Assessing rehabilitated land post-mining using a field-based score card

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Abstract

A rehabilitation score card has been developed to assess the efficacy of terrestrial rehabilitation for mine sites. This tool is informed by a review of NZ rehabilitation outcomes and of international mine rehabilitation at closure and restoration standards. The draft score card uses a spreadsheet format to assess the likelihood and magnitude of impacts on critical components of rehabilitation. This assessment generates two visual 'traffic light' outputs: a 'raw' ranking representing current conditions and a residual or 'mitigated' ranking based on application of specific management or controls. Red cells identify high risk and/or high negative impact outcomes, green cells indicate positive outcomes. The difference between 'raw' and 'mitigated' ranking can be used to help prioritise actions and monitoring. The draft score card has been applied to three contrasting rehabilitated areas at the closed Tui Mine, Te Aroha, Waikato and will be included in the CMER programme 'Mine Environment Life Cycle Guides'.

Keywords: mine rehabilitation, closure, rehabilitation assessment

Introduction

A field based tool for assessing rehabilitated land is being developed to assess rehabilitation progress towards mine 'closure'. At closure, a mine site should typically have reached a condition at which it can be returned to a land owner, and the majority of any rehabilitation bonds are returned. Sites should nearly always be geotechnically stable, with minimal surface erosion. Where vegetation is desired[1], a suitable root zone and topography that is capable of sustaining the agreed plants or ecosystems should be in place. This plant cover may however need specific ongoing maintenance to reach or maintain its productivity and/or develop into the agreed long-term, 'post-closure' condition. For many areas, whether pasture, plantation or native ecosystems, this may be similar to 'reference' or undisturbed ecosystems.

Although the score card focuses on closure, it is designed to help identify the positive and negative impacts of actions taken during and prior to revegetation. The objectives for developing the scorecard were:.

- To cross reference closure criteria (commonly used in resource consents and access arrangements) and long term success criteria.

[1] In some cases vegetation is not required to be established across a site, for example, alluvial gold mines may create farm infrastructure such as stand-off pads and races, and some coal mines create areas covered with a high proportion of boulders and rock, sometime for erosion control or to create ecosystems that naturally have a high proportion of rock cover.

- To promote the mitigation hierarchy, i.e. Avoid – Remedy – Mitigate under the Resource Management Act (1991) because damage avoided/minimised is nearly always preferred to rehabilitation, as long as adequate space is available to achieve water treatment and stockpiling of resources such as soil for rehabilitation.
- To be useful for small to medium sites and suitable for use by people with general ecological /land use knowledge, not specialists. Large sites will often have a scale of impact that justifies a more complex approach developed by in-house or consultant specialists.
- Able to be applied over several hours using readily-available information.
- Applicable throughout mining life cycle, not just near closure, to indicate future likely risks and success. This means it includes four stages of rehabilitation: landforms, root zone/surfaces, initial vegetation, and sustained plant cover. Two additional criteria are included for native ecosystems.
- To enable actions that would adversely impact reaching the desired closure conditions to be identified early, and remedied
- Cross reference to international standards, for example, The Society for Ecological Restoration scorecard (six classes of attributes: controlling threats, physical conditions, species composition, community structure, ecosystem function, external changes)

Development of the scorecard

Common factors that determine the success or failure of rehabilitation were identified by reviewing national literature, with findings published as a book chapter (Simcock and Ross 2017) and by reviewing international mine rehabilitation closure and restoration standards (findings not published). In New Zealand, the majority of mines are rehabilitated either to pasture (for grazing) or to native ecosystems; a smaller proportion is rehabilitated to plantation forestry. Common factors underpinning successful rehabilitation of mined land to pastoral uses are well established. The technical capacity to deliver successful outcomes has been demonstrated since the mid- to late-1980s across a range of mine sizes and mine types. Pasture production similar or greater than pre-mining has been achieved after dredging of alluvial and coastal deposits for gold or iron sands, and open cast coal and gold mining from the loess-covered landscapes of Southland and Otago to the ash-mantled Waikato.

At all sites the extent and efficacy of 'avoidance' of impacts is assessed (Step B in Table 1). The assessment focuses on site margins, drains, access roads, drill tracks, sediment ponds and watercourses. The objective is to reinforce practices that avoid the need, expense and risk to? rehabilitation, and prioritise protection of high-value or highly vulnerable ecosystems or landscapes. There are currently four features are assessed in this criterion:

a. Impact along mine edges. The condition and extent of buffer zones is assessed – these are areas that are not covered/stripped but are impacted (dewatering, wind causing dieback, weed impacts) but may need active rehabilitation.
b. Impact of tracks and cut-off drains taking into account practices are used to limit their impacts
c. Impact on watercourses, usually assessed by comparing u/s and d/s of the mine site and its discharges.
d. Impact on unmined, high-value /highly vulnerable areas (e.g. evidence of physically protection)?

Table 1 Steps in the proposed rehabilitation score card.

Step	Description
A. Define rehabilitation objectives	Identify reference site, if relevant. Define closure criteria (short term criteria for bond release) Cross-reference specific consent conditions
B. Assess 'avoidance'	Assess Mine edges, tracks and cutoff drains, watercourses, management of high-value and/or vulnerable areas
C. Assess criteria that underpin rehabilitation success	1. Safe stable topography that creates suitable drainage conditions and erosion controls for identified land use/species 2. Chemically and physically favourable surrogate root zone 3. Dense, erosion-resistant and weed-resistant plant cover 4. Sustainable pasture biomass and soil recovery
D. Assess additional criteria for native ecosystems	5. Natural regeneration indicators 6. Actual and potential pest plant and weed pressures 7. Replacement of wood/logs and habitat features 8. Connectivity across the site and landscape
E. Assess potential for changes	Checklist of indicators of changed risk profile
F. Assess non-vegetation closure requirements	Checklist of structural requirements, e.g. removal of plant, roads, filling of sediment ponds, fencing, historic feature reinstatement etc.

Research and practice at mines rehabilitated to pasture over 30 years has identified four factors or criteria underpinning success: 1) creating a safe, stable topography that strikes a balance between gradients steep enough to ensure adequate drainage yet gentle (and short) enough to resist erosion (e.g. Connolly et al. 1981, Gregg et al. 2003); 2) creating a chemically and physically favourable surrogate soil profile that is usually topsoil over suitable overburden (Ross and Widdowson 1985, Mew and Ross 1991); 3) rapidly establishing a dense vegetative cover to protect surfaces from erosion; and, 4) maintaining pasture biomass that rebuilds organic matter and minimises weed competition by managing fertilisers, soil acidity and grazing pressure. Assessment of these four factors forms the core of the scorecard for pastoral rehabilitation (Step C in Table 1). At many pasture sites these closure conditions can be achieved in less than 5 years given an adequate maintenance regime.

Within each of the criteria, the proposed score card identifies conditions that equate to a high probability of favourable, or unfavourable outcomes. For example, assessment of the volume/depth and quality of salvaged topsoil is prioritised, as in most cases, re-constructed soil profiles that use salvaged topsoil have the highest productivity in the short and medium term, the greatest resilience to variation in climate variation and maintenance, and require the least ongoing inputs. In most cases, mixed topsoil/subsoils and fine textured soils on gentle topography are most vulnerable to compaction, structural and biological degradation and poor outcomes.

Research on rehabilitation to native ecosystems is more recent than that for pasture, being 'virtually non-existent' before 1990 (Gregg et al. 1998). The four main factors underlying success for native ecosystems are similar to those of pasture (e.g. Langer et al. 1999, Rufaut and Craw 2010, Norton et al. 2013, Simcock and Ross 2014). However, the optimal root zone and drainage properties for native ecosystems may differ markedly from pasture. Some native ecosystems require impeded drainage, high acidity, and low chemical fertility – high fertility usually increases competition with non-native species, enhances palatability of introduced pests, and negatively impacts symbiotic mycorrhizae. Native forest ecosystems also benefit from return of wood/logs and slash, unlike pasture sites, and habitat features for specific native animals may be required to enhance re-colonisation and re-establish connectivity across the rehabilitated site. Whereas uniformity of plant growth within paddocks or plantations is highly desirable – and this is underpinned by uniform slopes and root zones, this is not necessarily the case for native ecosystems. The scorecard therefore encourages the 'reference' or 'baseline' conditions that support the desired long-term native ecosystems to be described (Step A in Table 1). These become the conditions against which rehabilitation to post-mining land use can be assessed in the long term, but not at closure.

Unlike pasture, the 'reference' condition is highly unlikely to be met at mine closure for most native ecosystems for two reasons. First, revegetation usually needs to start by establishing a narrow range of native 'seral' species that can establish into the exposed conditions and bare soils of a bare mine site. Second, native shrub land and forests may take decades to centuries to develop height and structural complexity present before mining. Hence the practical guide for 'Revegetation of Alluvial Gold Mines in Westland tai Poutini (DOC 2010) indicates success (closure) is achieved when *'a core of healthy fast-growing native shrubs and trees are established, that can be left without further human assistance to aid development of the site to a complete indigenous plant cover*'. Further, the native seedlings will '*exhibit positive growth... have foliage of a normal healthy cover.. and not be suppressed by weeds*', but natural regeneration through (non-native) weeds is accepted.

These 'interim' conditions for native ecosystem closure criteria are included as the fifth to eighth criteria in the rehabilitation score-card (Step C in Table1). The fifth factor is 'indicators of natural native regeneration'. This is primarily recorded as seedlings self-establishing within rehabilitated areas, and can be predicted by the density of favourable surface microsites, wood/log or boulder density and the plant species present in the seedbank, in any planted areas, and in adjacent areas. The sixth factor is an assessment of the pest plant and animal pressures and the vulnerability of the site to these pest plants and animals. The pest plant criterion is also applicable to some pastoral areas; the pest animal criterion is only relevant for some pastures (for example, West Coast sites affected by pasture-eating beetles) but is critical for many native ecosystems that are vulnerable to browsing hares, goats, possums and deer, even at canopy closure. Browse can reduce survival and growth of palatable native species. The adverse impacts of browsing animals were measured by comparing fenced and unfenced treatments at Giles Creek where broadleaf (*Griselinia littoralis*) and karamu (*Coprosma robusta*) were severely browsed by deer (Langer et al. 1999) and monitored in permanent transects at Strongman Mine, where tutu (*Coriaria arborea*) was eliminated from most monitored transects sites over 6 years. At Tui Mine karamu, wineberry (*Aristotelia serrata*), and koromiko (*Hebe stricta* syn *Veronica stricta*) were removed over three years by goats. At Stockton mine, growth of *Coprosma propinqua* and broad-leafed tussock (*Chionochloa conspicua)* adjacent to fenced plots was suppressed by hares. Mew et al. (1997) also reported native seedlings browsed by stock where fences were ineffective in West Coast mine sites.

Within each criterion, current performance is scored using the matrix below. The risk likelihood/probability and severity of consequence delivers a 'raw' ranking. The basis for low, medium, high or extreme ranking is provided in supporting photos, descriptions and case studies A second ranking is also given based on residual or 'mitigated' ranking after specific management or controls are applied. The specific controls are recorded as written line items on a separate sheet; the rationale is that these will be useful to identify and prioritise actions that deliver the most beneficial outcomes for closure.

Likelihood	Magnitude of biodiversity impacts				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	H	H	E	E	E
Likely	M	H	H	E	E
Moderate	L	M	H	E	E
Unlikely	L	L	M	H	E
Rare	L	L	M	H	H

L=low **M**=medium **H**=high **E**=extreme

Figure 1 Matrix for assessing and scoring each rehabilitation criterion.

A final section (E in Table 1) is a checklist of factors that influence the likelihood that planned rehabilitation will meet closure criteria. Again, each point on the checklist is rated according to the likelihood and magnitude of risk to rehabilitation success. The factors include the following:

a. Change in life of mine (especially if this is decreased), or new areas opened up (creating opportunities) or remining of areas (may impact rehabilitated areas and outcomes as root zone quality usually decreases with rehandling);
b. Changes in mine plan direction, mining process (or processing, e.g. tailings change), scale (new infrastructure) or rate;
c. Change in equipment or method of stripping root zones or overburden (especially if the site contains acid-producing rocks that must be separately managed);
d. Change in rehabilitation plan – methods/process, scale or pace of rehabilitation including changes in root zones, landform contours, sediment/erosion control strategies (e.g. use of hydroseeding instead of slash cover), change in suppliers of plants/planting contractors, change in plant species or suppliers of plants;
e. Non compliances or design changes that indicate flaws in construction or operation or assumptions (e.g. ex pit overburden stability, tailings properties);
f. Change in land use or operation in areas adjacent to the mine (e.g. clearance or drainage for pasture establishment reducing connectivity and native propagules, felling of plantations creating sudden increase in weed pressure);
g. Evidence of adaptive management in rehabilitation. Adaptive management reduces risk, especially if it is based on monitoring by the mining company, and use of ‘control’ sites in which standard practice is used, alongside areas where alternative management is applied, and recorded.

The rehabilitation score card is intended to be useful all sites, but small and medium sites in particular, as these mines do not usually have specialist rehabilitation staff, and their compliance with revegetation requirements may be assessed by staff for whom mining is a small component of their work. In this case, there may be little information to underpin the adaptive management required to improve outcomes; actions that may adversely impact reaching the desired closure conditions may not be detected early enough. Such actions may be driven by short-term financial indicators that incentivise cost controls at the expense of sub-optimal or more expensive medium to long-term rehabilitation outcomes. Cost control actions that have these unintended consequences include: mining low overburden ratio areas/high grades; delaying rehabilitation; reducing overburden contouring and any backfills that require double handling, and; adopting short hauls that can lead to poor placement of soils and overburden, reducing blending of acid and non-acid material in backfill, or delaying covering of acid-generating material. Less valuable (lower grade) areas may be left behind. All these actions may slow rehabilitation and 'closing' areas.

Conclusion

A draft terrestrial rehabilitation score card requires definition of closure (short term) and long term rehabilitation objectives. The scorecard identifies high and low risk rehabilitation approaches. If used throughout mining, it should help avoid high-risk practices such as creating inaccessible high walls or inadequate root zones (e.g. hostile overburden, absence of topsoil, inadequate drainage) or deferring rehabilitation. Low-risk practices such as topsoil replacement and direct transfer of vegetated sods or soil should be encouraged.

Identification and assessment of areas where avoidance of minimisation of impact could or has been achieved (i.e. along disturbance edges) are intended to specifically encourage application of the mitigation hierarchy specified in the Resource Management Act 1991. When done at an active mine site such assessment may help direct future 'optional' impacts away from highest-value or most vulnerable ecosystems (e.g., oldest trees, most intact ecosystems, watercourses) and help evaluate impacts of mine plan changes on 'closure' against shorter term benefits that might be gained by, for example, deferring rehabilitation or not salvaging or immediately using suitable root zones for rehabilitation.

The score card could be used to assess sites with a range of rehabilitation outcomes, by separately analysing areas with similar topography, root zones and vegetation cover. For example, high walls have limited root zones, and drainage on overburden landforms is controlled by slope and root zone permeability (and depth). We plan to add cultural indicators to the score card as it is tested and refined over summer 2017/18, using case study sites volunteered by industry, DOC and regional councils.

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