



A standard for design life and durability for engineered mine wastes structures



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ABSTRACT

Within Australia, and arguably more widely, there is a dearth of mine site rehabilitation that has been validated as successful against agreed objectives and targets. One reason for this is the absence of accepted design life and durability standards, applied during the planning and design of major mine wastes landforms such as tailings storage facilities and waste rock dumps, against which performance can be assessed. The themes of design life and durability have been applied in other engineering disciplines such as construction, manufacturing, and transport infrastructure. Therefore, the template exists; albeit its application to mine wastes landforms is more complex, given the uniqueness of each mine site and the materials available for landform construction. Given the poor rehabilitation performance of the industry to date, an increasingly informed and sceptical public may no longer accept assurances that structures will be risk free for periods of 1000 years or more. In view of this, the industry and the regulator must present realistic expectations and be clear about, and have mechanisms in place to manage, residual risks. This paper aims to address this question and provides a framework around which standards that account for different levels of risk can be developed for design life and durability for engineered mine wastes structures.

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1. Introduction

The premise for this paper, first presented in [Butler et al. \(2015a\)](#), is that poor rehabilitation outcomes are an inevitable consequence of the lack of consideration of design life and durability in the construction of mine wastes structures that usually account for the greatest residual risk to the environment after mine closure. The authors believe this is partly due to the absence of an appropriate standard or code for engineers to work towards. This paper provides a framework for the development of such standards in the expectation that this will result in further discussion and development of this approach in the mining sector. It is a pragmatic alternative to the current nebulous case of nominating performance in perpetuity. The framework provides a mechanism that regulatory agencies may adopt to standardise assessment of potential long-term consequences associated with these structures, including the quantification of relevant time periods and a funding structure to capture costs for on-going management once they are

relinquished.

The following provides the context for this position. It presents a broad review of critical aspects of rehabilitation performance as a precursor to the discussion on standard development.

1.1. Rehabilitation

Rehabilitation may be defined as the return of a disturbed site to a form, productivity level, and environmental condition that conforms to an agreed land use that may not necessarily be the original use (adapted from [Bell, 1996](#)).

Four general rehabilitation goals have been established in Queensland and Western Australia ([DEHP, 2012, 2014](#); [EPA, 2011](#)) that require the rehabilitated areas to be:

- safe to humans and wildlife (this is related to mass stability and the presence of hazards such as voids and adits)
- non-polluting (referring to residual contamination that might affect human health and environmental values such as land, air, surface water, and groundwater)
- stable (resistant to erosion)

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- able to sustain an agreed post-disturbance land use (long-term sustainability of agreed rehabilitation outcome whether it be a conservation, agricultural, recreational, or other nominated post-mine land use, but generally including a revegetation component).

These do not require, nor do they imply, restoration to original condition.

The technical approach to rehabilitation is straightforward; broadly, the rehabilitation strategy is a function of the:

- characteristics of each landform land area (pre-disturbance and post-disturbance) and raw materials available for rehabilitation (site biophysical opportunities and constraints)
- desired post-mine land use and rehabilitation outcome for each land area (environmental protection requirements and within the context of community desires and capacity).

Delivering this on the ground is not so simple and is made more difficult by the poor definition of agreed objectives and targets that can be used to validate the attainment of the desired goals.

1.2. Performance to date

Despite extensive knowledge of the rehabilitation process and component parts (AMIC, 1990; Bell, 1996; DEFRA, 2004; DEHP, 2014; DITR, 2006; EPA, 1995a; Hannan, 1984; Hannan and Bell, 1986), and contrary to numerous publications that purport rehabilitation is well in hand, or that certain rehabilitation methods have been validated (e.g. AMIC, 1987, 1989; Astolfi et al., 2000; DITR, 2006; EPA, 1995a, 1995b, 1997), successful rehabilitation outcomes for mining related activities are scarce in Australia.

Examples of rehabilitation previously reported in various publications describing “Best Practice” or “Leading Practice Sustainable Development” (notably EPA, 1995a, 1995b, 1997; DITR, 2006), and/or achieving environmental excellence awards from government and/or non-government professional bodies (e.g. *Queensland Premier's Excellence Award*, *AMEEF Environmental Excellence Award*), have not achieved the environmental outcomes that were promoted. A decades old example is the Mary Kathleen mine, which was rehabilitated between 1982 and 1985 and received an award for environmental excellence from the Institute of Engineers Australia in 1986 (Lottmoser, 2012). Evidence-based reporting detailed in Lottmoser (2012) demonstrates that key predictions made on the geochemical behaviour of the waste rock dumps and tailings storage facility have proved to be incorrect. Following nearly 50 years of mining activities at one of the world's largest open cut bauxite mines in Cape York in Queensland, where rehabilitation works commenced in 1966, demonstrated rehabilitation performance against agreed outcomes has not been achieved (Gould, 2012).

A key outcome of a review undertaken for the preparation of a rehabilitation standards benchmarking study (NRA, 2013; unpublished), that informs this overview of rehabilitation, was the lack of documented rehabilitation success. Over the past 15 years many authors have reported that, for some parts of Australia, there are significant areas of mining disturbance that cannot be relinquished (Anderson, 2002; Haymont, 2012; Lamb et al., 2015; Mudd, 2004; Short, 2015). Some have suggested this lack of performance is, at least, in part because the rehabilitation standards established by mining companies and/or the regulator are poorly defined, unmeasurable, inappropriate (not site-specific), or simply unachievable (Blommerde et al., 2015; Butler et al., 2015b; Butler and Anderson, in preparation; Glenn et al., 2014). Legacies created by mining activities occur globally (e.g. Fourie and Brent, 2006;

Laurence, 2011; Moran et al., 2014; Nehring and Cheng, 2016; Schoenberger, 2016; Unger et al., 2012; Worrall et al., 2009); the need for a change in practice, to avoid the significant social, economic and environmental problems which impact across generations, is clear.

Rather than being a temporary land use, mining is a transformative land use. The implication of this is that, following mining, it may not be possible to reinstate the pre-mine land condition and/or land use (Butler et al., 2015a; Doley and Audet, 2016; Worrall et al., 2009). When formulating rehabilitation standards, it is necessary to acknowledge the uncertainties associated with biological systems relied on in revegetation practices, and limitations inherent in any engineered structure.

1.3. Uncertainties and limitations

1.3.1. Vegetative component

There is still a perception perpetuated in mine approval submissions or conditions of approval that particular desired or pre-mined land uses or natural ecosystems can be established on the reconstructed landforms, and that natural recovery processes can be harnessed through carefully planned rehabilitation management.

Where there has been little modification to the landform or substrate used for soil profile reconstruction (such as in mineral sand or bauxite mining), the re-establishment of similar communities may be possible (see Doley and Audet, 2016 for a good precis of the rehabilitation success achieved for bauxite mining in Western Australia).

In the majority of cases, particularly where waste landforms are constructed to contain reactive mine wastes, the limited success of reinstating pre-mine ecosystems is not surprising considering the scale of the biotic and abiotic disturbance associated with changes in lithology, hydrology, geomorphology, biogeochemistry, and soil physical characteristics. A failure to understand that these changes require a careful approach to setting appropriate post mine land use or vegetation community targets, accounts for the inability to return vast areas of land disturbed by mining to sustainable cattle grazing (documented in Erskine and Fletcher, 2013).

The biotic and abiotic constraints can be addressed, but in these situations the establishment of a novel ecosystem (one with no natural analogue based on the concept of Hobbs et al., 2006; Seastedt et al., 2008) is almost inevitable (Doley et al., 2012; Mascaro et al., 2013; OTML, 2009). There is some controversy about whether this is a legitimate outcome, with some suggesting it is the lowest common denominator (Aronson et al., 2014; Humphries and Tibbett, 2015; Murcia et al., 2014). It is, however, an appropriate objective, provided appropriate standards are applied. Butler et al. (2015b) suggested that such standards should reflect the establishment of a rehabilitated ecosystem that:

- contains sufficient biotic and abiotic resources to continue its development without further assistance or subsidy (inputs)
- is able to sustain itself structurally and functionally (no dysfunctional elements)
- can demonstrate resilience to normal ranges of environmental stress and disturbance
- interacts with contiguous ecosystems in terms of biotic and abiotic flows and cultural interactions (ecologically, socially and culturally integrated into the landscape).

There is sufficient evidence available to provide guidance on the time required before desired rehabilitation outcomes (or, at least, certain trajectory towards it) can be demonstrated. In a review by the authors documented in Ok Tedi Mining Ltd. (OTML 2009),

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