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Towards the assessment of residual biodiversity impacts to support mining rehabilitation and offsets decision-making

RC Maree *SRK Consulting, UK*

Abstract

Global concerns related to the loss of biodiversity and the benefits it provides are rapidly increasing. The extractives industry is responding to this threat, demonstrated by members of the International Council on Mining and Metals (ICMM) who acknowledge that miners, as significant land and water stewards, have responsibility to understand their footprint, mitigate impact and maximise opportunities for the conservation and restoration of nature.

The ability to restore viable and functional ecosystems on disturbed mining footprints is key to the meaningful restoration of biodiversity value (BV). The biodiversity mitigation hierarchy is central to this process, through the prioritised steps of avoidance, minimisation and restoration of detrimental impacts to biodiversity to achieve no net loss (NNL) or net positive impact (NPI) to BV. Biodiversity offsetting is considered to address residual impacts after appropriate avoidance, minimisation and restoration measures have been applied.

This study represents a retrospective application of the biodiversity offset principles for an operational site that has been active for approximately 12 years. Therefore, strict adherence to the mitigation hierarchy was not possible. This assessment presents a case study for the merits of a retrospective application of the mitigation hierarchy, whilst also highlighting aspects to proactively influence decision-making for new projects and future extensions to existing mining operations.

The approach that was followed to quantify the residual impacts to BV, involved a series of sequential steps:

1. *Understanding of BV and identification of Biodiversity Management Units (BMUs)*
2. *Understanding of mining extent and impacts to BMUs*
3. *Execution of a BV loss/gain assessment to determine residual BV loss or gain*

Within the scope of the assessed BMUs, the study demonstrates that impacts to BV have either been avoided, resulted in a net gain in BV or resulted in a net loss of BV considering existing offset opportunities. In all cases, the rehabilitation gains do not achieve NNL, requiring offset opportunities to reach NNL or NPI.

Activities undertaken in this study to assess residual BV should ideally be integrated with the mine closure planning process. Biodiversity NNL/NPI objectives need to be considered in the context of, and aligned with, the identification of appropriate post closure land uses (PCLUs) for the site.

This study confirms that strict adherence to the mitigation hierarchy is not always achievable but the residual BV impact assessment provides a useful approach when companies decide to adopt NNL/NPI objectives for existing, operational assets. The approach evaluates the contribution of the rehabilitation process towards achieving BV gain objectives, in broad alignment with the principles of biodiversity offsets. The process recognises the value that offsite conservation activities add towards achieving the NNL/NPI objective which in effect results in these areas acting as potential offsets, as they would if the mitigation was implemented. Mining companies are adopting more rigorous biodiversity objectives and this approach demonstrates how existing operational sites can utilise their rehabilitation programmes, together with offsite conservation interventions towards NNL/NPI targets.

Keywords: *biodiversity value, residual impacts, mitigation hierarchy, offsets, biodiversity losses, biodiversity gains, no net loss, net positive impact, rehabilitation, restoration, closure criteria, mine closure plans*

1 Introduction

Global concerns related to the loss of biodiversity and the benefits it provides are rapidly increasing (United Nations Environment Programme 2022). These concerns are exacerbated by awareness of the risks of widespread ecosystem collapse (www.icmm.com). Despite ongoing efforts, the biodiversity decline is projected to continue or worsen. The post-2020 global biodiversity framework adopted at the United Nations (UN) Biodiversity Conference (COP 15) in 2022 aims to galvanize urgent and transformative action by Governments and society to achieve the objectives of the Convention on Biological Diversity.

The extractives industry is responding to this threat. This is demonstrated by members of the International Council on Mining and Metals (ICMM) who acknowledge that the mining industry is dependent on healthy functioning ecosystems, and that miners, as significant land and water stewards, have responsibility to understand their footprint, mitigate impact and maximise opportunities for the conservation and restoration of nature. Through the ICMM Mining Principles, ICMM members commit to contribute to the conservation of biodiversity and to assess and address risks and impacts to biodiversity and ecosystem services by implementing the mitigation hierarchy, with the ambition of achieving No Net Loss (NNL) of biodiversity (www.icmm.com). Several mining companies have made an explicit commitment to achieve NNL or Net Positive Impact (NPI) of biodiversity.

Restoration of biodiversity value (BV) through mine closure planning and rehabilitation processes is generally a key part of strategies to meeting NNL/NPI commitments. This restoration must address relevant aspects of the biodiversity mitigation hierarchy.

Principles, requirements and guidance related to the design and implementation of the mitigation hierarchy and biodiversity offset programmes are published in several international guides. These include the *Business and Biodiversity Offsets Programme* (BBOP)(2012), Organisation for Economic Co-operation and Development (OECD) *Biodiversity Offsets, Effective design and implementation, Policy Highlights* (2016), International Union for Conservation of Nature (IUCN) *Policy on Biodiversity Offsets* (2016) and World Bank Group *Biodiversity Offsets: A User Guide* (2016).

This paper presents a mining case-study for the practical application of the mitigation hierarchy and biodiversity offset requirements. The case study has been extrapolated from a real example into a theoretical example, with detail redacted to protect confidentiality. The study illustrates quantification of the required compensation for residual adverse impacts to biodiversity, in line with biodiversity offsetting principles requiring a NPI outcome. The study involved determination of BV as part of mine planning, residual biodiversity losses or gains, and objectives and priorities for rehabilitation strategies.

1.1 Restoration of BV

The extractives industry has a significant impact on the natural resources and people who depend on these within its zone of influence. The impacts may be direct, indirect and cumulative. Biodiversity losses (species richness and diversity) are typically manifested through loss of habitat, loss of ecosystem services and/or habitat fragmentation. Mining generally causes a regression in ecosystem structural and functional complexity (Australia Department of Industry, Innovation and Science 2016).

The development and implementation of mine closure plans (MCPs) aims to identify and mitigate post-closure risks, via a disciplined and integrated planning approach. A balanced closure approach fully incorporated into mine planning activities leads to better outcomes across a range of considerations, including health, safety, social, environmental, legal, governance and human resources (ICMM 2019). MCPs are typically supported by the development of a rehabilitation strategy, designed to schedule and implement actions to meet closure criteria (to mitigate risks) and meet the desired biodiversity success criteria.

Factors that impact the ability to restore viable and functional ecosystems on disturbed mining footprints include the extent and characteristics of the pre-mining ecosystem, the sensitivity of the ecosystem and its ecological components, the nature of identified closure criteria (including associated costs to implement the criteria) and the disciplined execution of rehabilitation prescriptions. These all impact on the ability to meet success criteria that demonstrate meaningful restoration of BV.

When identifying biodiversity success criteria, the alteration of geotechnical and geochemical characteristics of disturbed areas following the implementation of closure criteria (via rehabilitation activities) need to be considered. These characteristics present constraints in terms of what may be achieved. The Australia Department of Industry, Innovation and Science handbook for mine rehabilitation (2016) distinguishes between the 'rehabilitation' and 'restoration' of land impacted by mining. Rehabilitation "aims to reinstate ecosystem functionality and land productivity, although it will probably assume a different land-use and species composition from the original ecosystem" whereas restoration "aims to re-establish an ecosystem that develops along a successional pathway so that it assumes a similar, but not necessarily identical, structure, function and composition to the original ecosystem". Rehabilitated ecosystems may be simpler in structure than the original whereas restoration has the more ambitious aim of re-establishing ecosystem structure and function to an image of its state before disturbance, or of replicating a desired reference ecosystem (Australia Department of Industry, Innovation and Science 2016).

The extent to which BV is restored, therefore, depends on the specific rehabilitation/restoration objectives and the post closure land use (PCLU) and land capability that is pursued. Opportunities and constraints associated with the restoration of BV are realised via the closure criteria and associated rehabilitation prescriptions to meet the predetermined success criteria.

1.2 The mitigation hierarchy

The biodiversity mitigation hierarchy (Fauna and Flora International 2017, Organisation for Economic Co-operation and Development 2016, World Bank Group 2016) is central to the assessment of residual BV. The hierarchy is a set of prioritised steps to address loss of BV through avoidance, minimisation (or reduction) and restoration of detrimental impacts to biodiversity (Figure 1). Biodiversity offsetting is considered to address residual impacts after appropriate avoidance, minimisation and restoration measures have been applied (Fauna and Flora International, 2017).

Avoidance includes activities that change or stop actions before they take place, to prevent their expected negative impacts on biodiversity and decrease the overall potential impact of an activity. Avoidance reduces the need for later steps in the mitigation hierarchy and is imperative for protecting the integrity of valuable and threatened biodiversity and ecosystem services. Minimisation measures are taken to reduce the duration, intensity, extent and/or likelihood of impacts that cannot be completely avoided (Fauna and Flora International, 2017).

Restoration involves altering an area in such a way as to re-establish an ecosystem's composition, structure and function, usually returning it to its original (pre-disturbance) state or to a healthy state close to the original. This is a holistic process aiming to return an ecosystem to a former natural condition and to restore ecological function (Fauna and Flora International, 2017). Rehabilitation activities implemented by mines may not achieve necessarily achieve restoration targets, as highlighted by the Australian Department of Industry, Innovation and Science (2016).

Biodiversity offsets are measurable conservation outcomes resulting from actions designed to compensate for residual adverse biodiversity impacts arising from project development and persisting after appropriate avoidance, minimisation and restoration measures have been taken. A biodiversity offset should be designed and implemented to achieve measurable conservation outcomes that can reasonably be expected to result in no net loss and preferably a net gain of biodiversity (Fauna and Flora International, 2017).

Biodiversity offsets are relevant after all reasonable measures have been taken first to avoid and minimise the impact of a development project and then to restore biodiversity on-site (effectively as a 'last resort'). Consequently, biodiversity offsets should only be applied to residual adverse biodiversity impacts. The application of this mitigation hierarchy, and how far each step should be pursued before turning to the next is one of the key issues for consideration in biodiversity offset design (BBOP 2012).

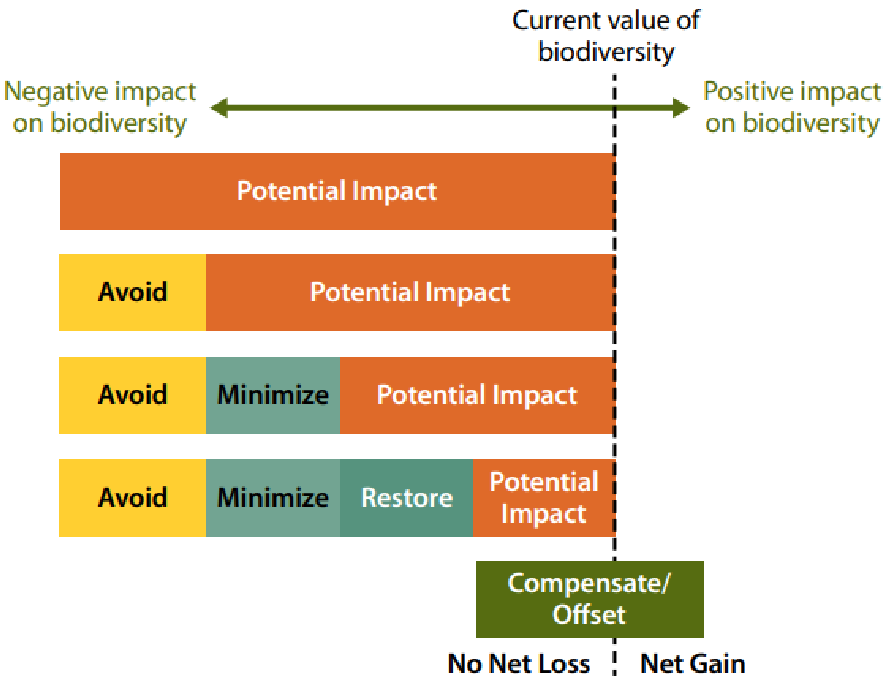

Figure 1 The Biodiversity mitigation hierarchy (from World Bank Group, 2016)

1.3 Residual impacts to BV

NNL is achieved when biodiversity gains from the combination of avoidance, mitigation, rehabilitation and targeted conservation actions match biodiversity losses from the impacts of the development. NNL is the minimum target required for the implementation of biodiversity offsets. NPI, or 'net gain' refers to the point where biodiversity gains exceed biodiversity losses due to the impacts of the development (Fauna and Flora International, 2017).

Key to the design and implementation of biodiversity offset programmes are the principles of additionality, equivalence and permanence. Additionality ensures that the offset delivers conservation gains beyond those that would be achieved by ongoing or planned activities that are not part of the offset (World Bank Group, 2016). Equivalence requires that the offset conserve the same BV (species, habitats, ecosystems, or ecological functions) as that lost to the original project, following a principle known as 'like-for-like' (World Bank Group, 2016). In some circumstances, where there is good scientific justification, it could be appropriate for the offset to conserve a different kind of biodiversity that is of higher conservation priority than the type affected ('like-for-like or better') (IUCN, 2016). Permanence ensures the offset delivers conservation outcomes for at least as long as the biodiversity loss persists at the development site (OEDC, 2016).

The design of biodiversity offsets should be integrated with the impact assessment phase of new developments, in order to ensure biodiversity considerations are integrated into the project decision-making processes as early as possible (BBOP 2012). This study represents a retrospective application of the biodiversity offset principles for an operational site that has been active for approximately 12 years. Therefore, strict adherence to the mitigation hierarchy as advocated by BBOP (2012) was not possible. This assessment presents a case study for the merits of a retrospective application of the mitigation hierarchy, whilst also highlighting aspects to proactively influence decision-making for new projects and future extensions to existing mining operations.

2 Approach

The approach that was followed to quantify the residual impacts to BV, in line with the requirements of the mitigation hierarchy involved a series of sequential steps (Figure 2), summarised:

1. Understanding of BV and identification of Biodiversity Management Units (BMUs) (steps 1 and 2 in Figure 2).
2. Understanding of mining extent and impacts to BMUs (step 3 in Figure 2).
3. Execution of a BV loss/gain assessment to determine residual BV loss or gain (steps 3 to 5 in Figure 2).

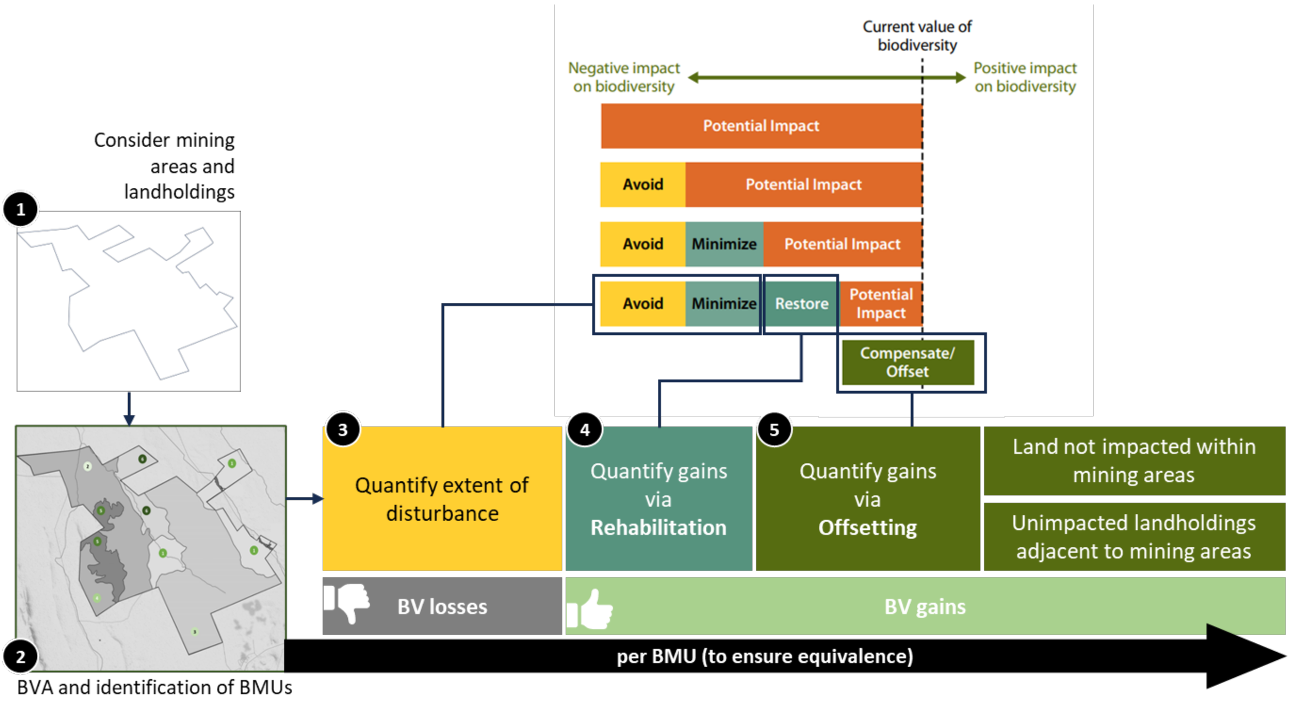

Figure 2 Summary of the approach followed for the study

This study represents a conceptual and limited assessment. The assessment provides initial indications of potential BMU specific loss/gain scenarios to facilitate residual biodiversity impact mitigation decision making. It does not present detailed, auditable BV loss/gain calculations. Further work will be required to achieve this as discussed in this paper.

2.1 Biodiversity Value Assessment and identification of BMUs

A Biodiversity Value Assessment (BVA) was conducted by ecological specialists, detailing vegetation types, sensitive areas, species and populations of species of designated conservation importance. This was conducted on the land holdings owned by the mine, within the mining area and directly bordering the mining area.

The BVA output was used as the basis to identify BMUs which, to a large extent, are indicative of sensitive areas and species. Some of the BMUs incorporate more than one vegetation type to simplify implementation and management of both fauna and flora of these units. Six BMUs were identified within the mining right area and prioritised for management intervention and potential for inclusion into offset areas. BMUs with the potential to contribute as eco-corridors for the offset areas were also identified.

The BV associated with each identified BMU was determined considering a combination of the conservation status and ecological functional status of an area, including the amount of the area or system remaining in the region, the diversity and presence of ecosystems/habitats and species which are endemic, threatened, vulnerable or have particularly high religious/cultural value and the degree to which the area or system is representative of its original state.

2.2 Mining impacts to BMUs

The extent of physical disturbance footprints of the mine infrastructure and domains (including open pits, waste facilities, infrastructure, treatment facilities and stockpiles) were mapped in relation to the BMUs. The assessment was applied to an operational site where existing disturbance, as well as projected life of mine disturbance footprints were considered. This allowed for the assessment of existing impacts as well as proposed future disturbance to facilitate mine development decision-making.

A database detailing the disturbance footprints for each domain, within each BMU was developed. The assessment was conducted independently for each BMU, to enable comparison of surface areas that are equivalent in terms of BV (i.e. compare 'like-for-like' impacts across the mitigation hierarchy steps). The assessment output expresses comparative biodiversity loss/gains as BV in hectares.

2.3 BV loss-gain assessment

A BV loss-gain assessment was conducted with available information for the mine site, with the objectives to determine, per BMU:

- The losses to BV for impacted areas.
- The potential BV gains contributed by rehabilitation activities.
- The potential BV gains contributed by conservation activities within undisturbed areas within the mining right area.
- The residual, net BV loss/gain status.
- The remaining BV deficit to be addressed through implementation of a biodiversity offset to attain NNL/NPI. This output will identify the most suitable network of offset areas and actions to achieve NPI for the life of mine for each of the affected BMUs, which will form an input into the development of a detailed Biodiversity Offset Management Plan (BOMP).

The BV loss/gain assessment aims to facilitate a reasonable application of the mitigation hierarchy principles and NNL/NPI determination requirements, in line with the requirements of relevant biodiversity offsetting guidance, considering BMU delineations as determined by independent ecological studies and the mine's existing Biodiversity Management Plan (BMP).

2.3.1 BV losses

Losses to BV as result of mining activities were determined based on the measurement of current disturbance footprints and estimation of projected future disturbance in line with the latest LOM plan. Projected losses account for direct impacts (physical disturbance footprints) to BV only. Potential indirect impacts to BV in areas adjacent to physical disturbance footprints are assumed to be zero, although this is likely not the case. The extent and quantification of impacted 'buffer' zones and associated impacts to BV, per BMU, need to be determined (see disturbance loss assumptions in Table 1).

2.3.2 BV gains

2.3.2.1 BV gains via rehabilitation

Assessment of the potential BV gains contributed by rehabilitation activities was subject to the following methodology and assumptions:

- Rehabilitated areas are able to increase BV and thereby contribute to BV restoration gains, towards NNL/NPI objectives. Given that ‘restoration’ targets may not be pursued, the quantified extent of BV contribution, however, needs to be further refined based on future monitoring of success criteria (see rehabilitation gain assumptions in Table 1). The extent to which rehabilitated areas represent ‘alien’ habitats (that bear no relation to the lost habitat) needs to be better understood.
- BV gains are based on projected rehabilitation interventions, in line with the closure criteria and rehabilitation plan, as detailed in the mine closure plan.
- The rehabilitation plan does not include closure criteria to reinstate the ecological components of relatively sensitive or complex habitats (such as pans and wetlands within BMU 3 of this study, for example). Therefore, the potential BV gain contributed via the rehabilitation of relatively sensitive or complex baseline ecosystems is considered to be low, relative to other, less ecologically complex BMUs (see rehabilitation gain assumptions in Table 1).

2.3.2.2 BV gains via offsetting

Assessment of the potential gains contributed by offset opportunities was subject to the following methodology and assumptions:

- Undisturbed areas within the mining right area must show improvements to their current condition in order to contribute as BV gains (i.e. demonstrate the principle of ‘additionality’). The BV in these areas, therefore, must be actively improved to contribute positively (see potential offset assumptions in Table 1).
- The mine owns a number of landholdings adjacent to the mining area, that were considered as potential offset opportunities. Areas representing a similar landscape to impacted BMUs may be identified as priority landholdings for potential offsets.
- Potential offset landholdings were applied only where they could contribute to BV within the same BMU.
- The extent of BV gains on potential offset landholdings depends on future land use and successful implementation of conservation efforts to achieve the principle of ‘additionality’.

Table 1 BV loss/gain assessment conditions, limitations, and assumptions

Mitigation hierarchy component	Mine activity	Limitations	Assumptions
Avoid and minimise	Disturbance	Lack of information regarding baseline BV condition	BV losses are similar for all disturbances with respective BMUs and do not account for differences in baseline BV

		Lack of quantifiable information regarding indirect impacts to BV	BV loss calculated due to direct impacts (physical disturbance footprints) only. Excludes potential BV losses due to indirect impacts
		Impact to BV due to physical disturbance in all areas considered equal	Calculated at 100% loss of BV for all areas
		Differing closure criteria and rehabilitation prescriptions applied to different mine domains	BV gain assumptions are applied only to areas that are actively rehabilitated. Areas not actively rehabilitated (e.g. open pits areas that will not be backfilled) contribute zero BV gain
Restore / rehabilitate	Rehabilitation	Site-specific rehabilitation contribution to BV for BMUs that are less sensitive remains unknown (BMU 1,2,4,5 and 6)	Closure criteria and rehabilitation prescriptions may not restore the original ecology of less sensitive habitats – a projected BV restoration success of 50%, relative to BV baseline applied
		Site-specific rehabilitation contribution to BV for BMUs that are more sensitive remains unknown (BMU 3)	Closure criteria and rehabilitation prescriptions may not restore the original ecology of Sensitive habitats - a projected BV restoration success of 10%, relative to BV baseline applied
		Potential restoration success (due to rehabilitation activities) in all areas considered equal	Despite the implementation of different closure criteria and rehabilitation prescriptions for mine domains, the same % of BV gains are applied to all rehabilitated landforms / domains
		Lack of information regarding BV for areas within the mining right area that are undisturbed by mining impacts	Based on the concept of additionality, the gain calculations assumed that a BV improvement of 10% of total BMU areas will be achieved, via active improvement initiatives and land use management
Offset	Compensation to achieve NPI	BMUs for impacted areas are not represented in all potential offset landholdings	The loss/gain assessment includes loss and contributions between representative BMUs only
		Lack of information regarding BV for areas associated with potential offset landholdings	Based on the concept of additionality, the gain calculations assumed that a BV improvement of 10% of total BMU areas will be achieved, via active improvement initiatives and land use management

3 Results

Figures 3 to 5 present three examples of the loss/gain calculations (presenting the contributing loss and gain components) for the BMUs impacted directly (physical footprint disturbances only) by mining activities on the Mine, considering the limitations and assumptions as presented in Table 1. In all cases, surface area (ha) is used as a proxy to represent relative BV losses and gains.

Losses and gains presented in Figures 3 to 5 are structured in alignment with the mitigation hierarchy, where BV losses are represented by grey bars, until a maximum foreseeable loss (MFL) is reached (note that currently in this study, MFL may be underestimated due to the lack of consideration of indirect impacts to BV losses).

BV gains are realised via rehabilitation efforts (green bars) and BV offset opportunities (blue bars). The extent to which maximum rehabilitation gain (MRG) is achieved depends on the closure criteria (and associated financial resources to execute rehabilitation prescriptions), BV and sensitivity of the ecological community to be restored, relative to the BV baseline. Maximum potential gain (MPG) is achieved considering the cumulative gains of rehabilitation effort and maximised offset opportunities (Figures 3 to 5). MPG demonstrates whether a residual (net) BV loss or gain is realised.

Table 2 presents a summary of the outcomes for all six BMUs. Within the extent of BMU 4, impacts to BV have been avoided, maintaining the integrity of its high BV. The extent of disturbance within BMU 3, coupled with a low likelihood that this sensitive ecosystem will be effectively restored (given existing rehabilitation closure criteria) results in a net loss of BV, considering existing offset opportunities. All other BMUs present a net gain in BV after the contribution of potential offset opportunities either within or adjacent to the mining areas. In all cases, the MRG does not achieve NNL, requiring offset opportunities to reach NNL or NPI.

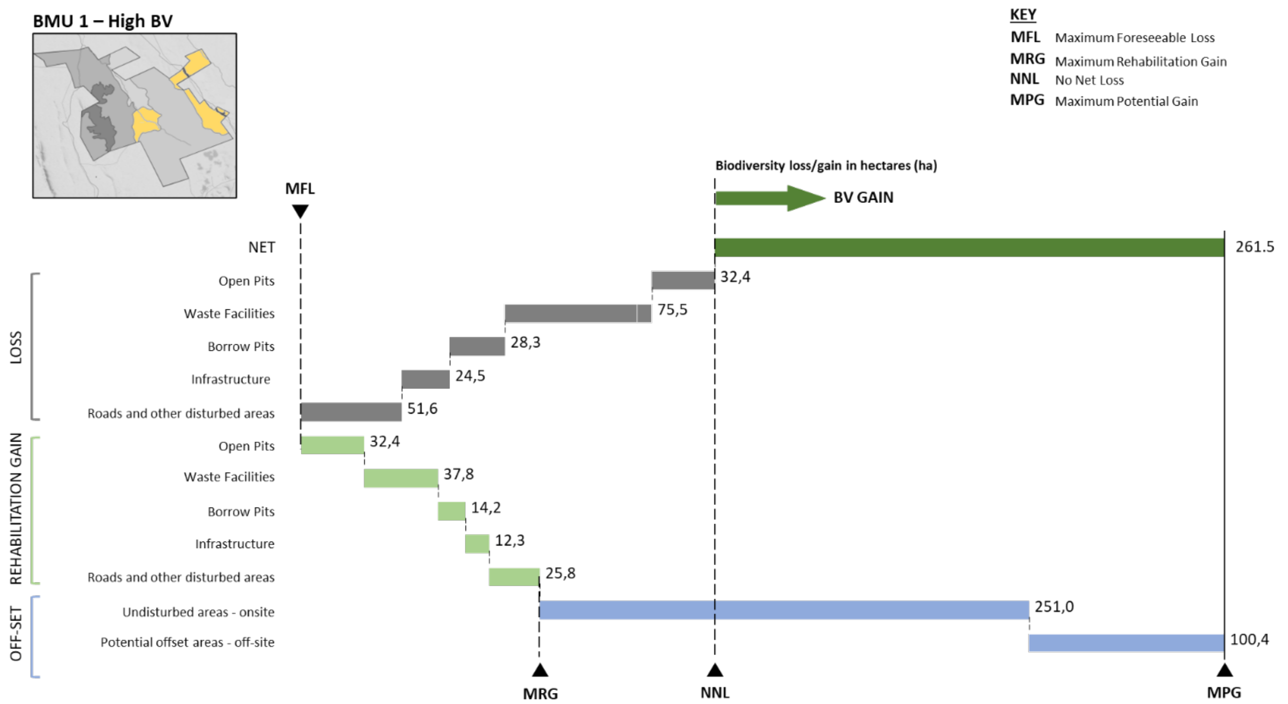

Figure 3 Residual impact to BV (represented in ha) for BMU 1

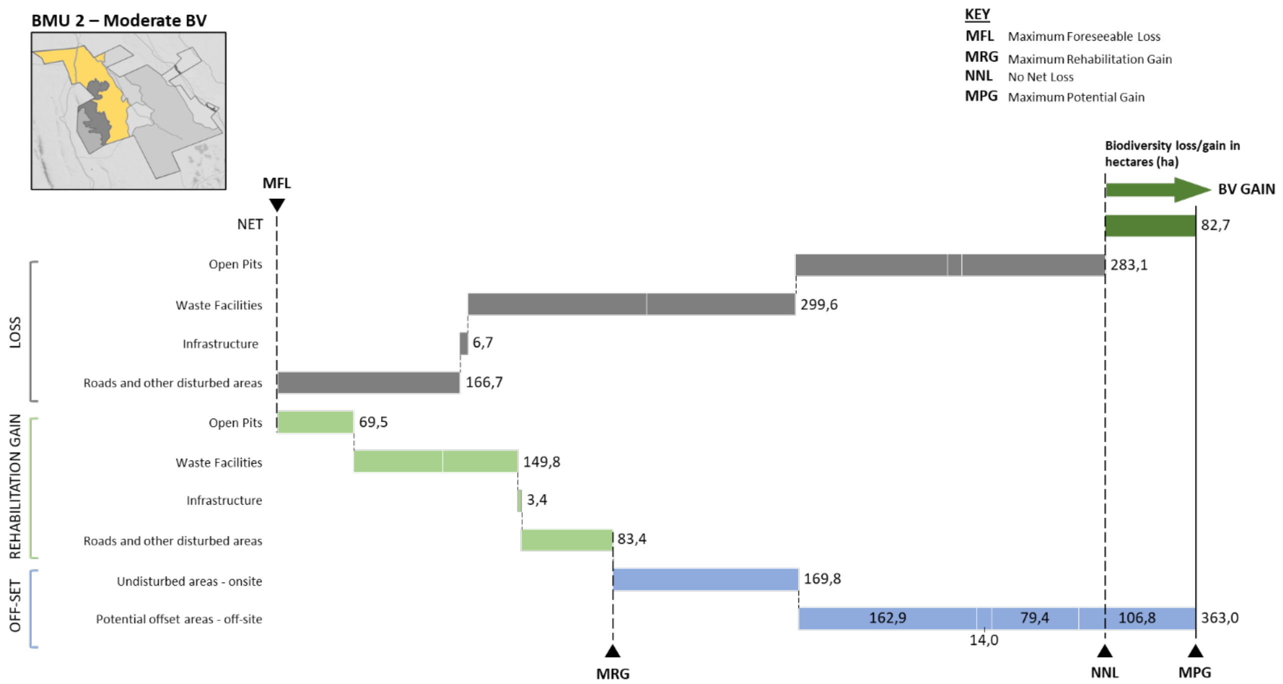

Figure 4 Residual impact to BV (represented in ha) for BMU 2

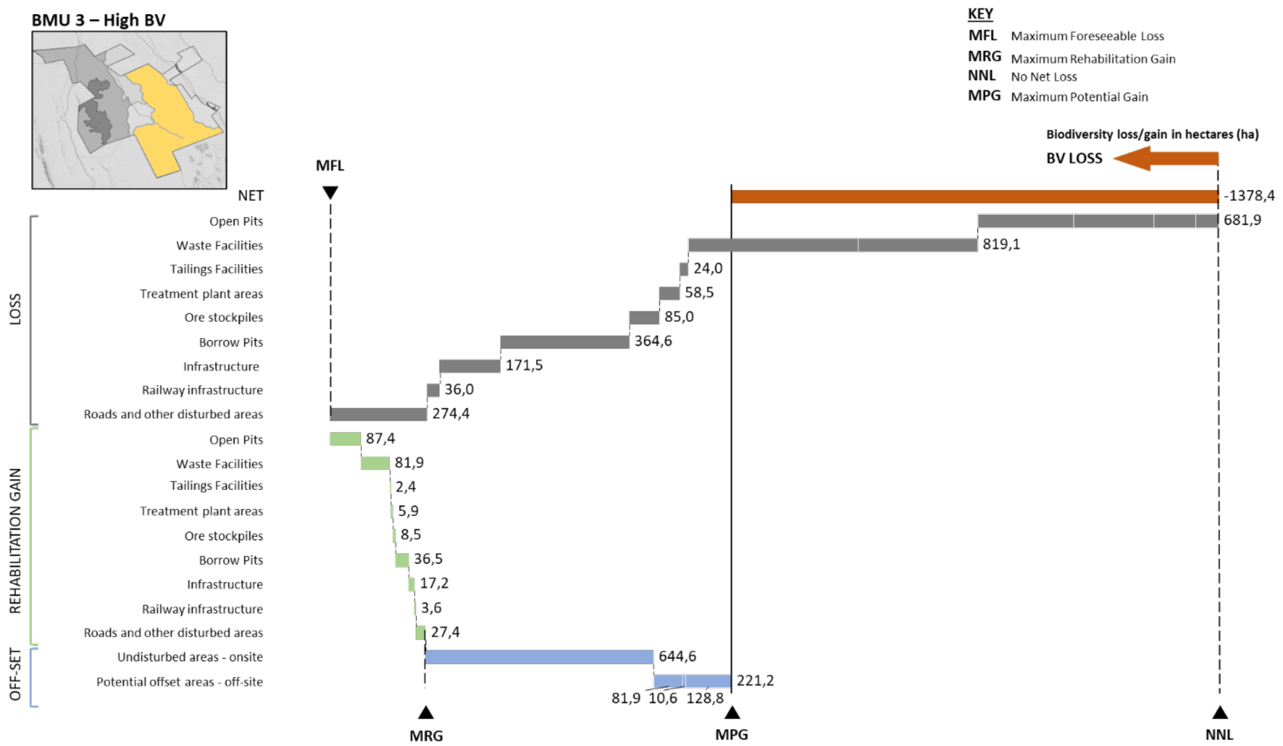

Figure 5 Residual impact to BV (represented in ha) for BMU 3

Table 2 Outcomes of the BV loss/gain assessment for all BMUs

BMU (Extent)	BV (vegetation type)	Surface area of BMU physically impacted by mine activities	Residual BV loss/gain	Observation
BMU 1 (2,689 ha)	High (Indigenous woodland)	179 ha 6.6%	Gain 262 ha	Low disturbance within BMU 1. Due to its high BV, this BMU may contribute positively to additional conservation actions (ACA).
BMU 2 (2,315 ha)	Moderate (Grassland)	617 ha 26.6%	Gain 83 ha	Offset landholdings are required to reach NNL (and achieve NPI).
BMU 3 (8,680 ha)	High (Ephemeral pans and wetlands)	2,234 ha 25.7%	Loss 1,378 ha	Confirmed biodiversity loss (considering existing rehabilitation criteria and offset opportunities). PCLU for potential off-set properties will need to be conservation-based.
BMU 4 (1,199 ha)	Very High (Sandy Shrubland)	0	Impacts avoided	High BV. Due to its high BV, this BMU may contribute positively to ACA.
BMU 5 (1,364 ha)	High (Thorn Shrubland)	78 ha 5.7%	Gain 136 ha	Low disturbance within BMU 5. Further conservation of offset landholdings where BMU 5 is represented may be considered to be ACA.
BMU 6 (675 ha)	Moderate (Dwarf Shrubland)	13 ha 1.9%	Gain 179 ha	Very low disturbance within BMU 6. Further conservation of offset properties where BMU 6 is represented may be considered to be ACA.

4 Discussion

4.1 BV losses

MFL was determined for all BMUs, by assuming a 100% loss of BV within disturbed areas due to direct impacts (physical disturbance footprints) only. It is important to understand the ecological status and associated BV baseline of the ecosystem (prior to disturbance) to better understand the relative BV gains and targets that may be achieved following the rehabilitation process. The rehabilitation of relatively degraded (baseline) systems may result in higher BV gains compared to gains in scenarios where relatively healthy or pristine ecological systems are disturbed.

Indirect impacts to BV are not clearly understood at the site and were not considered. Therefore, BV losses are likely to be underestimated. Indirect impacts to biodiversity include:

- Impacts within a 'buffer' zone surrounding (in proximity to) the direct impacts footprint (e.g. due to vibration, noise, fallout dust). The nature, drivers and extent of impacts in the 'buffer' zones relative to mining activities are yet to be determined at the site.
- Impacts to biodiversity due to the use of, or alteration of natural resources and ecosystem service components such as surface water, groundwater and soil resources. The nature and extent of indirect impacts to BV are yet to be determined at the site.
- The fragmentation of biodiversity corridors, thereby potentially impacting on adjacent ecological units.

4.2 BV gains

MRG was calculated at an assumed, projected BV restoration success percentage, relative to BV baseline that was originally disturbed. The assumptions were driven by the existing lack of knowledge related to the extent that current rehabilitation activities restore BV. Factors that will contribute to an improved understanding of BV restoration include:

- Gains that may be reasonably achieved by closure criteria and associated rehabilitation prescriptions (defined in the mine closure plan) to restore the habitat in question.
- Rehabilitation and/or restoration objectives, depending on the closure criteria and effort implemented to meet pre-determined post closure land use and land capability objectives. Rehabilitation targets are unlikely to achieve NNL objectives (as opposed to 'restoration' targets as highlighted by the Australia Department of Industry, Innovation and Science (2016)). BV gains from the rehabilitation process may not restore all BV losses, but may restore a proportion of losses. The rehabilitation BV gain assumptions in this case study (Table 1) provide an estimated opinion/indication regarding the BV gains that may be achieved and, therefore, remain at a low level of confidence. Further scientific work and monitoring is required to improve this confidence and rehabilitation success projection.
- Varying closure criteria applied to domains on the mine site and the extent to which BV gains can be achieved on the respective domains. This study assumes a static BV gain percentage for all domains following rehabilitation activities. This is likely not the case and potential BV gains to be achieved via the implementation of rehabilitation prescriptions should be independently understood for all respective mining area domains and landforms (given differences in their geotechnical and geochemical characteristics).
- Sensitivity of ecosystems and their components to being restored.
- Monitoring programme on progressive rehabilitation areas informs the knowledge base and confirm the extent to which success criteria have been met.

4.3 BV offsets

To achieve the principle of 'additionality', the contribution of offsets to BV improvement was calculated at an assumed, projected percentage relative to current BV, assuming no indirect impacts. The validity of these assumptions remains untested and are yet to be determined at the site. The achievement of MPG is dependent on future land use and successful implementation of conservation efforts to achieve additionality within the identified offset landholdings.

4.4 Integration of residual BV impacts and mine closure planning

This study confirms that strict adherence to the mitigation hierarchy is not always achievable (given the existing operations at the site) but the residual BV impact assessment provides a useful approach when companies decide to (retrospectively) adopt NNL/NPI objectives for existing, operational assets. The approach evaluates the contribution of the rehabilitation process towards achieving BV gain objectives (and the relative contribution to achieving NNL/NPI), in broad alignment with the principles of biodiversity offsets. The process recognises the value that offsite conservation activities add towards achieving the NNL/NPI objective which in effect results in these areas acting as potential offsets, as they would if the mitigation was implemented. Mining companies are adopting more rigorous biodiversity objectives and this approach demonstrates how existing operational sites can utilise their rehabilitation (or restoration) programmes, together with offsite conservation interventions towards NNL/NPI targets.

A further challenge related to effective retrospective application of BV loss/gain assessments is the lack of adequate baseline BV information. Typically, baseline biodiversity studies (undertaken during project development and environmental impact assessment processes) are not scoped to gather information to the level of resolution necessary to quantify BV effectively. These studies (that pre-date the decision to pursue NNL/NPI objectives) are typically inadequate to inform an adequate understanding of BV and therefore may not be suitable to be used as part of BV loss/gain assessments. This elevates the need for such projects to commission additional biodiversity specialist studies and increase the reliance on adjacent, analogue (or reference) sites to contribute to the determination of BV, which may often not be directly comparable to rehabilitated sites.

Activities undertaken in this study to assess residual BV should ideally be integrated with the mine closure planning process (ICMM 2019) (Figure 6). Biodiversity NNL/NPI objectives need to be considered in the context of, and aligned with, the identification of appropriate post closure land uses (PCLUs) for the site. The achievement of NPI is typically facilitated by a conservation-based PCLUs, which may be threatened by PCLUs that aim to mitigate alternative closure risks related to socio-economic or industrial objectives post closure, as an example.

Specific steps as presented in Figure 2 are referenced in Figure 6, demonstrating their contribution to the improved integration of biodiversity conservation within the mine closure planning process. Other relevant aspects that should be considered to integrate the biodiversity planning and mine closure planning processes are also presented (Figure 6).

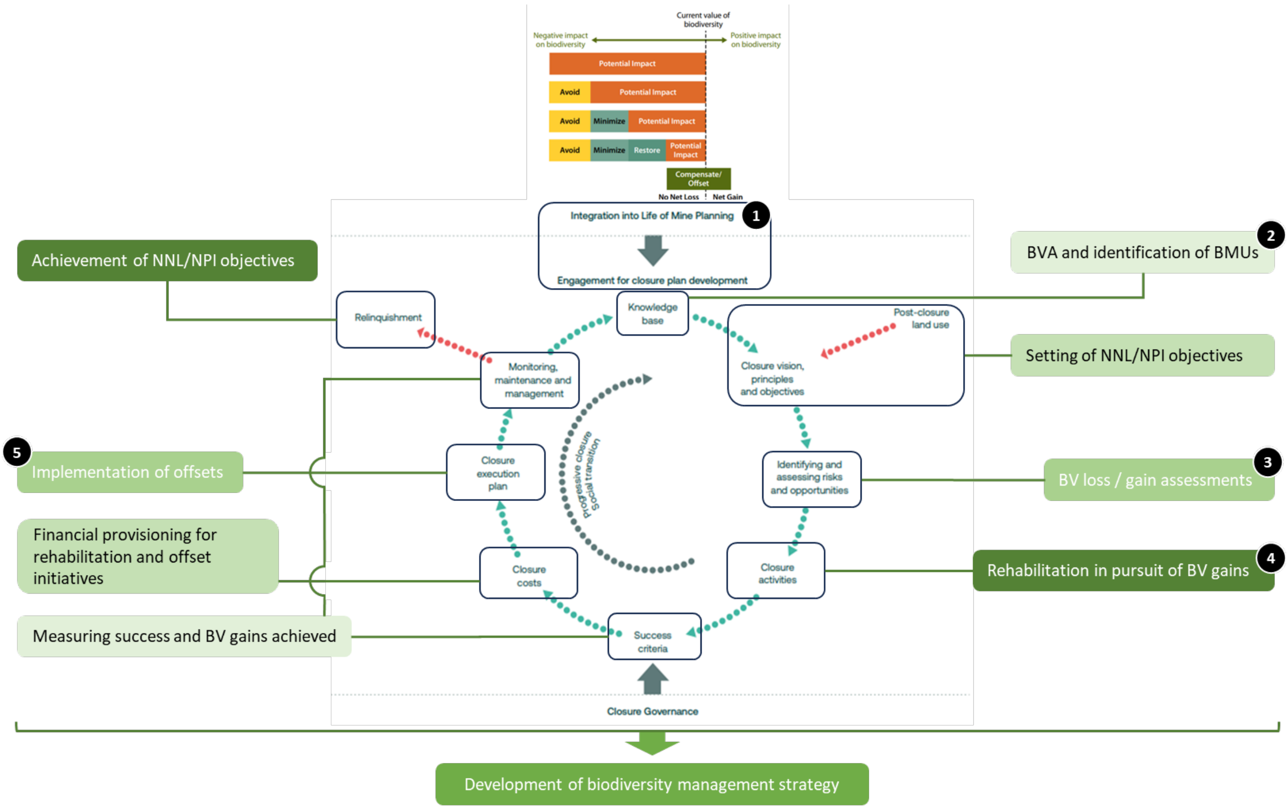

Figure 6 **Areas of integration of residual biodiversity impact assessment into the generic mine planning lifecycle (adapted from ICMM 2019)**

5 Conclusion

The approach presented in this study remains a conceptual, limited assessment of BV and its contribution to residual BV. The approach requires further development where assumptions used to determine BV losses and gains are addressed, particularly pertaining to the quantification of BV loss, and gains via rehabilitation and offset parameters.

This study has highlighted important considerations towards the assessment of residual biodiversity impacts to support mining rehabilitation and offsets decision-making. These are discussed below.

Robust characterisation of BV and the associated delineation of BMUs is key to understanding the BV baseline and meeting the principle of equivalence. The development of rehabilitation success criteria (via the mine closure planning process) is reliant on a well-defined BV baseline, to set appropriate and informed targets to combat the loss of BV.

BV gains from the rehabilitation process should not be expected to achieve NNL, given that restoration of the original baseline ecological communities is not necessarily pursued. The achievement of restoration targets would require the implementation of more onerous closure criteria, typically increasing the financial resources required to reinstate the foundations of a relatively more complex ecosystem. Complex ecosystems typically also require a relatively extended period to demonstrate successful ecological succession.

A robust knowledge base addressing relevant information and monitoring requirements is key to BVA and informing biodiversity management plans. The development of a credible and reliable knowledge base will facilitate the quantification of BV losses and gains, relative to BV baselines, in line with rehabilitation or restoration targets. This includes the need for an improved understanding of indirect BV losses, relative BV gains as a result of the rehabilitation/restoration programmes and the realistic contributions of offset opportunities to demonstrate the principle of additionality. Assumptions used in this study represent a low level of confidence, which should be improved and informed via an effective and targeted BV monitoring programme. Identification of appropriate ecological parameters during the BVA/BMP process is key.

The potential role of additional conservations actions (ACA) should be investigated. Where a biodiversity offset is not required, ACAs may play an important role in generating net positive contributions to biodiversity, including identifying opportunities for investment in biodiversity stewardship.

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