

Multiple frameworks informing closure criteria at Ranger Mine

M Iles *BMT, Australia*

Abstract

The Ranger Project Area (RPA), site of Energy Resources of Australia Ltd.'s Ranger Mine, is surrounded by (but separate from) Kakadu National Park (KNP) World Heritage Place and Ramsar wetland. Closure requirements differ for on and off the RPA.

The Mirarr Indigenous landowners source food and drinking water up and downstream of the mine and wish to resume these activities on the site after closure. The regulatory Environmental Requirements (ERs) specify that waters and tailings from the mine must not impact the KNP values which includes the local Indigenous culture, health of the local people and the biodiversity and ecological processes of the region. The ERs also state that impacts on the RPA must be as low as reasonably achievable (ALARA). Closure criteria for water and sediment on and off the RPA need to support these diverse values and goals.

The ANZG (2018) water quality monitoring framework (WQMF) was used to identify indicators to represent KNP values, human health and biodiversity and derive water and sediment quality criteria to support management of these values. Risk and vulnerability assessments were used, as relevant components in the WQMF, to assess the results of sediment and water quality monitoring and predicted post-closure water quality.

ALARA is widely understood and applied to radiation hazards but not chemical hazards. A fourth framework is required to provide information that will be used to assess if impacts on the RPA are ALARA. This paper demonstrates the role of these frameworks in water and sediment closure criteria development at Ranger Mine.

Keywords: *water quality objectives, risk assessment, ecological vulnerability, as low as reasonably achievable (ALARA), closure criteria*

1 Introduction

Energy Resources of Australia Ltd. (ERA) is undertaking closure activities at its Ranger Mine, which is surrounded by (but separate to) Kakadu National Park (KNP) World Heritage Place and KNP Ramsar site in the Northern Territory of Australia (Figure 1).

If not properly managed, water on and leaving the mine site following closure has the potential to impact community values on and off the Ranger Project Area (RPA) after closure. High level environmental requirements (ERs) for the protection of people and the environment during and after mining at Ranger have been set by the Australian Government (Commonwealth of Australia 2000). Those relevant to water quality specify that:

- Waters leaving the RPA do not compromise the achievement of the primary environmental objectives related to protection of the people, ecosystem (biodiversity and ecological processes), and World Heritage and Ramsar values of the surrounds.
- Impacts on the RPA are as low as reasonably achievable (ALARA).
- The strategy for closure of the mine is assessed using a best practicable technology (BPT).

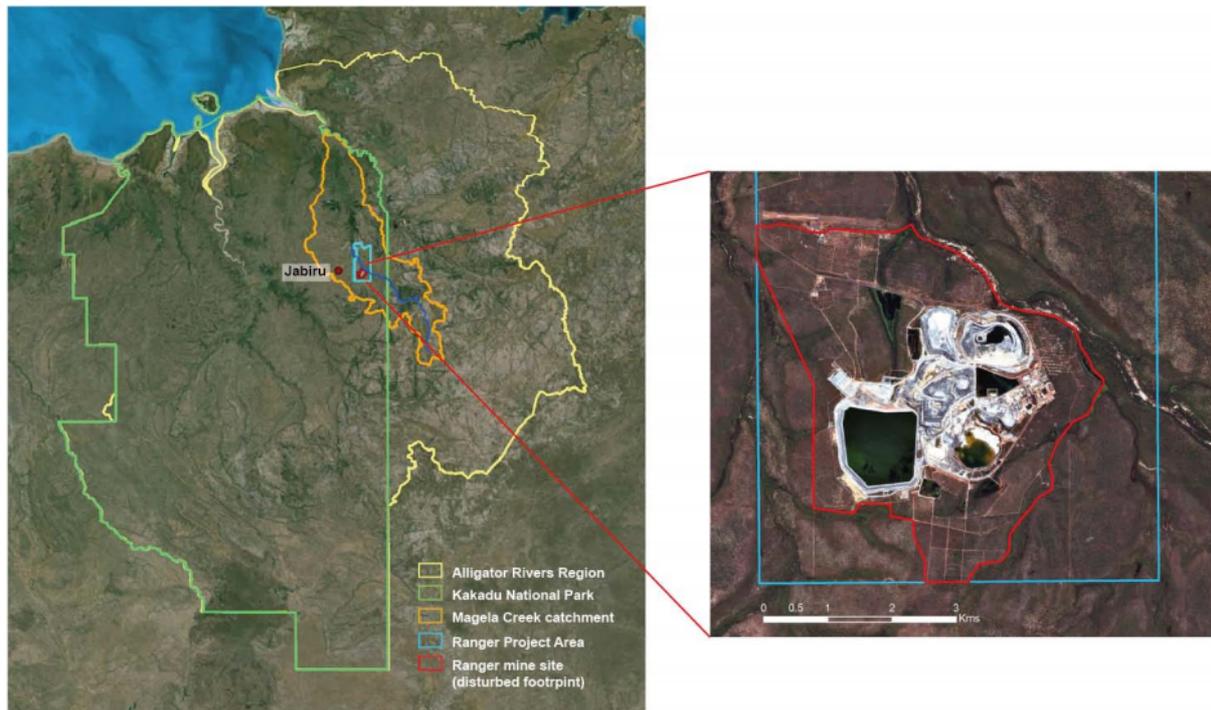


Figure 1 Ranger project area and mine site location

The Mirarr Indigenous landowners source food and drinking water up and downstream of the mine and wish to resume these, and other cultural activities, on the site after closure. In recognition of the importance of waterways on the RPA they requested that, in riparian zones and water bodies, the standard of rehabilitation be as high as is technically possible and the level of contamination be as low as technically possible.

Closure criteria for water and sediment on and off the RPA and decision-making processes need to optimise these diverse values and water management goals. Iles (2019) discussed plans for: (i) applying the ANZG (2018) water quality management framework (WQMF) for setting closure criteria at Ranger, and (ii) the role of BPT and understanding of ecosystem vulnerability when determining if impacts are ALARA. Stakeholders agreed in principle with the planned approach, provided they were involved in decisions on what is reasonable (the R in ALARA), the goal of ‘technically possible’ was properly considered and it was clear how these different frameworks inform the different management goals on and off the RPA.

This paper describes:

- The holistic framework that is being adopted by ERA to identify closure options that are BPT and most likely to result in impacts on the RPA that are ALARA.
- How risk and vulnerability assessments are being applied to understand the impacts associated with water quality.
- How the process can inform decisions on ‘technically possible’ and ‘reasonable’.
- How these fit within the WQMF to establish closure criteria and assess compliance with the ERs and community values.

These processes, their implementation and outcomes, are reviewed and considered by various stakeholder committees and working groups responsible for making decisions and approving activities related to the operation and closure of the Ranger Mine. Details of these committees and their roles are provided in Chapter 4 of ERA (2020).

2 Assessment frameworks to support water closure criteria

Multiple assessment approaches are being used to develop closure criteria for the water related management goals for Ranger Mine and assess compliance with these. These include the:

- ANZG (2018) WQMF.
- Environmental risk assessment framework.
- Ecological vulnerability assessment framework (VAF).
- BPT multi-criteria decision analysis framework.
- ALARA framework.

These different frameworks have many aspects in common (Table 1) and do not stand alone with steps in common creating a web of frameworks (Figure 3).

Table 1 Approach for assessing compliance with water quality related environmental requirements

| Environmental requirement | Assessment approach | Applicable framework |
|--|--|---|
| Protect the people and biodiversity | Quantitative source-pathway-receptor risk assessment comparing current or predicted water and sediment concentrations to guideline values for species protection, drinking water, recreational water | ANZG (2018) WQMF Environmental risk assessment Ecological VAF |
| Protect ecological processes, World Heritage and Ramsar values | Identify key indicator species/groups and sensitivity to main contaminant | As above. Indicators for World Heritage and Ramsar values set under the VAF |
| Impacts to be ALARA on the RPA | Iterative risk, vulnerability and BPT assessments | As above plus ALARA framework |
| Closure strategy is BPT | Multi-criteria decision analysis | BPT framework (a step within the ALARA framework) |

2.1 Water quality management framework

ERA is following the ANZG (2018) WQMF to provide a process for stakeholders to develop agreed water quality objectives that apply both on and off the RPA. The WQMF provides a sequential stepwise approach (central wheel in Figure 2) to setting management goals through to assessing, refining and deriving water and sediment quality objectives and guideline values. Several of the steps are also common to the VAF and ALARA framework and the environmental risk assessment is embedded both within the WQMF and the ALARA framework. The relationships are illustrated in Figure 2.

Steps 1 to 5 of the WQMF set objectives for each value being protected and identify the most stringent of these as draft guideline values. At Step 6, attainment of the objectives/guidelines is tested using a source-pathway-receptor environmental risk assessment (Section 2.2.1). This is also part of the ALARA process (Section 2.3.2). If exceedance of the objectives/guideline values results in unacceptable risk, Steps 7 and 8 of the WQMF are triggered.

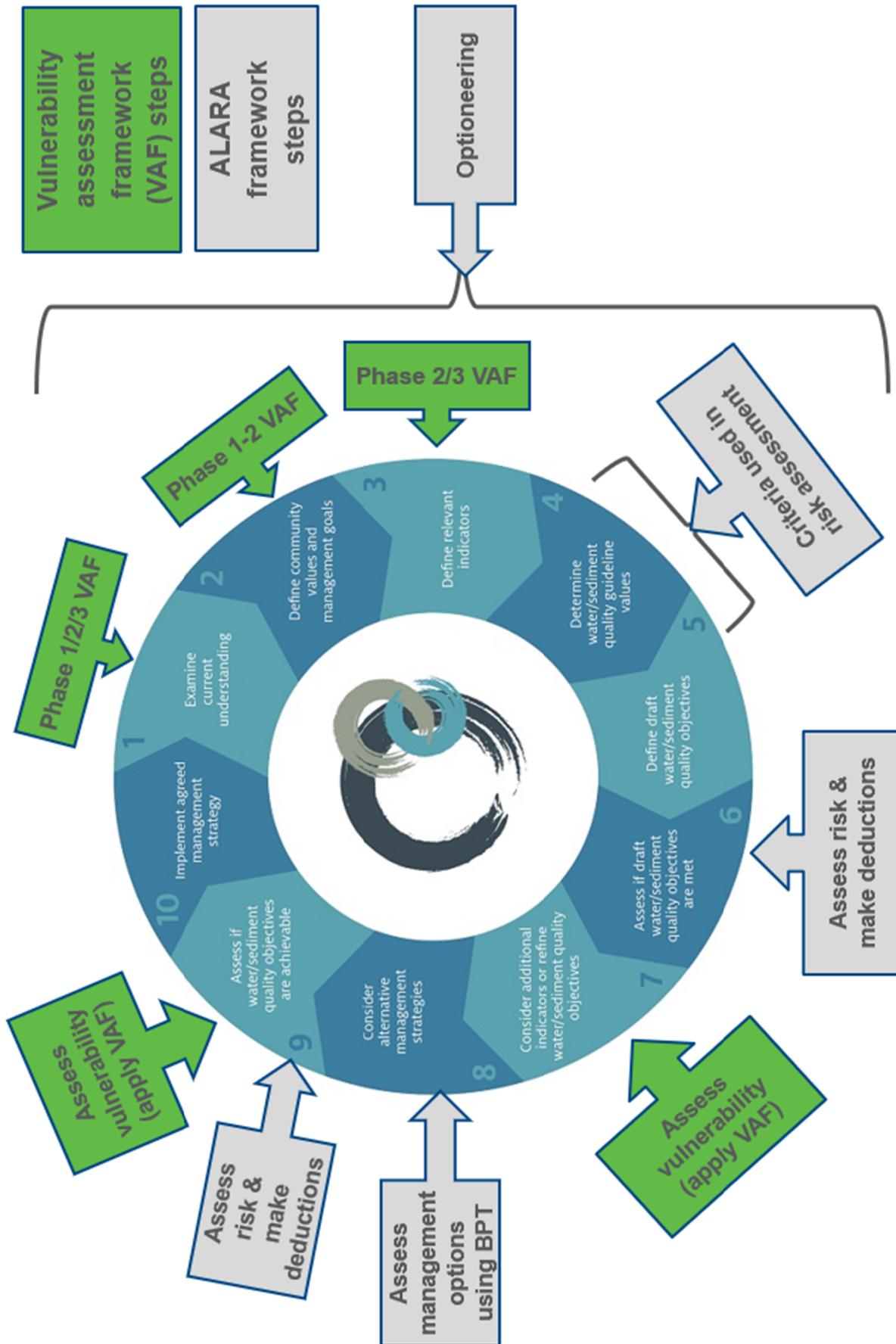


Figure 2 Alignment of the water quality management framework (central wheel) with the ALARA and vulnerability assessment frameworks

Step 7 of the WQMF involves a review of additional information and possible amendment of the criteria. The activities at this point differ for water bodies on and off the RPA. A review of conservatism in the solute transport models that provide the predicted water quality following closure is relevant to all sites being modelled and assessed. For water bodies on the RPA the VAF (Section 2.2.2) is applied to provide an additional line of evidence to support discussions on whether impacts on the RPA are and ALARA.

Step 8 of the WQMF, relevant to both on and off the RPA, considers alternative management options. For this ERA uses the BPT and ALARA processes described in Section 2.3.

It is important to note that Traditional Owners have reported concerns about trying to integrate cultural values with the 'scientific, legal and technical domains of a process that will take place within a framework controlled by those from the dominant non-Indigenous culture' (Garde 2015). The application of these frameworks has been, and will continue to be, discussed with representatives of the Traditional Owners and other key stakeholders, through various decision-making working groups and committees, and during consultative forums and site visits. These groups are responsible for agreeing on management goals for waterbodies on the RPA and determining if impacts are ALARA. See Chapter 4 of ERA (2020) for details on the roles and responsibilities of these groups.

2.2 Risk assessment and ecological vulnerability

2.2.1 *Environmental risk assessment*

A key environmental risk onsite is the release of dissolved substances from mineralised and contaminated materials in mine areas (Bartolo et al. 2013). An understanding of potential impacts from these contaminants on environmental and cultural values is an important element of planning for closure. Studies have been conducted for over 40 years to understand the contaminants and nature of, and risks to, the health of the ecosystem and people.

An assessment was conducted by ERA and BMT Ltd (Iles & Rissik 2021) to identify the risks posed from the different contaminants and contaminant sources on the mine site or predicted to come from the site after closure. The assessment was conducted using the ERA risk assessment tools modified to make use of the detailed evidence available for the site. Quantitative predictions of future water quality (including predictions for 10,000 years) and evidence of existing contamination was compared to water and sediment quality objective and guideline values identified in Steps 4 and 5 of the WQMF. The risk assessment fits into Step 6 of the WQMF and is also an activity under the ALARA framework (Section 2.3.2). At several sites risks were identified which triggered application of the VAF (Section 2.2.2) and a review of solute transport model conservatism and management options. These activities are part of the WQMF (Steps 7 and 8) and the ALARA framework.

A separate paper in these proceedings (Iles & Rissik 2022) describes the risk assessment.

2.2.2 *Ecological vulnerability*

Ecological vulnerability assessment fills the knowledge gap that exists between laboratory and field effects experiments on a sub-set of species or assemblages, to understanding risks to higher levels of organisation and/or to other species and species groups (De Lange et al. 2010). Ecological vulnerability assessment considers not only the direct sensitivity of organisms to a stressor, but the potential for indirect flow-on effects through trophic and habitat relationships.

ERA commissioned BMT to develop a framework (the VAF; Figure 3) to assist in understanding the potential impacts from contamination levels of magnesium greater than the 99% species protection guideline value. The initial phases of the project identified relevant water types, environmental values and indicators for waterways at, and adjacent to, the RPA which specifically reflect community values and meet statutory requirements outlined in the ERs (BMT WBM 2017). The later phases of the project developed the VAF to

assess the vulnerability of the key species and functional groups identified as important ecological components underpinning the environmental values related to the ERs (BMT 2021).

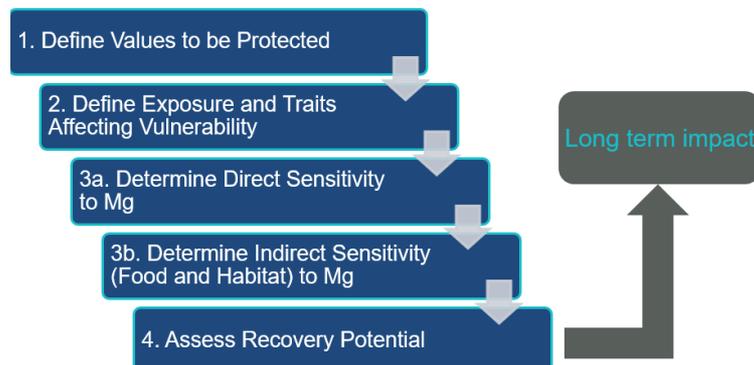


Figure 3 The ecological VAF (source BMT 2021)

The VAF assesses: (i) exposure of ecological components based on water quality modelling and distribution of identified indicator species/communities, (ii) their direct and indirect sensitivity to contaminant exposure based on laboratory and field studies, and (iii) their capacity for recovery based on a review of the traits of ecological components. A separate paper in this series of proceedings (Richardson et al. 2019) provides details on developing and applying the VAF to Ranger waterbodies. The findings provide information on the vulnerability of the important ecosystem components for water quality predicted to occur under modelled closure scenarios. Knowledge gaps are identified and plans to address these gaps are underway.

The understanding of ecosystem response to predicted water quality for given closure scenarios provides important information for deciding if impacts are acceptable and ALARA or if additional/alternative management strategies are needed.

2.3 ALARA & BPT

2.3.1 *Best practicable technology*

To comply with the ERs, the closure of Ranger must be implemented in accordance with BPT. The Supervising Scientist Branch (SSB) interprets BPT as the technology that is consistent with achieving the primary ERs and ranks highest when considering: world best practice, cost-effectiveness, proven effectiveness, Ranger's location, age of equipment and social factors (Supervising Scientist 2000). To ensure the BPT concept was effective for driving the closure strategy at Ranger, ERA expanded these categories to include cultural and heritage aspects and protection of the environment in the closure criteria themes of tailings, water, sediment, erosion and ecosystem establishment (Johnston & Iles 2013). The new criteria remained consistent with the original broad matters in the formal definition of BPT (ERA 2020). ERA reviews and updates the BPT criteria to keep them relevant to the phase of operations. This is done as part of the continuous improvement cycle and in consultation with stakeholders.

The BPT assessment process compares different management options and ranks them against each other based on scores for each of the BPT criteria. All scores are combined to a single value and the different options ranked (ERA 2020). The option with the best score is deemed to be BPT and taken through further assessments including further detailed risk assessment and BPT assessment of operational and design options for the chosen option.

Criteria can be weighted, and this has been suggested as a means of ensuring the highest level of protection for waterbodies and riparian zones and for allowing options to be compared on their technical ability to reduce impacts as well as comparison based on their cumulative score for all criteria. The risks associated with an option identified by such a weighted process would need to be assessed.

2.3.2 *As low as reasonably achievable*

The ALARA procedure is a stepwise options assessment process followed to arrive at an option that represents the most acceptable result. ALARA is well established for radiation protection but is not directly transferable to assessments of non-radiobiological hazards such as chemical pollutants. A fundamental issue is the difference in approach between optimising radiation protection and control of chemical pollution. The former is recognised as using a top-down approach, while the latter is based on a bottom-up approach (Domotor et al. 1999; Tran et al. 2000).

According to Tran et al. (2000) in radiation safety a top-down approach sets an upper limit and practices are put in place, using the ALARA procedure to consider cost and other factors, to reduce the risk further. The bottom-up approach works the opposite way. Numeric targets are based on an acceptable risk range. A target is set to limit exposure to the lower end of the acceptable risk range. If after considering the technical feasibility, costs, and other factors it is demonstrated the target is not achievable, a decision may be made to accept a higher risk and set a target allowing exposure at the upper end of the acceptable risk range.

The ANZG (2018) WQMF for setting water quality criteria follows a bottom-up approach as described by Tran et al. (2000). The water quality objectives adopted by SSB as rehabilitation standards for water leaving the RPA are an example of numerical risk targets. If the targets cannot be achieved steps in the WQMF can be followed and alternative targets proposed. There is a need though to do this in the context of demonstrating that the relaxed targets are aligned with ALARA impacts.

Tran et al. (2000) recommends a flexible risk management framework and assessment of multiple or cumulative risks as an approach to dealing with the differences between the top-down radiation safety ALARA approach, and the bottom-up numeric targets approach. Bryant et al. (2017), modified the radiation safety ALARA procedure to sit within a holistic hazard assessment framework for multiple hazards (Figure 4). ERA is adopting this framework of combined options-risk assessments in an iterative approach to identify a rehabilitation strategy with environmental impacts on the RPA from exposure to chemical pollutants that are ALARA.

The optioneering stage of the ALARA framework established goals and criteria and undertakes multi-criteria decision analysis of potential options. ERA uses the WQMF to set goals and criteria and the BPT framework for decision analysis. This is where options that would achieve contamination that is as low as technically possible can be considered.

The risk assessment stage is where the environmental risk assessment and VAF occur along with other assessments in the ERA risk management process (e.g. assessments of health, safety and compliance with other closure requirements). Options and risk assessments are also steps in applying the ANZG (2018) WQMF.

If the impacts are not acceptable, steps in the ALARA framework (and the WQMF) can be revisited with discussions on cost, technical feasibility, and social expectations occurring to identify alternative management options.

Domotor et al. (1999) suggested that ALARA is not a given value or numeric limit but is a process to assess a situation and ensure appropriate factors are considered. ERA propose that the concentration of water quality parameters achieved with the ALARA option (identified through applying the ALARA framework) be considered as numeric closure criteria (ERA 2020). Stakeholders agreed with this approach coupled with discussions on whether the proposed management option and resulting impacts are reasonable. Such discussions will involve stakeholders via the various forums mentioned above.

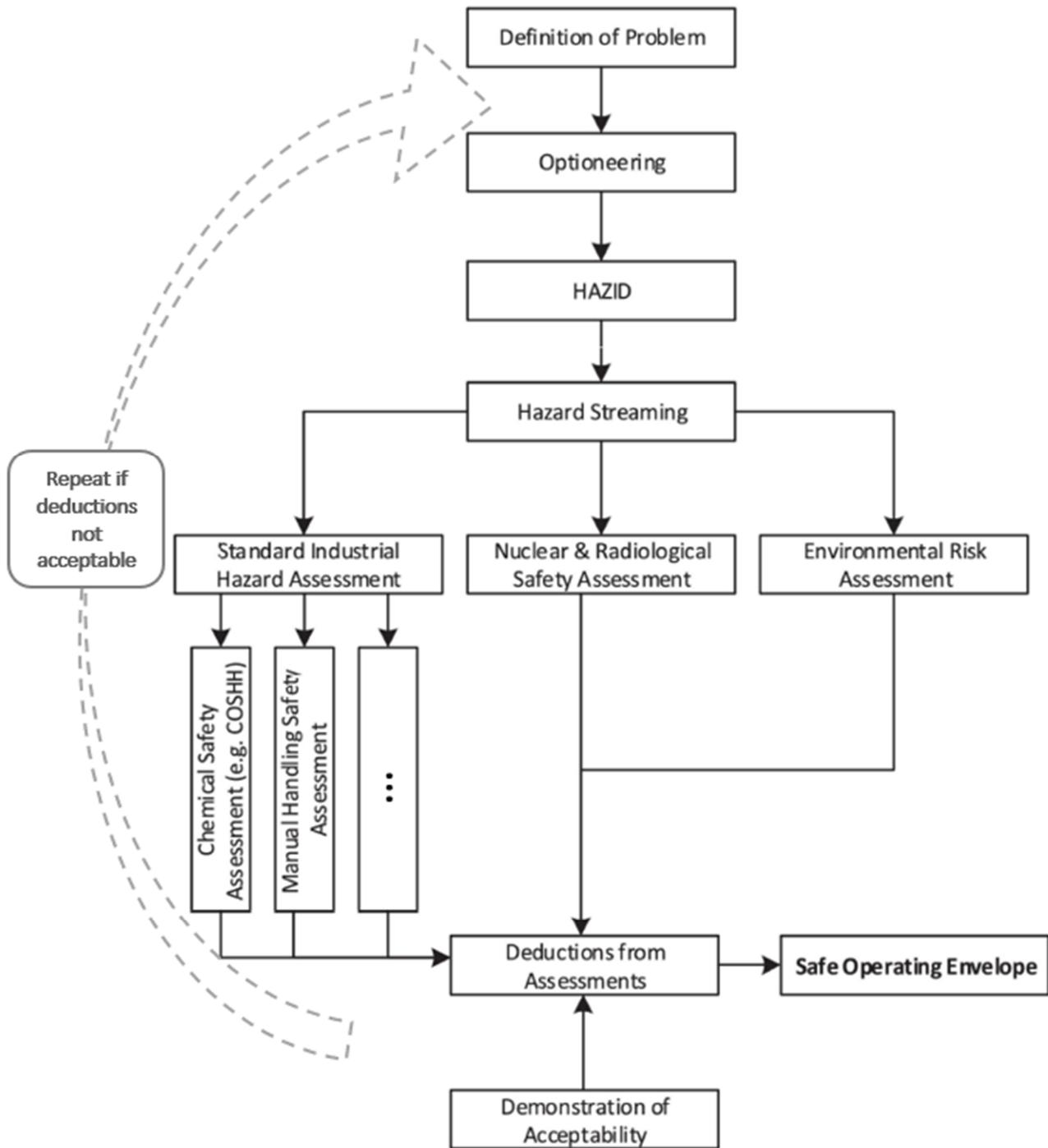


Figure 4 Framework for the integration of risks from multiple hazards into a holistic ALARA demonstration (modified from Bryant et al. 2017)

3 Conclusion

ERA has applied multiple frameworks to inform derivation of water quality closure criteria for the Ranger Mine to protect people, the ecosystem, and the World Heritage and Ramsar values of KNP and impacts that are ALARA on the RPA. The ANZG (2018) WQMF is central to this and is related to the other frameworks that are being used.

Deriving goals, indicators and guideline values that support the legislative ERs and Traditional Owner expectations occurs both within WQMF and the optioneering step in the ALARA framework. Assessing

compliance with these is done by conducting assessments of source-pathways-receptor risks and ecological vulnerability. These are done under their own frameworks but sit within the WQMF and ALARA frameworks.

Using the approach demonstrated by Bryant et al. (2017), ERA's BPT and risk management processes can be used, iteratively if required, to identify closure options that provide an ALARA outcome according to the process.

ERA has proposed that: (i) by applying the ALARA framework in an iterative manner, management options that have been assessed as BPT and have acceptable levels of risk and impact (compared to management goals) can be identified, and (ii) the concentration of water quality parameters achieved with this option be used as closure criteria for water bodies on the RPA.

Stakeholders agreed with this approach coupled with discussions to determine if the proposed option is reasonable considering what is technically possible. Flexibility within the BPT decision-making process can be used to assess options that provide pollution control at the lowest technically possible concentrations. Demonstrating the application of the ALARA framework and WQMF and sharing results from the BPT, risk assessment and VAF activities undertaken within these frameworks is vital to inform these discussions with stakeholders through several decision-making working groups and committees.

Acknowledgement

I acknowledge the Mirarr, the Traditional Owners of the lands that form the Ranger Project Area and ERA, my previous employer, for whom this work was completed.

Understanding the different assessment approaches and how to apply the various frameworks was greatly assisted by collaboration over the years between ERA staff, members of various Ranger stakeholder committees and key consultants. I would like to acknowledge the help of Ms Sharon Paulka (ERA), Dr Chris Humphrey and Dr Andrew Harford (SSB), Dr Darren Richardson and Dr Dave Rissik (BMT) Dr Chris Brady (NLC), and Dr Arthur Johnston (formerly from the Supervising Scientist Division).

References

- ANZG 2018, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Governments and Australian state and territory governments, www.waterquality.gov.au/anzguideline
- Bartolo, R, Paulka, S, van Dam, R, Iles, S & Harford, A 2013, *Rehabilitation and Closure Ecological Risk Assessment for Ranger Uranium Mine: Documentation of Initial Problem Formulation Activities*, internal report 624, Supervising Scientist, Darwin.
- BMT 2021, *Ranger Mine Closure Water Quality Framework Project – Phase 3 Final Report*, report prepared for Energy Resources of Australia Ltd, Darwin.
- BMT WBM 2017, *Ranger Mine Closure Framework Project – Phase 1 Review of Field Effects of Magnesium Guideline Exceedance (Final Report)*, report prepared for Energy Resources of Australia Ltd, Darwin.
- Bryant, PA, Croft, J & Cole, P 2017, 'Integration of risks from multiple hazards into a holistic ALARA/ALARP demonstration', *Journal of Radiological Protection*, 2018 Mar, vol. 38, no. 1, pp. 81–91, <https://doi.org/10.1088/1361-6498/aa8e53>
- Commonwealth of Australia 2000, s.41 Authority, *Environmental Requirements of the Commonwealth of Australia for the Operation of Ranger Uranium Mine*, <https://www.environment.gov.au/science/supervising-scientist/publications/environmental-requirements-ranger-uranium-mine>
- De Lange, H, Sala, S, Vighi, M & Fabera, JH 2010, 'Ecological vulnerability in risk assessment – a review and perspectives', *Science of the Total Environment*, vol. 408, pp. 3871–3879.
- Domotor, S, Peterson, H, Jr & Wallo, A, III 1999, 'DOE's process and implementation guidance for decommissioning, deactivation, decontamination, and remedial action of property with residual contamination (IAEA-SM--359)', *International Atomic Energy Agency (IAEA)*, https://inis.iaea.org/collection/NCLCollectionStore/_Public/30/060/30060352.pdf?r=1&r=1
- Energy Resources of Australia Ltd 2020, *2020 Ranger Mine Closure Plan*, viewed 10 December 2020, <https://www.energyres.com.au/sustainability/closureplan>
- Garde, M 2015, *Closure Criteria Development – Cultural, ERA Ranger Integrated Tailings, Water & Closure*, confidential report.
- Iles, M 2019, 'How can frameworks inform water quality objectives for the closure of the Ranger mine?', in AB Fourie & M Tibbett (eds), *Mine Closure 2019: Proceedings of the 13th International Conference on Mine Closure*, Australian Centre for Geomechanics, Perth, pp. 437–446, https://doi.org/10.36487/ACG_rep/1915_36_Iles
- Iles, M & Rissik, D 2021, *Ranger Closure Aquatic Pathway Receptors Risk Assessment*, Energy Resources of Australia Ltd and BMT report, CDM.03–1114-MR-RAS-00001, version 0.

- Iles, M & Rissik, D 2022, 'Risk-based contaminant management: Ranger Mine case study', in M Tibbet, AB Fourie & G Boggs (eds), *Mine Closure 2022: Proceedings of the 15th International Mine Closure Conference*, Australian Centre for Geomechanics, Perth, pp. 633–644.
- Johnston, A & Iles, M 2013, *Integrated, Tailings, Water and Closure Prefeasibility Study – Analysis of Best Practicable Technology*, Energy Resources of Australia Ltd, Darwin.
- Richardson, DL, Bourke, G, Rissik, D, Fisk, GW & Iles, M 2019, 'Development of a vulnerability assessment framework to evaluate potential effects of mine water discharges from Ranger Uranium Mine, Northern Territory', in AB Fourie & M Tibbett (eds), *Mine Closure 2019: Proceedings of the 13th International Conference on Mine Closure*, Australian Centre for Geomechanics, Perth, pp. 1519–1532, https://doi.org/10.36487/ACG_rep/1915_119_Richardson
- Supervising Scientist 2000, *Ranger Environmental Requirements Section 19.2 Explanatory Material: Best Practicable Technology*, viewed 26 June 2022, <https://www.dcceew.gov.au/science-research/supervising-scientist/publications/ranger-environmental-requirements-section-192-explanatory-material-best-practicable>
- Tran, NL, Locke, PA & Burke, TA 2000, 'Chemical and radiation environmental risk management: differences, commonalities, and challenges', *Risk Analysis*, vol. 20, no. 2, 2000, pp. 163–172.