utilises much of the existing Minerals Sector Environmental Framework (Cavanagh et al., 2015) within the permitting and consenting stage but extends this to incorporate economic considerations, particularly in relation to bonding, and stakeholder consultation, in particular Maori engagement and input, to ensure all relevant closure options are adequately considered. Research undertaken within the current programme also fills gaps in environmental science relating to accurate long term predictions of impact.

During the operational phase of a project, further information will be obtained, the uncertainty related to closure and post closure will be reduced and the bond can be adjusted to reflect more certain outcomes. Similarly, more specific post-mining outcomes can be determined, and agreed with stakeholders. The MELG greatly expands on the information required during operations to ensure that the post-mining outcomes can be achieved in a cost-effective manner. This is achieved by moving from laboratory based studies on small samples to field trials and mass balanced experiments under local environmental conditions. Specifically, the MELG aims to identify the critical elements that will influence the likelihood of success and/or cost of achieving the agreed outcomes at closure, the information that can be used to reduce the uncertainty for these outcomes. The increased certainty benefits all stakeholders because bond quantum becomes related to real data rather than estimates. The research base also provides greater levels of certainty for stakeholders most interested in the post-closure outcomes.

The MELG also identifies that ongoing stakeholder engagement is required during operations, particularly with the ebb and flow of operational projects associated with changing global commodity prices, to provide assurance that specific agreed post-mining outcomes will be achieved. This also reflects changes to the Crown Minerals Act (1991) in 2013 that brought in a requirement to provide an annual engagement report with relevant (i.e. affected) iwi.

Figure 1 provides a pictorial overview of the content of the MELG, reflecting the type of information that can be obtained at each stage of the mine life cycle (e.g., laboratory studies, field trials), and the focus of effort required in different areas to reduce the uncertainty associated with the bond and ensure post-closure outcomes are met.

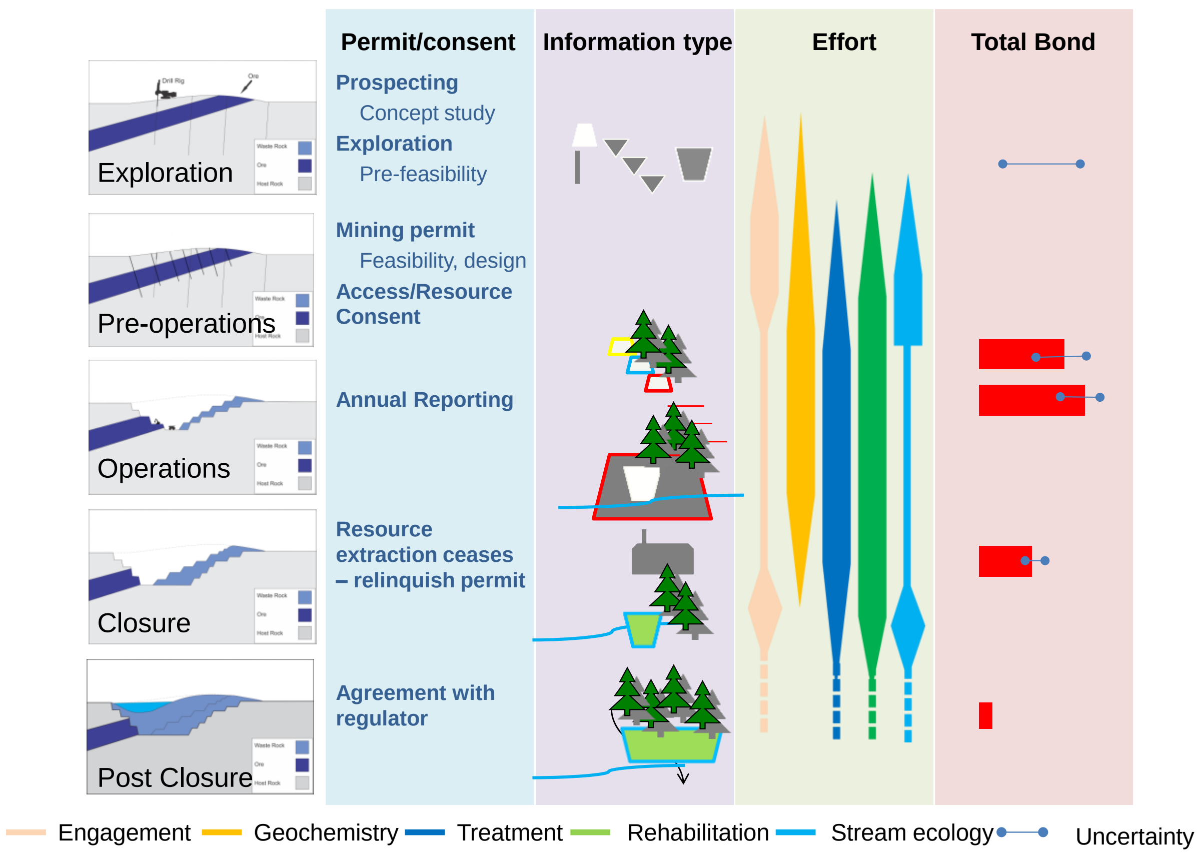

Figure 1. Summary of the relationship between the mine life cycle, the type of information able to be obtained at each stage of the mine life cycle (*e.g.*, laboratory studies, field trials), and the focus of effort required in different areas to reduce the uncertainty associated with the bond and ensure post-closure outcomes are met.

A critical component of the MELG, and of the whole research programme, is the involvement of key partners in the planning and implementation of the research undertaken, and guidance on the key areas that should be included in decision-making to achieve successful closure. To this end, we have established a North Island and a South Island governance panel with whom we meet bi-annually. The governance panels include representatives from Ngati Hako, Ngatiwai, Ngai Tahu, West Coast Regional Council, Waikato Regional Council, Northland Regional Council, Environment Southland, Department of Conservation, Straterra, Minerals West Coast, OceanaGold, Solid Energy of New Zealand, Francis Mining Group and Bathurst Resources. At the suggestion of these governance panels, it has been agreed to produce a separate MELG for different generic mine types. This paper provides an overview of the MELG for Epithermal gold.

Epithermal gold MELG

Epithermal gold deposits are located on the North Island and are mostly hosted in Coromandel area but also in the Northland and Taupo areas. In the Coromandel area deposits are hosted within Miocene to Pliocene volcanic sequences of the Coromandel and Whitianga Groups. These rocks are typically felsic to intermediate volcanic rock sequences, commonly rhyolites or andesites. These deposits are epithermal veins and stock-work systems with classic zoned alteration and mineralised systems.

Mining of gold in the Coromandel area commenced in the late 1800s and continues presently at large opencast and underground mines. Important mineral deposits that have been mined in the last 50 years include the Tui Deposit, Golden Cross, Martha and related underground deposits. Tui is an andesite-hosted polymetallic epithermal style deposit mined mostly through underground methods near Te Aroha, south of the Coromandel Peninsula, until the 1970s. Golden Cross is an andesite-hosted deposit mined by both opencast and underground methods that ceased operations in 1998. Golden Cross is west of Waihi at the south of the Coromandel Peninsula. The Martha deposit is a large quartz vein system that occurs in andesitic rocks currently mined by opencast methods. The Martha deposit has several satellite vein systems (Favona, Corenzo, Trio etc.) that are currently mined by underground methods.

Other epithermal style mineralisation occurs in Northland and the Taupo area. However, only exploration activity without mining takes place in these areas. The host rocks in Northland are the Pliocene Pura Beds and the deposit style is shallow epithermal or sinter deposits. In the Taupo area rare vein mineralisation is hosted by ignimbrites. Northland and Taupo epithermal deposits are currently being explored. The most abundant trace elements associated with the different epithermal deposits that may lead to environmental issues if not appropriately managed are shown in Figure 2.

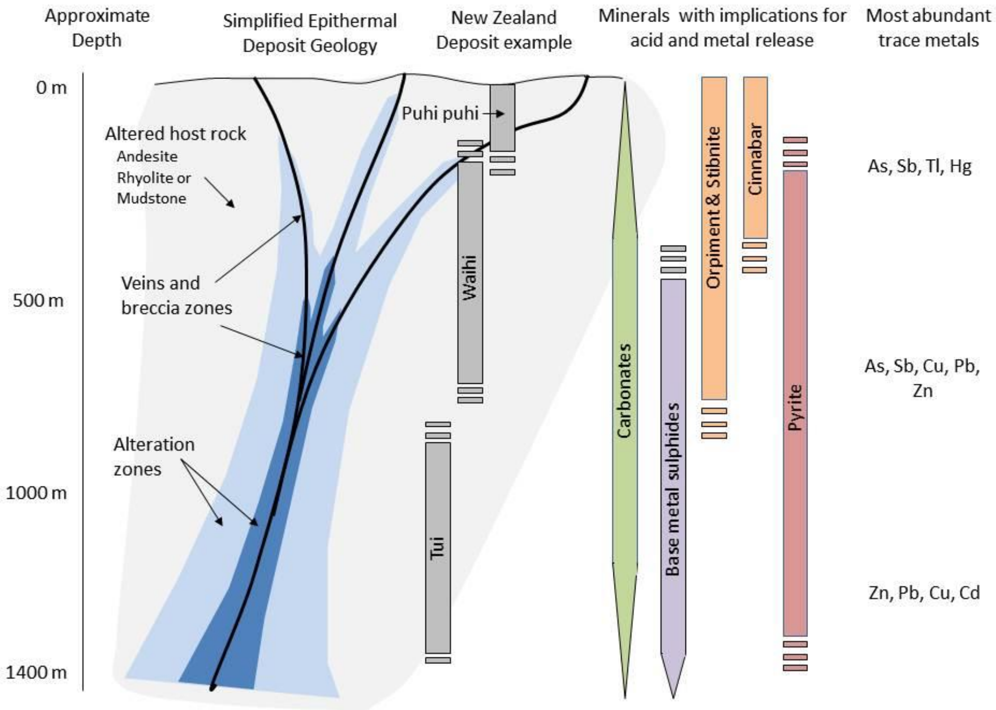

Figure 2 Schematic of epithermal mineral deposit with a generalised model for the distribution of selected minerals that release or neutralise acid or contain trace elements.

A draft version of the epithermal gold MELG has been developed. The MELG includes an introduction and then separate section for each of exploration, pre-operation, operations, closure and post-closure, with Figure 4 providing an overview of the information provided in these different sections. The **Introduction** provides an overview of epithermal gold deposits and mining in New Zealand, regulatory requirements, potential environmental effects including those affecting cultural values, arising from epithermal gold mining, as well as highlighting the need for early and meaningful engagement with stakeholders, including iwi to ensure the critical post-closure outcomes are identified. The introduction also includes the background to the development of the MELG.

Exploration is a small section that covers prospecting and early-stage exploration activities. For the purpose of the document, later-stage exploration activities that are used to help define the feasibility of mining the identified resource is covered under the development section of the Guide.

The **Pre-operations** section is intended to inform initial mine planning and assessments of environmental effects that are required for any Department of Conservation land access arrangements and resource consents. This section outline the types of information that should be collected, guidance on how some of the information should be collected (e.g. baseline studies), and guidance of how this information can be used to inform mining operations. This includes stakeholder engagement to identify desired post-mining outcomes, including different rehabilitated environments (e.g. pasture, native ecosystem), and the identification of resources required to achieve those outcomes

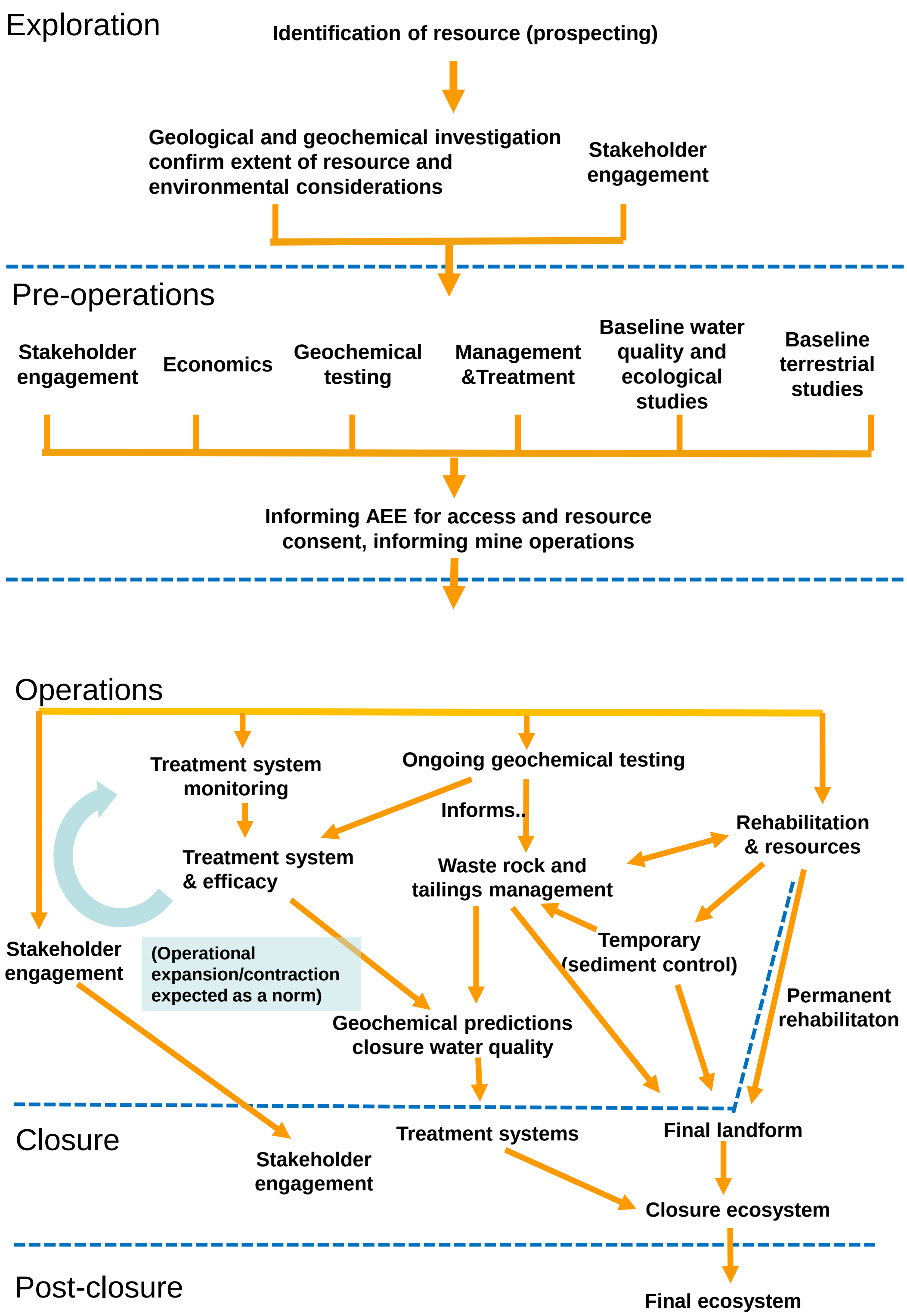

Figure 4. Outline of the content of information to be provided by the Mine Environment Lifecycle Guides. AEE = Assessment of Environmental Effects.

Details on technical studies and monitoring to inform operational management, and to minimise potential environmental impacts are contained within the **Operations** section of the MELG. This includes details on rock geochemical monitoring, kinetic testing, leachate monitoring, management of high walls, waste rock and tailings to minimise negative environmental impacts, requirements to achieve different rehabilitation outcomes. This section highlights the success of different management approaches at different sites through case study examples, and illustrates how information can be used to inform bonding processes. Guidance on external (compliance) monitoring and ongoing stakeholder engagement is provided. Finally, this section provides information on refinement of monitoring and modelling approaches to provide confidence in achieving identified post-mining outcomes. It is recognised that as mining proceeds, some sections of the mine may move towards closure, while other sections of the mine remain operational.

The **Closure** section outlines ongoing monitoring of water treatment systems and rehabilitated areas and stakeholder engagement to ensure that post-mining outcomes can be achieved. It is expected that companies will be actively refining and monitoring treatment systems to ensure that water quality criteria will be met. Similarly, ongoing rehabilitation and monitoring of rehabilitated areas will be occurring to provide evidence for the success of rehabilitation. A mine is considered to have moved to full closure status when mining permits have been relinquished, i.e. no further resource extraction is occurring.

The **Post-closure** section is a small section that essentially outlines the anticipated trajectory to achieving different post-mining outcomes and guidance for monitoring of any enduring treatment systems. A mine is considered to have moved to post-closure when agreement has been reached with regulators (councils, Department of Conservation) that rehabilitated areas are tracking towards the agreed post-mining outcomes and any appropriate systems (e.g. trusts to provide for ongoing maintenance of treatment systems) are in place. This recognises that in some cases it may take many years for the final agreed post-mining outcome to be reached (e.g. for return to native forest ecosystems), but if there is sufficient confidence that with time, the outcomes will be met, then it may be appropriate for the final bond to be released and the company to no longer have liability for the site.

Summary

A draft Mine Environment Lifecycle Guide for epithermal gold mining has been developed. This draft provides the general structure and content for Mine Environment Lifecycle Guides that are being developed for other mine types (e.g. mesothermal gold, potentially acid-forming coal mines). We welcome constructive feedback to ensure that the MELGs provide useful and usable information to ensure the appropriate post-mining outcomes are identified and achieved and that environmental impacts throughout the life of a mine are minimised in a cost-effective and efficient manner. Please contact Jo Cavanagh at Landcare Research or James Pope at CRL Energy if you would like further information.

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