Developing the Mine Environment Life Cycle Guide for mesothermal gold mines

J.E. Cavanagh[1], J. Pope[2], J.S. Harding[3], D. Trumm[2], D. Craw[4], R. Simcock[1], J. Webster-Brown[4], P. Weber[5], K.Simon[6] and F. Eppink[1]

[1] Landcare Research, PO Box 69040, Lincoln 7640, cavanaghj@landcareresearch.co.nz
[2] CRL Energy, PO Box 29-415 Christchurch 8540, j.pope@crl.co.nz
[3] School of Biological Sciences, University of Canterbury, Private Bag 4800, Christchurch 8140, jon-harding@canterbury.ac.nz
[4] School of Geological Sciences, University of Otago, PO Box 56, Dunedin 9054, dave.craw@otago.ac.nz
[5] O'Kane Consulting, PO Box 8257, Christchurch 8440, pweber@okc-sk.com
[6] School of Environment, Auckland University, Private Bag 92019, Auckland 1142, k.simon@auckland.ac.nz

Abstract

A collaborative Ministry of Business, Innovation and Employment (MBIE) funded research programme led by CRL Energy, working with Landcare Research, Otago University, Canterbury University and O'Kane Consulting and key mining partners including mining companies, regional councils, Department of Conservation and iwi is assisting processes for planning and operations of mine developments to minimise environmental impacts. A particular focus is ensuring that post-mining outcomes 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.

This paper reports on the integration of new science, with previous research to develop a draft mine environment life cycle guide for mesothermal gold mines. This includes an overview of the new research that has been undertaken, as well as providing details on the information provided for the different stages (pre-operations, operations, closure and post-closure) of the mine life-cycle and how that can be used to assist in decision-making for mine operations to cost-effectively achieve agreed post-mining outcomes.

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, Southland and the Coromandel Peninsula, for example, have long 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 mining 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 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 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[1]	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

[1]Adapted from GARD Guide

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 Mine Environmental Lifecycle Guide (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, to ensure all relevant closure options are adequately considered. Research undertaken within the current programme will fill also fills gaps in (e.g. in-depth understanding of geochemistry of waste rock stockpiles and high walls).

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 is related to real data rather than estimates and for stakeholders most interested in the post-closure outcomes, and greater levels of certainty of achieving post-mining 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 able 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.

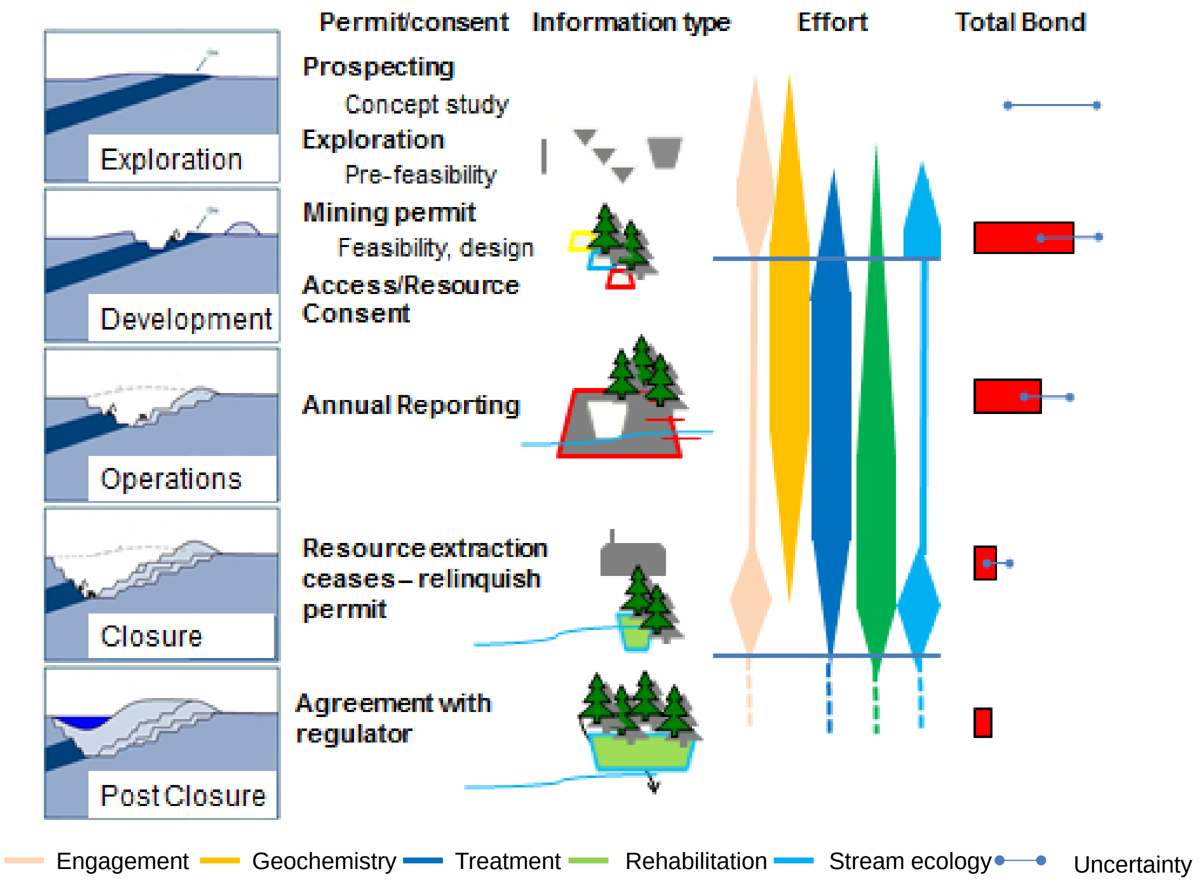

Figure 1. Summary of the relationship between the mine life cycle, the type of information able to be obtained at each stage of the mine life cycle (*e.g.*, laboratory studies, field trials), and the focus of effort required in different areas to reduce the uncertainty associated with the bond and ensure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

A critical component of the MELG, and of the whole research programme, is the involvement of key mining 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, Oceana Gold, Newmont, 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. Mesothermal gold is the first to be developed.

Mesothermal gold MELG

Mesothermal or orogenic gold deposits are confined to the South Island. They occur in the basement rocks of the West Coast, Southland and Otago. These basement rocks are mainly schist and greywacke. The gold deposits consist of mineralised rocks: quartz veins (metre scale), and associated sheared and altered rocks that contain minerals (including gold) that were added to the rocks by hot water passing through faults and fractures. The volume of these mineralised rocks is small compared with the surrounding basement rocks, which are unaltered and unmineralised.

Hard-rock gold deposits involve mining of the narrow mineralised zones in bedrock, either as large open cuts or in underground tunnels. Opencast gold mines produce very large amounts of waste rock, and waste-rock piles 1 km across and 50 m high are common. However, most of this waste rock is barren host rock, with negligible amounts of sulphide and trace minerals. Instead, the principal environmental issues for aquatic systems are discharge of neutral waters enriched in As and Sb (referred to as Neutral Mine Drainage NMD) and high suspended solid loads from tailings dams (Figure 2). The concentrations of As and Sb in mine drainage depend on the mining methods and waste disposal systems used (Figure 3).

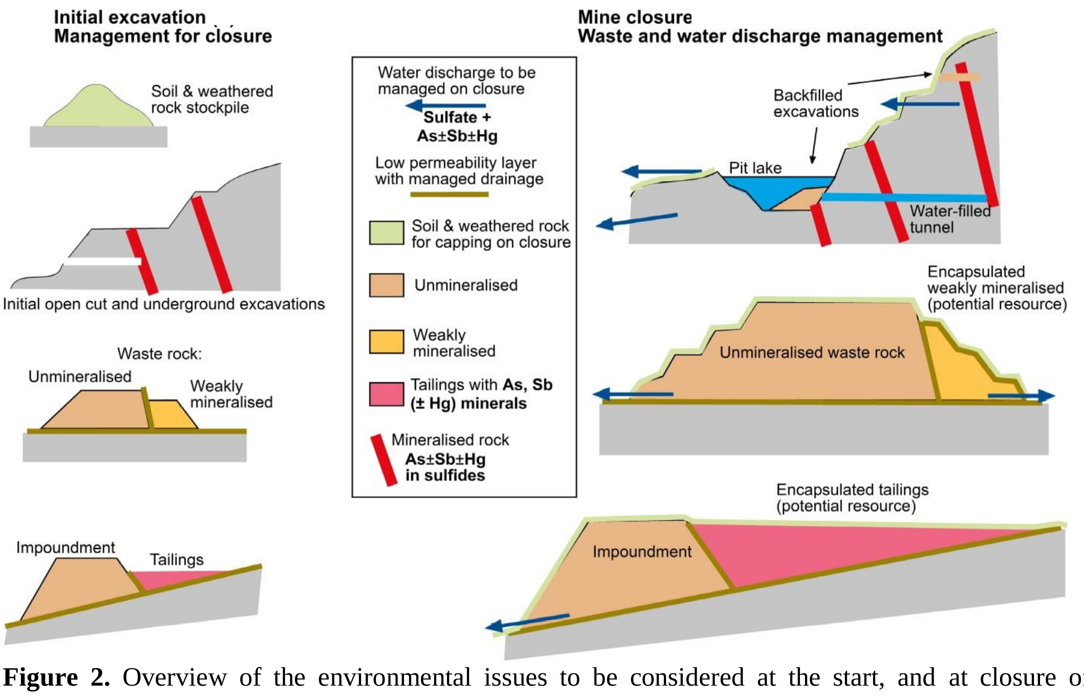

Figure 2. Overview of the environmental issues to be considered at the start, and at closure of mining of mesothermal gold deposit to ensure that post-mining outcomes are achieved.

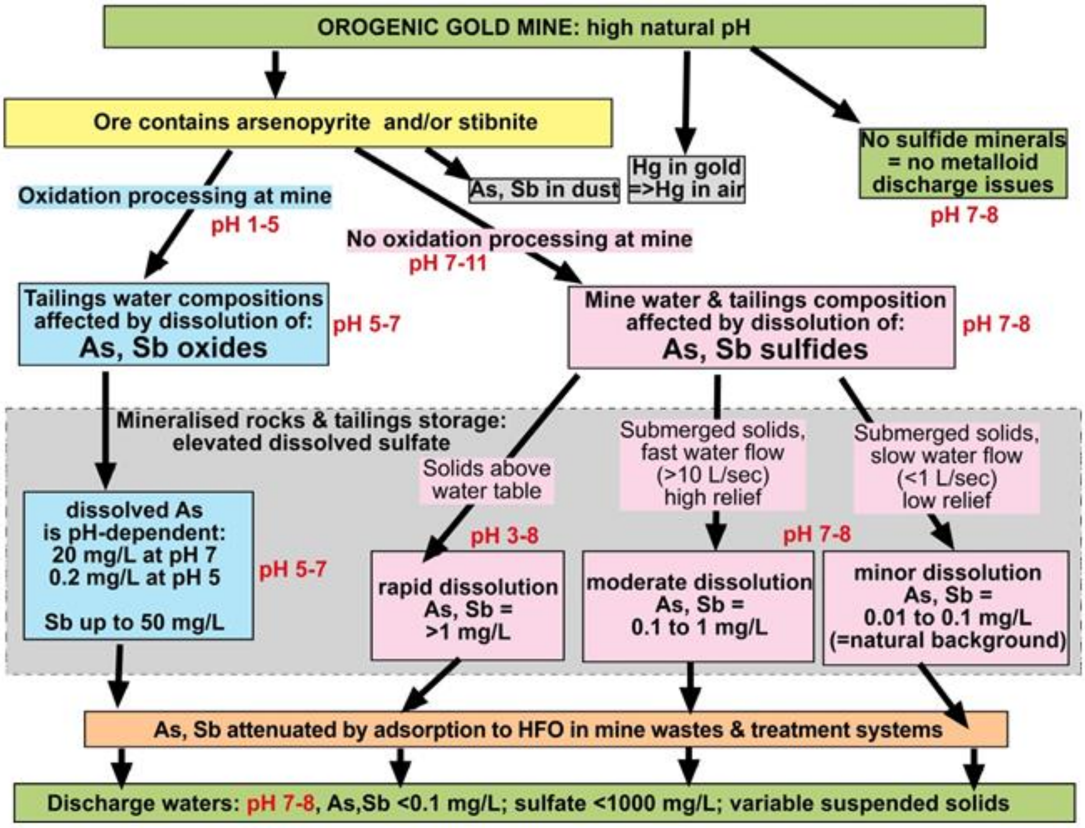

Figure 3. Predicted water quality associated with a mesothermal (orogenic) gold mine, depending on mineralogy of mineralised rock (ore), mine processing system, and topography of the site where waste is deposited.

A draft version of the mesothermal gold MELG has been developed. The MELG includes an introduction and then separate section for each of exploration, development, operations, closure and post-closure, with Figure 2 providing an overview of the information provided in these different sections.

The **introduction** provides an overview of mesothermal gold deposits and mining in New Zelaand, regulatory requirements, potential environmental effects including those affecting cultural values, arising from mesothermal 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 essentially 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 **development** 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

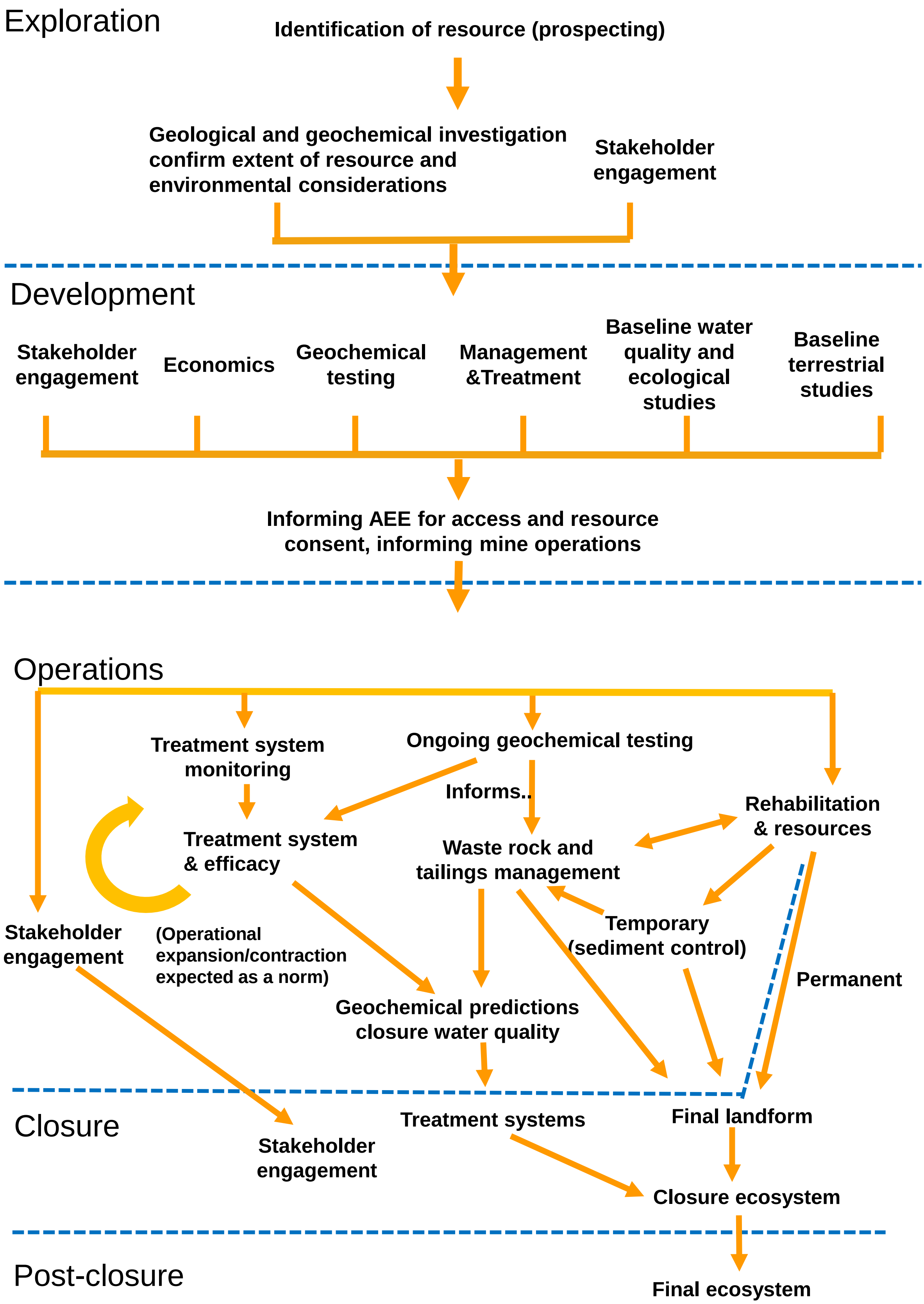

Figure 2. Outline of the content of information to be provided by the Mine Environment Lifecycle Guides.

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. 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. It is expected that companies will be actively refining and monitoring treatment systems and 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.

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 mesothermal gold mining has been developed. This draft provides the general structure and content for Mine Environment Lifecycle Guides that will be developed for other mine types (e.g. epithermal 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.

Acknowledgements

This research was financed by the Ministry for Business, Innovation and Employment, contract CRLE 1403. We thank Ngati Hako, Ngatiwai, Ngai Tahu, West Coast Regional Council, Waikato Regional Council, Northland Regional Council, Department of Conservation, Straterra, Minerals West Coast, Oceana Gold, Newmont, Solid Energy of New Zealand, Francis Mining Group and Bathurst Resources for their involvement and support for the research programme. More information on the Centre for Minerals Environmental Reserch (CMER), including research currently being undertaken is available at: http://www.crl.co.nz/cmer/.

References

Cavanagh, J.E., Pope, J., Harding, J.S., Trumm, D., Craw, D., Simcock, R. and Ross, C. 2015. New Zealand Minerals Sector Environmental Framework. Landcare Research Contract Report LC2033. CRL Report 10-41100. Landcare Research and CRL Energy Ltd.