

## **Reliable mine rehabilitation and closure to minimise residual risk**

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### **Abstract**

Mineral extraction and processing are temporary land uses that have the potential to create long-lasting effects on water and land uses. These residual risks must be managed and mitigated, during mining if rehabilitation and closure are to meet community expectations. Previous research highlights features of failure to rehabilitate and close a mine site successfully, however, cases of successful rehabilitation and closure that mitigate residual risks are less well understood. This research reveals what constitutes successful rehabilitation and closure through a lens of ‘high reliability’ or ‘reliability seeking’ theory. This uses an alternative, socially constructed, paradigm to show that organisations seeking successful mine rehabilitation and closure apply the five processes of ‘high reliability organising’ (HRO) (Weick & Sutcliffe, 2001). We found there is a sixth process, ‘designing and planning for long time periods into the future’ by undertaking document analysis on four cases of rehabilitation and closure – three in Australia and one overseas. An additional novel observation is the degree to which diverse external stakeholders are engaged in all but one process.

### **Introduction and background**

A multi-national corporation’s sale of a large mine for \$1 to a smaller, junior company, or the abandonment of a mine without proper closure, are indicators of the widening gap between expectations and practice in Australian minesite rehabilitation and closure (R&C) (Lamb, Erskine, & Fletcher, 2015; WAtoday, 2018; Willacy, 2016). These practices indicate that environmental liabilities can exceed the value of a mining asset (Lock the Gate, 2016b; Willacy, 2016). The cumulative scale of historic mine R&C failure externalised onto the environment and community has been estimated in the billions of dollars (Queensland Commission of Audit, 2012; Unger, Lechner, Kenway, Glenn, & Walton, 2015; Woollard, 2014). This liability has prompted greater scrutiny of R&C regulation in the last decade particularly on residual risk (Queensland Government, 2018).

Despite significant scientific knowledge about good practices for R&C there are few successful examples (Lamb et al., 2015; Mulligan, 2014). Hence, this study seeks to understand the processes undertaken in those organisations that have achieved, or are seeking low residual risk from mining. In order to understand the social processes of R&C that create and sustain low residual risk we draw upon a theory of high reliability organising by Weick and Sutcliffe (2001). This theory prompts the question: **‘How does the organising of mine R&C for low residual risk in a sample of mining-related cases align with the processes of HROs?’**

A review of the literature shows a number of single-disciplinary studies on environmental, economic, financial modelling, engineering and risk management from the outside of the

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organisation. HRO theory provides a different perspective by directing research attention to social processes of R&C from the inside. High Reliability Organisation (HRO) theory (Weick & Sutcliffe, 2001) argues that reliable performance requires continual attention to five processes (Table 1) that detect and contain small anomalies so they do not disable the organisation.

### Study methods

To explore the complex, dynamic and uncertain phenomenon of R&C residual risk required a qualitative research methodology. Documents were analysed for selected relevant cases. These social texts reflect the experiences of those enacting the process inside the organisation thereby providing a holistic approach to this study of an under-explored issue (Corbin & Strauss, 2015).

Cases met selection criteria that were theoretically relevant and practical. Cases had to be: included in leading/good practice guidance, be holistic and reflect positive stories in the public domain; open cut mines (including one coal mine) or mineral processing plants; contemporary or recently closed (within last 7 years), company (not government) funded and planned R&C; and documented in English. From 41 cases in leading practice publications and the top 50 results for six search terms in a Google search the cases were screened for eligibility resulting in four confirmed cases.

They are:

- Alcoa’s bauxite mines, Darling Ranges, Western Australia, (Alcoa),
- ERA’s Ranger uranium mine, Northern Territory, (ERA),
- RWE’s lignite mines, near Cologne, Germany, (RWE), and
- Hydro Aluminium’s refinery, near Kurri Kurri, New South Wales, (Hydro)

Document analysis systematically reviews written accounts and requires interpreting socially organised and used data to elicit meaning and gain understanding (Bowen, 2009). The analysis considered data and theory in tandem (Gioia, Corley, & Hamilton, 2013) by starting with initial ideas and framing based on HRO theory (Weick & Sutcliffe, 2001) (Table 1), and identifying themes based on empirical analysis of selected, relevant documents.

**Table 1: Organising processes of HRO theory (Weick & Sutcliffe 2001) and associated descriptors**

Processes of HROs	Process labels used in this study	Process descriptors
Preoccupation with failure (HRO1)	Detecting anomalies	Purposeful seeking for anomalies, irregularities or failings when they are small and manageable (rather than being preoccupied with successes or denying/normalising failures)
Reluctance to simplify interpretations (HRO2)	Exploring complexity	Seeking a highly nuanced and complete picture of a problem rather than accepting a superficial explanation.
Sensitivity to operations (HRO3)	Paying attention to work and performance	Paying attention to actions/work to identify factors that contribute to detected anomalies irrespective of plans/strategy.

<b>Processes of HROs</b>	<b>Process labels used in this study</b>	<b>Process descriptors</b>
Commitment to resilience (HRO4)	Building resilient processes	Amending processes, based on lessons from anomalies, to regain stability, improve practices and meet objectives.
Deference to expertise (HRO5)	Engaging diverse expertise	Engaging diverse expertise and those with deep knowledge ensuring decisions and recommendations come from those with the most expertise.

Selected documents included: annual reports, sustainability reports, social impact assessments, company rehabilitation and/or closure reports, peer reviewed papers and company websites. Thirty-two documents across the four cases and six document types were analysed.

## Findings

Progressive coding identified theoretical themes plus themes emerging from the documents. Collectively, the four cases reported over 40 practices under six processes (Table 2).

**Table 2: Themes from HRO theory and emerging from document analysis**

<b>Process</b>	<b>Themes of related practices</b>
Designing and planning for long time periods into the future (emergent theme)	<ul style="list-style-type: none"> <li>• Closure design</li> <li>• Developing models and modelling</li> <li>• Feasibility studies</li> <li>• Goal of sustainability integrated</li> <li>• Incentive schemes and targets</li> <li>• Meeting or exceeding compliance requirements</li> <li>• Objective and performance measure (criteria) setting <ul style="list-style-type: none"> <li>○ Clarifying when liability ceases</li> </ul> </li> <li>• Planning land use zones for compatibility after operations</li> <li>• Preparing a plan</li> <li>• Processes and guidance for longer term management</li> <li>• Sustainability benefits beyond boundaries</li> </ul>
Detecting anomalies (HRO1) (theoretical theme)	<ul style="list-style-type: none"> <li>• Engagement with external stakeholders</li> <li>• Financial auditing or reporting</li> <li>• Monitoring</li> <li>• Risk management</li> <li>• Modelling</li> </ul>
Paying attention to work and performance (HRO3) (theoretical theme)	<ul style="list-style-type: none"> <li>• Anomaly is taken seriously with performance examined</li> <li>• Auditing to verify performance or validate method</li> </ul>
Engaging diverse expertise (HRO5) (theoretical theme)	<ul style="list-style-type: none"> <li>• Capability is accessed internally</li> <li>• Deep knowledge is valued</li> <li>• External stakeholder role in acceptance</li> <li>• External stakeholders accessed for diversity and/or depth of relevant expertise <ul style="list-style-type: none"> <li>○ External communication procedures</li> <li>○ Indigenous stakeholder engagement</li> </ul> </li> </ul>
Exploring complexity (HRO2) (theoretical theme)	<ul style="list-style-type: none"> <li>• Engaging internal stakeholders</li> <li>• Evaluation of control effectiveness</li> <li>• Identifying future studies</li> <li>• Identifying opportunities as positive impacts</li> <li>• Investigations and research to dig deeper</li> </ul>

	<ul style="list-style-type: none"> <li>• Monitoring to reveal complexity</li> <li>• Progressive rehabilitation</li> <li>• Seeking to understand community aspects of R&amp;C</li> </ul>
Building resilient processes (HRO4) (theoretical theme)	<ul style="list-style-type: none"> <li>• Adaptive management embedding improved processes and procedures <ul style="list-style-type: none"> <li>◦ Bouncing back from an anomaly</li> </ul> </li> <li>• Applying learnings from other R&amp;Cs</li> <li>• Deeper understandings over time</li> <li>• Foundational conditions for resilient landscapes to develop</li> <li>• Implementing plans</li> <li>• Keeping records for evidence gathering and recording of commitments</li> <li>• Mitigation of community impacts</li> <li>• Provisioning and contingency</li> <li>• Recognised exemplar</li> <li>• Updating plans</li> <li>• Wider benefit to others from this work</li> </ul>

Although HRO theory does not explicitly include processes that engage external stakeholders (Weick & Sutcliffe, 2001, 2015), the theory does not preclude such engagement. Company engagement of external lay and professional stakeholders occurred, particularly when seeking ‘diverse expertise’, and to ‘explore the complexity’ of R&C. HRO 3 appeared to be the only process undertaken entirely by those inside the company. All other HRO processes engaged external stakeholders, as did ‘designing and planning for long time periods into the future’. Sample quotes in Table 3 illustrate documented practices and social processes of organising.

**Table 3: R&C processes that engage external stakeholders**

Process	Examples of practices engaging external stakeholders	Sample quotes from documents for illustration
Designing and planning for long time periods into the future	<ul style="list-style-type: none"> <li>a) Helping to define sustainability</li> <li>b) Setting objectives and clarifying the condition of the environment before liability ceases</li> <li>c) As contractors or consultants preparing specific-purpose plans</li> </ul>	<p>(a)(b) <i>The Working Group recommends changes to the Completion Criteria to the MMPLG [Mining Management Program Liaison Group] for its approval. The MMPLG then reviews and approves the availability of the Completion Criteria for public review</i> (Alcoa, 2015)</p> <p>(b) <i>[T]he report aims to provide the basis for development of a company-wide strategic approach to the management of biodiversity and related stakeholder needs.</i> (Imboden &amp; Moczek, 2015 with RWE)</p> <p>(a)(b) <i>In late 2016 ERA released the [closure] plan in draft form, seeking feedback from our wide group of stakeholders, including Traditional Owners</i> (Energy Resources of Australia Ltd, 2017).</p> <p>(b)(c) <i>Cultural health indices are based on early consultation work and studies into cultural closure criteria completed by ERA, NLC and GAC, and ...by Dr Murray Garde, linguistic anthropology expert. [indices are] developed using established models and methodologies used in New Zealand and include a scalar measurement tool developed in a bilingual format that includes information in both Gundjeihmi and English</i> (Energy Resources of Australia Ltd, 2018a)</p>
Detecting anomalies (HRO1)	<ul style="list-style-type: none"> <li>d) Engaging external stakeholders in identifying shortcomings/failings/gaps in plans and/or works</li> </ul>	<p>(d) <i>Renewed assessment of remediation methods and discussions with regulatory authorities resulted in an increase of NOK 183 million to the provision</i> (Norsk Hydro, 2017)</p> <p>(d) <i>The CRG does not have a decision-making role, but is a forum for identifying issues and where appropriate making recommendations to be put to various decision-making bodies.</i> (Hydro Aluminium, 2014)</p>
Paying attention to work & performance (HRO3)	n/a	
Engaging diverse expertise (HRO5)	<ul style="list-style-type: none"> <li>e) External stakeholders approving objectives and/or works completed</li> <li>f) Diverse stakeholders (e.g. specialists, consultants,</li> </ul>	<p>(e) <i>This deposition method is undergoing assessment as to its long-term ability to mitigate risk TBI-03. An option is to convert to a sub-aqueous method and ERA expects to submit an application to the MTC [Minesite Technical Committee]</i> (Energy Resources of Australia Ltd, 2018a). <i>The Mirarr Traditional Owners are also represented via the Gundjeihmi Aboriginal Corporation [GAC] on the Closure Criteria Committee Working Group and [GAC] are formal members of the Ranger Minesite Technical Committee</i> (Energy Resources of Australia Ltd,</p>

	indigenous landowners) accessed for expertise	2018b). (f) [recommendation from audit of Annual Environmental Management Report].. <i>highlighting the need for contaminated groundwater around the Spent Cathode Pile to be treated as an Area of Concern during any remediation process following the decommissioning of the smelter (DLA Environmental 2012, for Hydro)</i>
Exploring complexity (HRO2)	g) Specialist consultants and other external stakeholders evaluating control measures h) Identifying opportunities for positive impacts (through SIA/consultation) i) Investigations by specialist consultants and community local knowledge j) Explaining community aspects of closure (to be mitigated by company)	(g) <i>Accounting for the cost of rehab...\$525.7m provision...Given the significance of this balance and the factors outlined above, the provision for rehabilitation was a key audit matter. (Energy Resources of Australia Ltd, 2017)</i> (h) <i>The purpose of this limited social impacts assessment is to better understand the likely impacts on the community from job losses [and understand] what job opportunities exist and what training may be required for smelter workers within the region (Environ Australia Pty Ltd, 2012, for Hydro).</i> (i) <i>A consensus on the Ranger revegetation tree and shrub species list was reached during March 2016 by the flora and fauna closure criteria technical working group. (Energy Resources of Australia Ltd, 2018a)</i> (j) <i>[The CRG provides a forum] to discuss the project and related matters with the company ... and consider options to improve community impact (Hydro Aluminium, 2014)</i>
Building resilient processes (HRO4)	k) Contractors implementing specific tasks in plans eg. revegetation works l) Collaboration with other bodies	(k) <i>ERA has engaged local Indigenous business Kakadu Native Plants Pty Ltd to collect local native plant seeds under licence and to establish tube stock seedlings suitable for planting into the finished rehabilitated landform. (Energy Resources of Australia Ltd, 2017)</i> (k) <i>Urbis have been engaged by Hydro Aluminium Kurri Kurri Pty Ltd to undertake a market assessment of the proposed employment lands within the Site... with the objective of identifying the development opportunities and constraints that exist within the Lower Hunter industrial market that could support development of future employment lands on the subject site. (DWP Suters, 2013)</i> (l) <i>The early discussions with staff to prepare them for this possible eventuality, the tireless efforts to support people who prepare to seek employment with other employers and the partnership with DEEWR [Australian Department of Education, Employment and Workplace Relations] around the development and delivery of the Hydro Jobs Market was all done willingly, enthusiastically and professionally. (Norsk Hydro, 2016b)</i>

## Discussion of each case

Despite evidence of all six processes in the four cases, each case revealed unique emphases as typified in the following quotes:

- ‘We also serve as stewards of the land’(Alcoa, 2017: 11),
- ‘Closure is part of every asset’s life cycle’ (Rio Tinto, 2017: 9)
- ‘Shutting down with respect’ (Norsk Hydro, 2016, webpage)
- ‘Nothing is so good that it cannot be improved’ (RWE Power, 2005: 14)

Alcoa particularly attends to detecting anomalies (HRO1) and building resilient processes (HRO4) using monitoring to trigger early intervention, then embedding changes into practices, using primarily in-house expertise. By changing rehabilitation practices in response to new knowledge, Alcoa demonstrates resilient processes. Monitoring at local and national levels tracks performance against the cross-site goal of 1:1 ratio of disturbance to rehabilitation. Alcoa aims to exceed compliance requirements and achieve land uses compatible with surrounding areas.

ERA also focuses on detecting anomalies (HRO1) using monitoring and risk management. The company gives particular attention to ‘designing and planning for long time periods into the future’ by developing and running models (due to long time frames required for uranium waste containment) plus developing objectives, performance measures and closure criteria. At the Ranger site, progressive rehabilitation involves backfilling of voids with wastes. External stakeholders include consultants, government research bodies, national and territory regulators, and indigenous land owners (and their representative organisations).

Hydro, having ceased production is implementing R&C so it prioritises detecting anomalies (HRO1) by risk management, and building resilient processes by ensuring ‘provisioning and contingency’ for closure (HRO4). A Community Reference Group (CRG) informs the decommissioning and closure process and receives progress reports on company measures to mitigate community impacts. The site Masterplan under development takes account of CRG input and also the regional strategy for the Hunter Region.

RWE emphasises their internal capability and depth of expertise (HRO5) to explore complexity (HRO2). Besides the deep knowledge within the organisation from undertaking progressive rehabilitation and closure over an extended period (40-50 years), they access diverse expertise from external stakeholders (HRO5). Several completed open cut mining areas are used for recreation. The company supports these uses with resources including hiking maps. The company’s ‘building resilient processes’ (HRO4) is evident in exceeding regulatory requirements by guaranteeing productivity for recultivated land for the first 10 years of new ownership.

## Conclusions

This study analysed documents to interpret the social processes and practices of four exemplary cases of mining and mineral processing to define ‘reliability seeking’ for R&C. Documents and websites produced by companies reflect what they deem is important to achieve good outcomes, and what they want the public to know.

HRO1 ‘detecting anomalies’ was the most commonly reported process. In addition to finding evidence of the five HRO processes (Weick & Sutcliffe, 2001), all four cases demonstrated

additional prospective practices . ‘Designing and planning for long time periods into the future’ includes developing objectives and modelling scenarios. External stakeholders were engaged in all processes except HRO3. While HRO theory includes ‘engaging diverse expertise’ (HRO5) to inform decision making, it does not recognise the role of expertise from outside the organisation in creating and sustaining reliability. We found that external stakeholders are integral to reliability seeking organising processes for R&C. When actively engaged by companies, stakeholders clarify what is an acceptable standard for R&C, detect anomalies and identify opportunities, explore complexity and contribute to resilient processes.

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