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Internally draining rehabilitation: lessons from several decades of experience at Newlands Coal Mine

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Abstract

Internally draining rehabilitation (IDR) is a landform design approach applied in mine closure to enhance water retention, support vegetation establishment, and improve slope stability by reducing effective batter lengths. Variants of this concept include 'moonscaping' and internally draining landforms (IDLs). IDR has demonstrated potential to improve rehabilitation performance, particularly in arid and semi-arid environments where evaporation exceeds rainfall.

Newlands Mine, a large-scale open cut and underground coal operation in central Queensland Australia, operated from 1983 to 2023. Over its operational life, multiple landform design strategies were trialled, creating a valuable long-term record of rehabilitation performance and evolution.

Between 1991 and 2006, IDR was the preferred rehabilitation methodology at Newlands. The approach incorporated steep external batters and hummocky internal microtopography intended to maximise water retention, enhance hydrological function, and reduce sediment transport. Post-rehabilitation monitoring has shown variable performance across IDR areas, with outcomes strongly influenced by soil properties, particularly near outer batters where susceptibility to piping and erosion is elevated.

Although the site transitioned to conventional externally draining landforms after 2007, Newlands now provides a rare 20–30-year dataset on IDR performance. In addition, long-term erosion trajectories have been modelled over timeframes of up to 300 years using the SIBERIA landform evolution model (LEM).

Drawing on several decades of monitoring, maintenance records, and long-term geomorphic modelling, this paper evaluates the performance of IDR at Newlands and provides guidance on the conditions under which this landform design concept can be most effectively implemented.

Keywords: *mine rehabilitation, IDR, IDL, erosion, LEM, moonscaping, Newlands*

1 Introduction

Landform design is a critical component of mine closure, directly influencing long-term stability, erosion risk, hydrological function, and the establishment of sustainable post-mining land uses (PMLUs). In arid and semi-arid environments, conventional externally draining landforms often struggle to retain sufficient moisture to support vegetation establishment and may remain vulnerable to ongoing erosion and sediment loss.

These challenges have driven interest in alternative landform design approaches that explicitly prioritise water retention and run-off control. Internally draining rehabilitation (IDR) represents one such approach, seeking to modify surface microtopography and internal drainage pathways so that rainfall is retained within rehabilitated landforms rather than rapidly exported from the site.

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Newlands Coal Mine provides a unique long-term case study for evaluating IDR at operational scale. More than 3 decades of rehabilitation activity and multiple rehabilitation methodologies were implemented under evolving regulatory frameworks and operational constraints. This paper synthesises field observations, monitoring records, certification experience, and long-term geomorphic modelling to evaluate the performance of IDR and to clarify where this approach remains appropriate within modern industry rehabilitation practice.

2 Origins of internally draining rehabilitation

The literature traces the roots of IDR back to the 1970s. Jones et al. (2012) credits the development of the 'moonscaping' technique to the Mt Whaleback operation in Western Australia, where the technique was noted as being 'successful', although a clear definition of success with comparison to completion criteria was not provided.

The concept of moonscaping is conceptually similar to IDR referred to at Newlands. Moonscaping controls rainfall run-off in a manner that minimises erosion and maximises rainfall infiltration to assist in the development of a sustainable vegetation cover. Moonscaping was implemented through the formation of scallops in the landform as depicted in Figure 1. This photograph was taken following a cyclone and apparently performed very well.

Figure 1 Successful moonscaping in Western Australia, iron ore mine, after a major cyclone (Note: Photo taken by H. Jones in 1978 as presented in Jones et al. [2012])

There are examples from Western Australia where moonscaping approaches have not been successful. The example presented in Figure 2 shows a cascade failure that occurred in 1998. The failure was attributed to different physical properties of the waste materials and the more intense rainfall over a long period which resulted in major damage.

Figure 2 Failed moonscaping in northern Western Australia in the first wet season after construction, iron ore waste dump (Note: Photo taken by H. Jones in 1998 as presented in Jones et al. [2012])

Jones et al. (2012) concluded that standardised landform prescription and design technique cannot be developed, and site-specific considerations including soils, climate, geochemistry, vegetation and many other factors feed into the applicability of moonscaping.

In 2017, a team of Anglo American's rehabilitation representatives in South Africa benchmarked moonscaping in the Pilbara (Lacy et al. 2018). The quality of rehabilitation and stability given ~20–30 years since application appeared comparable with surrounding areas. Landforms appeared stable, vegetation (grass and trees) establishment was in progress, particularly if some fine wastes/topsoil were added to the coarse waste rock surface prior to treatment. The team were satisfied by looking at field tests of the concept to use the method at their mine.

These findings underscore that internally draining landforms (IDLs) are highly context-dependent, with performance strongly governed by material properties, climate, landform geometry, and construction quality rather than landform concept alone.

Moonscaping experience in Western Australia was the nucleus of IDR that would later be rolled out in Queensland.

3 Internally draining rehabilitation at Newlands

3.1 Adoption of internally draining rehabilitation

IDR was introduced at Newlands in the early 1990s, following similar adoption at Oaky Creek Coal Mine. IDR was championed by Mt Isa Mines (MIM) as a way to achieve rehabilitation outcomes in a cost-effective manner. IDR was the preferred rehabilitation methodology at Newlands through to 2006, being applied across a range of rehabilitation areas within the operation.

Under the Environmental Management Overview Strategy (EMOS) in force at the time, rehabilitation landforms were permitted to be constructed with angle-of-repose batters, typically around 37°, with benches integrated into the design. The IDR landform concept aimed to:

- capture most of the rainfall on the top of the landform
- retain water within defined 'cells' to support vegetation establishment
- reduce erosive run-off from rehabilitated surfaces.

Contour drains were constructed across landforms to intercept light rainfall events, while run-off from external slopes was directed to large toe bunds and diverted into mine water storages or clean water drainage systems. Topsoil was preferentially placed around the edges of the internal cells, with the expectation that vegetation established within the cells would progressively develop its own growth media over time. An example of the typical IDR created at Newlands is provided in Figure 3.

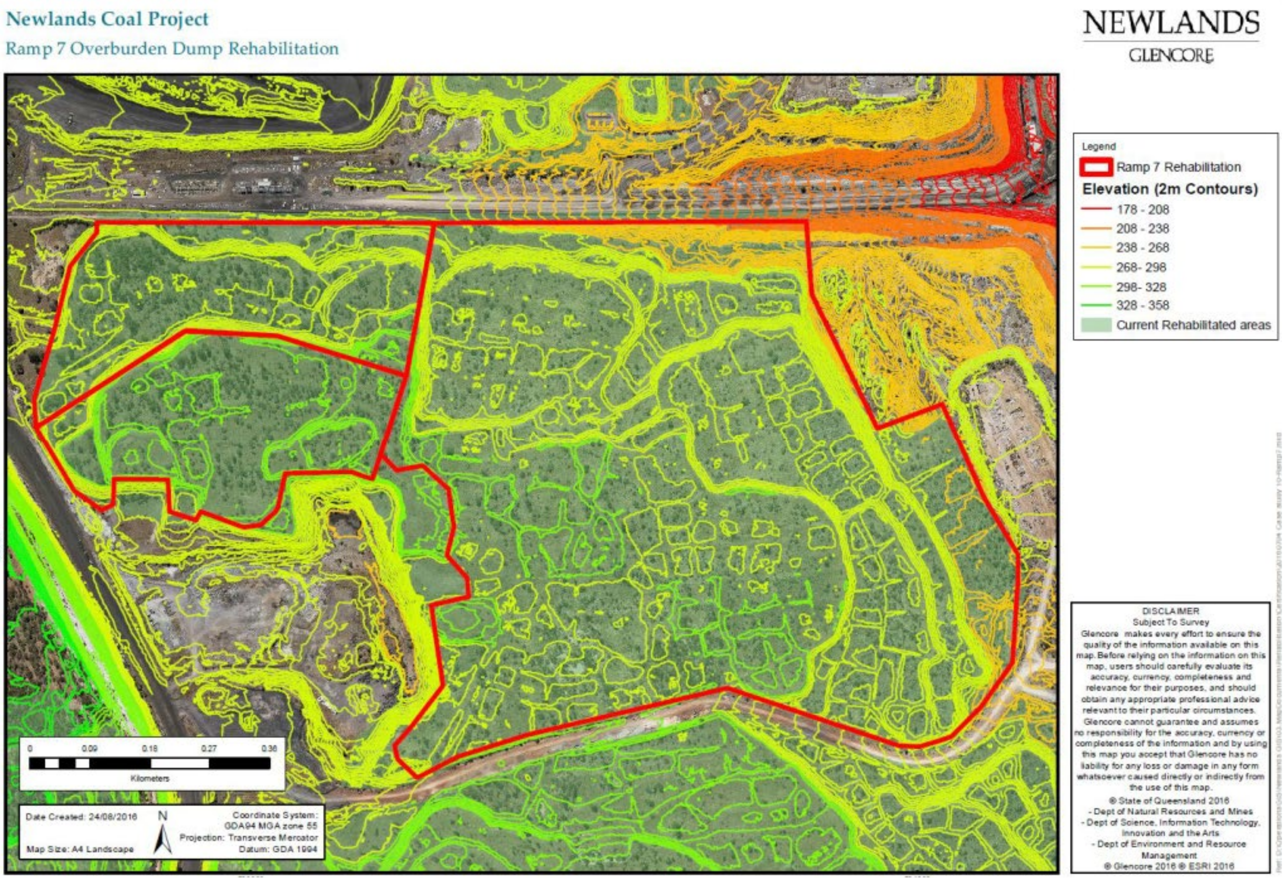


Figure 3 Ramp 7 IDR contours

While IDR aligned with regulatory expectations of the period, its active development and scaling at Newlands was driven by worsening erosion performance under conventional designs. The primary driver became recognition that erosion control was fundamentally a water retention problem, not simply a slope angle or revegetation issue. The IDR approach deliberately challenged prevailing industry practice by seeking to retain water on site, rather than drain it away rapidly.

3.2 Organisational change and regulatory acceptance

At the time, this approach was highly contentious with major operators and government bodies opposed to the minimum intervention and internally draining practices, viewing retained water as inherently unsafe or undesirable. Against this background, Newlands pursued IDR deliberately as a step-change approach, relying on dozer-pushed contouring and integrated landform shaping to slow run-off and improve infiltration.

Although technical performance initiated the rollout of IDR, the methodology increasingly became a mechanism for organisational and cultural change. Newlands faced a substantial rehabilitation backlog inherited from earlier mining phases. Rather than pursuing incremental improvements, leadership deliberately used IDR to shift from a compliance-defensive posture to a proactive, outcomes-focused outlook. This occurred during a period of record low coal prices, when rehabilitation investment was under intense scrutiny.

Prior experience within MIM, where large-scale rehabilitation programs had already been delivered, provided confidence that rehabilitation could be scaled without compromising operational viability.

Early rehabilitation efforts were constrained by regulatory uncertainty, particularly the reluctance to rehabilitate where formal approval pathways were unclear. Newlands addressed this through sustained engagement with regulators, research and monitoring. A deliberate emphasis was placed on demonstration and evidence, rather than reliance on theoretical arguments. Novel delivery methods were trialled, including helicopter-based aerial seeding and performance specification for seed suppliers based on germination rates.

To quantify the performance of the IDR methodology, Newlands completed technical assessments including large-scale infiltration experiments, ecosystem analysis, erosion studies and spoil characterisation (McNamarra et al. 1998; McNamarra et al. 1999). Field trials were performed to flood irrigate IDR cells, intentionally applying large volumes of water to stress-test infiltration, erosion resistance and surface stability. These plots were then forensically examined to review salt migration, and soil chemical changes with depth. Performance data were presented at industry forums to share learnings.

These efforts led to formal regulatory acceptance of IDR, effectively removing a significant barrier to its mainstream adoption on site. MIM won the 2000 Australian Minerals and Energy Foundation's Environmental Award for a large company in response to its environmental and mine site rehabilitation over the preceding 3 years.

3.3 Evolution of design methodology and recognised limitations

Internal rehabilitation quality reviews that occurred in mid-2000s, under new ownership, identified that historical IDR performance was variable. Some IDR landforms were found to be:

- rigid and unnatural in form
- prone to waterlogging and boggy internal areas
- susceptible to evaporation-driven salinity accumulation, inhibiting vegetation establishment.

This was particularly evident at Ramp 1, where fine materials had accumulated in low-lying areas, reducing infiltration and inhibiting vegetation establishment. Where these issues occurred, additional maintenance or re-work was required to meet contemporary rehabilitation expectations.

These findings reinforced that landform design is inherently dynamic. Rehabilitation methodologies have continued to evolve, informed by monitoring results, improved understanding of spoil behaviour, vegetation performance, changing climate and stakeholder expectations. Contemporary landform design now reflects conventional landform design that has been reflected in the progressive rehabilitation and closure plan schedule.

As a consequence of the evolution of practice at Newlands, there are 2 distinct periods: pre 2006 and post 2006. This coincides with a period of ownership change on site, and the new approach. Figure 4 shows the cumulative area of rehabilitation undertaken since 1992 and the predominant rehabilitation approach.

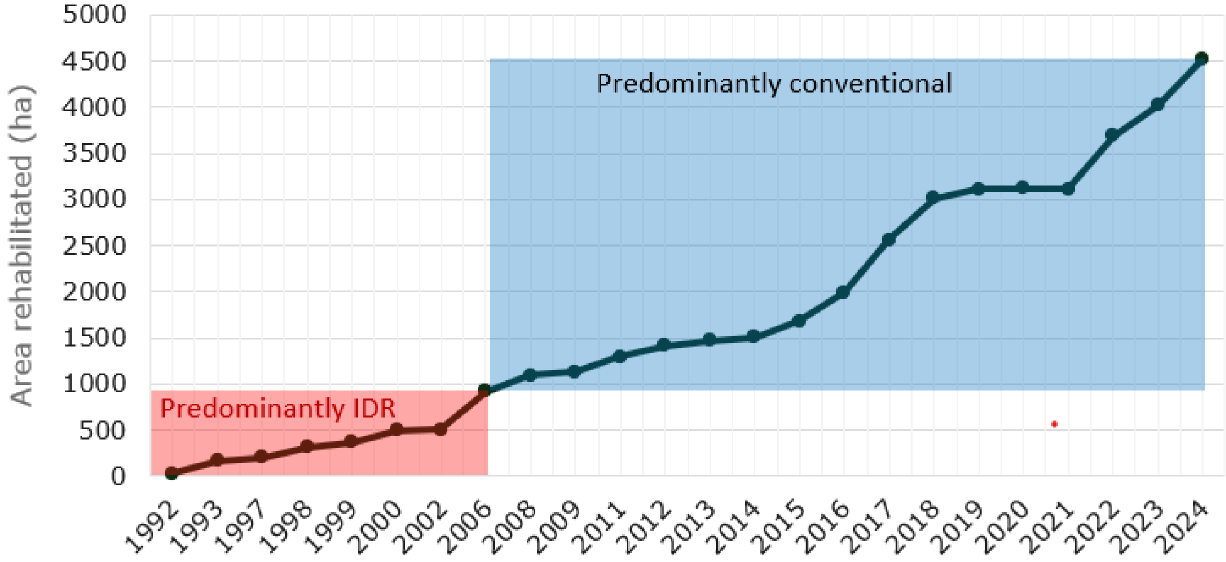


Figure 4 Progressive rehabilitation at Newlands

4 Performance measurement

4.1 Landform evolution modelling

Erosion performance of the Newlands IDR landforms was assessed using the SIBERIA LEM, a physically based computer program used by engineers and geomorphologists to simulate how landscapes change and erode over long periods (typically decades or centuries). Results were examined for both vegetated and non-vegetated scenarios to reflect likely bounds on long-term behaviour. This separation recognises the strong influence of vegetation on erosion rates and gully development at Newlands.

The model was run over a 300-year simulation period, with outputs assessed at 10, 100, and 300 years. Digital elevation model (DEM) inputs were supplied by ERM and provided as a high-resolution 2 m gridded DEM, sufficient to capture hillslope curvature, surface microtopography and drainage controls relevant to IDR landforms.

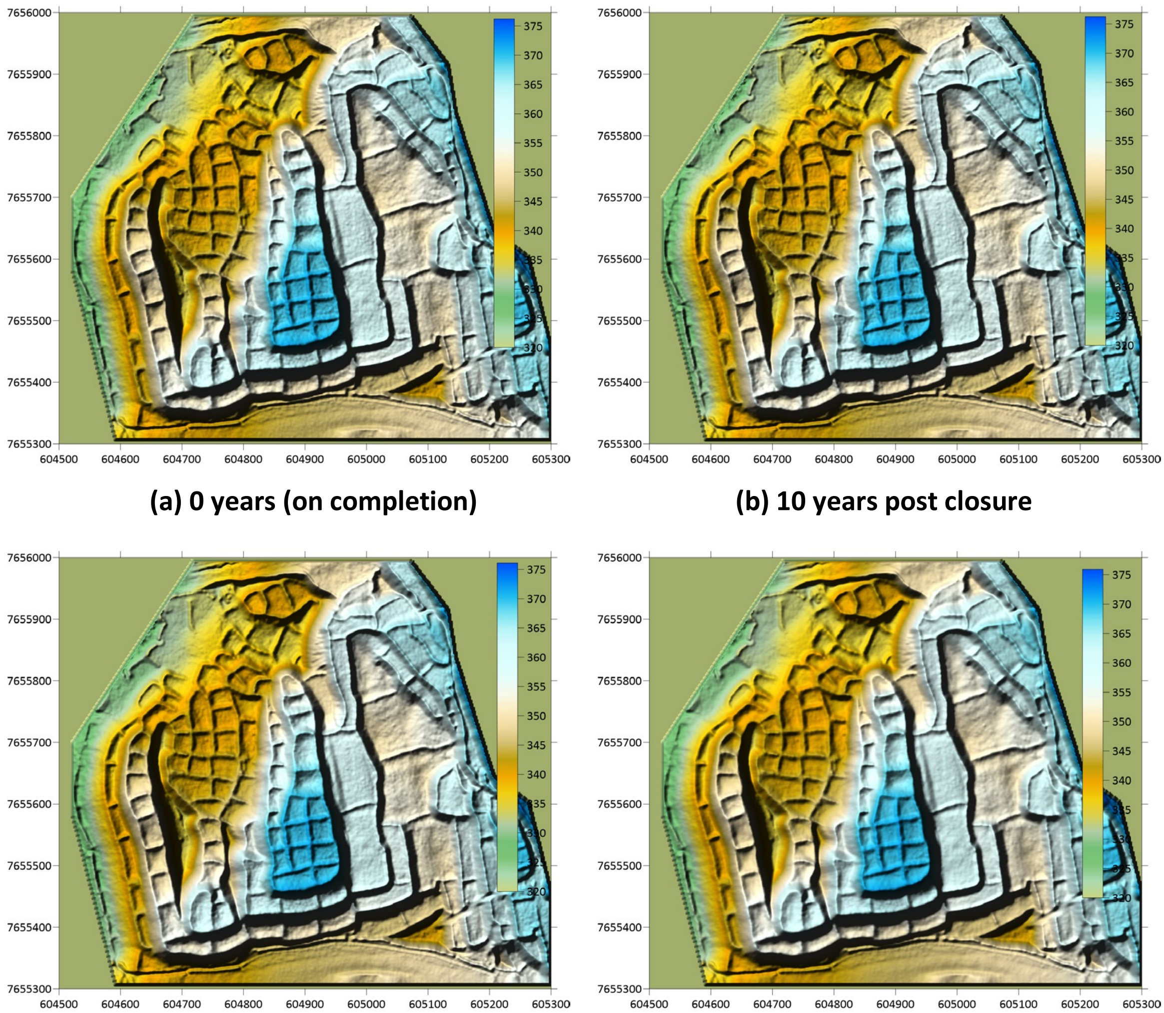
SIBERIA parameters were derived from Newlands-specific field data collected during earlier erosion research programs, including rainfall simulator and flume studies used to develop the Queensland Coal Association Version 1.0 erosion database (Gyasi-Agyei & Willgoose 1997; Sheridan et al. 2000; Willgoose 2005). These datasets were based on an extensive 3-year field campaign at Newlands and represent site-specific erodibility characteristics for mine spoil and surface materials.

The base parameter set represents topsoil-covered surfaces with no vegetation. For vegetated hillslopes, erosion rates were adjusted using a RUSLE vegetation cover C-factor, with a value of 0.1 adopted to represent moderate vegetation cover. This value was selected based on published literature (e.g. Wischmeier & Smith, 1978; Blanco & Lal 2008) and refined using Australian vegetation cover mapping (Teng et al. 2016). The reduction in erosion was implemented by modifying the SIBERIA b1 parameter accordingly.

While these parameters are robustly derived for Newlands materials, their direct applicability to all IDR surface configurations remains an uncertainty and is acknowledged when interpreting the results. Model outputs are presented in Table 1 and Figures 5 and 6.

Table 1 Modelled erosion rate (m³/ha/yr)

Year	No vegetation	Vegetation
10	3.94	3.82
100	3.80	3.66
300	3.21	3.00



(a) 0 years (on completion)

(b) 10 years post closure

(c) 100 years post closure

(d) 300 years post closure

Figure 5 Landform surface elevation (mRL) with vegetation at various points in time

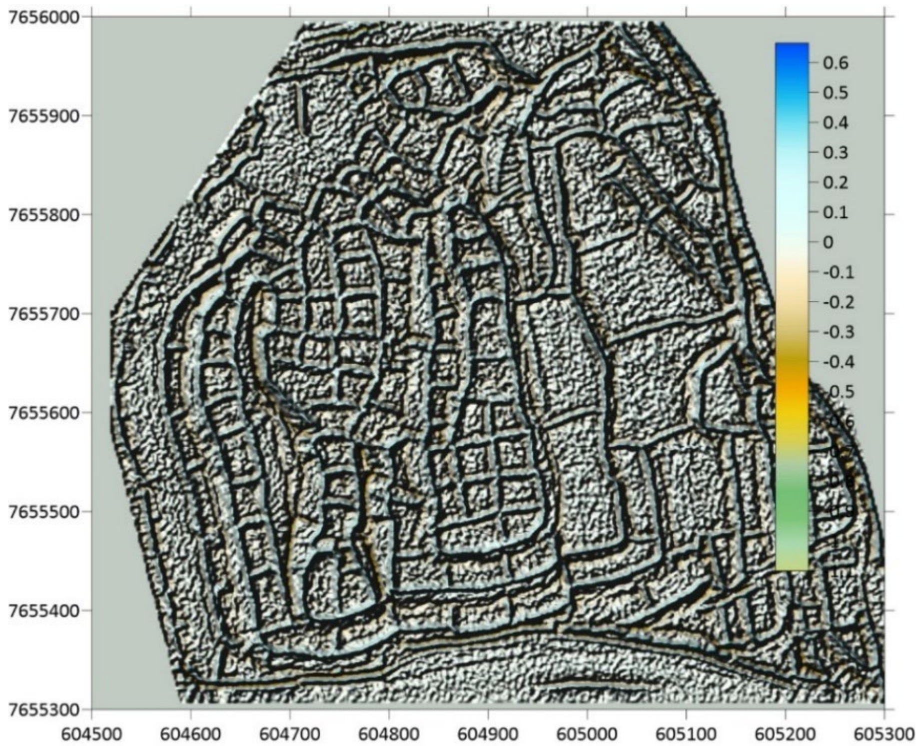


Figure 6 0 to 300 years difference plot – vegetation

These indicate that the IDLs are geomorphically stable, with low erosion rates and limited gully development under both vegetated and non-vegetated scenarios. Across all timeframes modelled, erosion rates remain low and gully depths shallow, particularly where vegetation is present.

Erosion rates decrease slightly over time, reflecting landform adjustment and smoothing. Maximum gully depths increase with simulation duration but remain modest relative to overall landform scale. Vegetation substantially reduces both erosion rates and gully depths, particularly at longer timescales.

As a sensitivity check, erosion rates were artificially increased by an order of magnitude within the model framework. Even under these exaggerated assumptions, increases in erosion and gullying remained limited, indicating a high degree of inherent stability in the IDL geometry.

The modelling results indicate that erosion and gullying are minimal across the IDL, supporting field observations that these areas are highly stable at the landform scale. The dominant long-term risk for IDLs is therefore not surface erosion, but rather subsurface processes, particularly where sodic or dispersive materials are present and tunnel erosion (piping) may develop near external batters.

4.2 Rehabilitation monitoring

Rehabilitation performance is assessed using Glencore Coal Assets Australia's Rehabilitation Report Card (RRC) methodology, originally developed by the University of Queensland and subsequently standardised across GCAA operations. The methodology provides an age- and land use–normalised assessment of rehabilitation progress, enabling site-wide evaluation against agreed success criteria.

Performance is scored against critical threshold values, representing the minimum sustainable condition under the relevant PMLU. Rehabilitation areas are then categorised as requiring rework, maintenance, monitoring, or being acceptable for certification.

Success criteria are derived primarily from the site Environmental Authority, with PMLU-specific benchmarks applied for grazing land, native ecosystems, riparian areas, and managed resource protection zones.

An example of transect monitoring over time is presented for the Ramp 7 area, an open cut mining area within the main deposit of Newlands. This area has been monitored 5 times in the ~20 years since it was completed. In 2000, 3 transects (LFA 13, LFA 14 and LFA15) were established to monitor the condition of Ramp 7. These transects were monitored in 2000, 2005, 2009 and 2013, with the data collected compared to undisturbed reference sites. In 2015, the process for collecting monitoring data was updated and an additional 5 sites were created to capture a better representation of the rehabilitation. The results are shown in Figures 7 and 8. Comparison photos over time are presented in Figures 9–11.

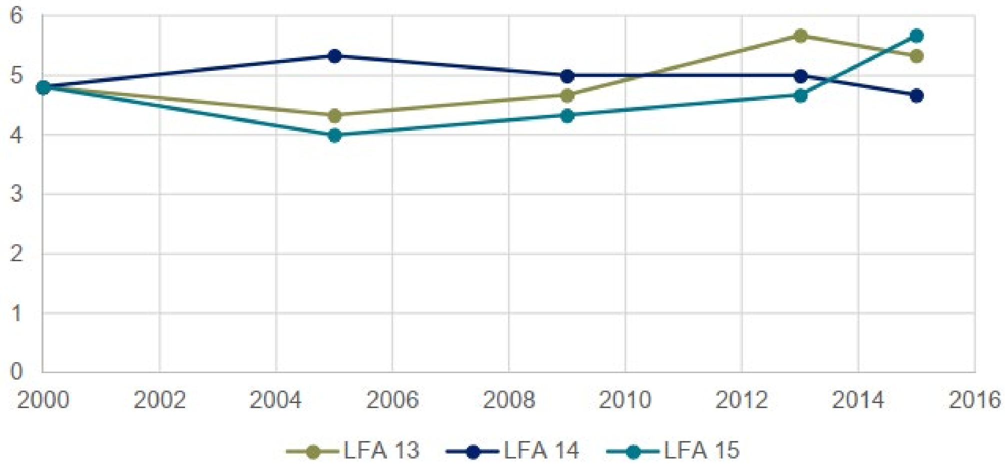


Figure 7 Habitat complexity score for the LFA monitoring sites from 2000 to 2015

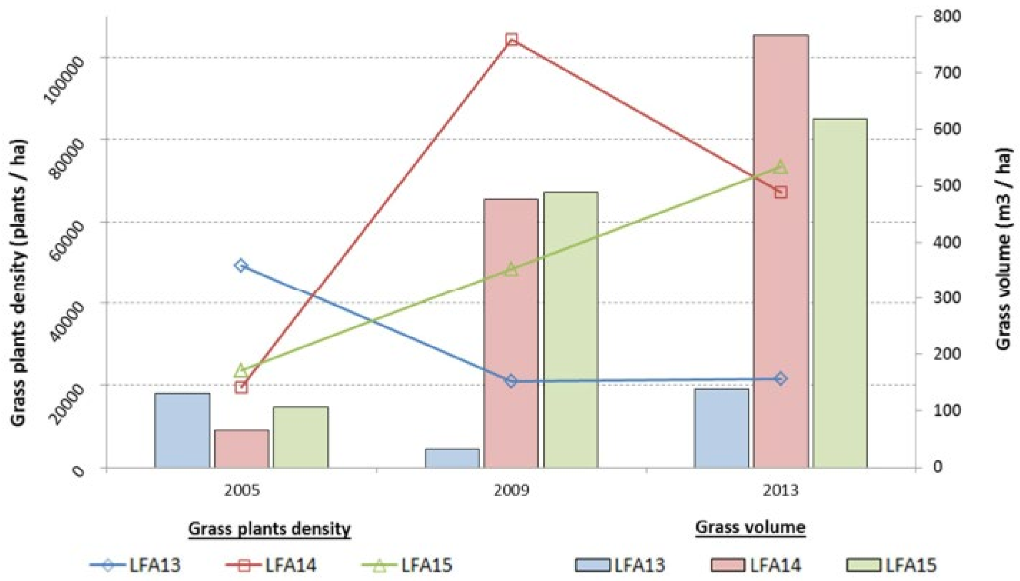


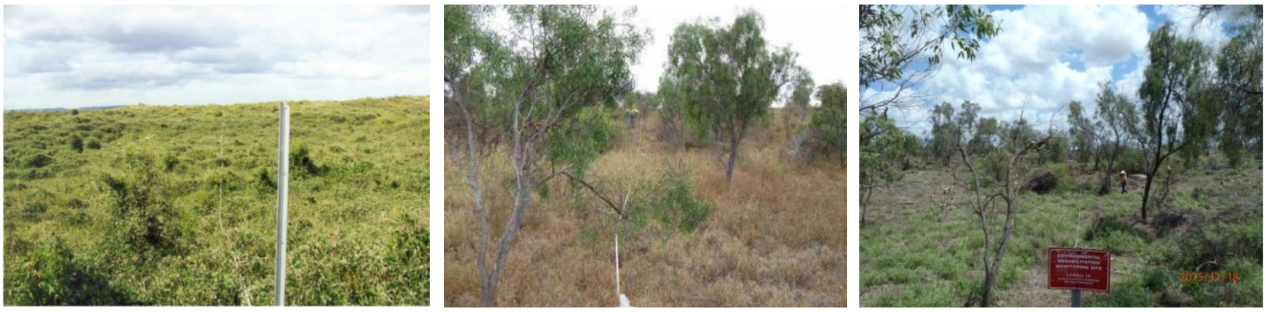
Figure 8 Grass plants density results comparison (Note: 2015 monitoring did not collect the data in this format and so these data were not included in the graph)

(a) (b)

Figure 9 Photograph of LFA 13 taken (a) December 2000; (b) November 2015

(a) (b) (c)

Figure 10 Photograph of LFA 14 taken (a) December 2000; (b) May 2005; (c) November 2015



(a) (b) (c)

Figure 11 Photograph of LFA 15 taken (a) December 2000; (b) May 2005; (c) November 2015

The transect monitoring results, coupled with soils, surface water and stability assessment were used as part of a rehabilitation certification application in 2017.

4.3 Rehabilitation certification

In 2017, Newlands was the first mine site in Queensland to achieve rehabilitation certification, with the bulk of certified areas in IDR. Since then, Newlands has applied successfully for 2 additional certification statuses in 2021 and 2025. Further rehabilitation certification is planned for 2026 and going forward to 2032.

Rehabilitation Reports were prepared for each certification application to describe the rehabilitation of the subject land in sufficient detail to demonstrate that the conditions of the Environmental Authority have been complied with and the land has been satisfactorily rehabilitated. Certification of IDR has been achieved for parts of Ramps 4 and 7 (2017), Ramps 3, 5 and Pub Hill (2021), and Ramps 9 and 10 (2025).

5 Implications for other sites

The long-term rehabilitation history at Newlands reinforces a consistent conclusion within the mine closure community: rehabilitation methods must be tailored to local material, climatic and landform conditions. IDR has a clear role in arid and semi-arid environments where water retention is critical to vegetation establishment and erosion control.

However, its application requires careful spoil selection and placement, particularly around landform margins. Preferential use of non-dispersive materials at external batters, appropriate internal bunding and targeted amelioration can materially reduce the risk of piping and surface instability. These considerations are central to successfully integrating IDR concepts into contemporary closure designs.

6 Conclusion

Newlands Coal Mine provides one of the most extensive operational datasets available for evaluating IDR over multiple decades. Drawing on long-term monitoring, certification outcomes and geomorphic modelling, this case study demonstrates that IDR can deliver stable landforms and improved rehabilitation outcomes when applied under appropriate design and material conditions. The lessons from Newlands provide practical, evidence-based guidance for the considered application of IDLs within modern mine closure planning and regulatory frameworks.

Acknowledgement

Thank you to Rob McNamarra for providing early history on the implementation of IDR across the Oaky Creek and Newlands Coal Mines. Rob was Principal Advisor – Environment and then General Manager – Environment for MIM between 1996 and 2001, during the formative years of IDR implementation in the Bowen Basin.

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