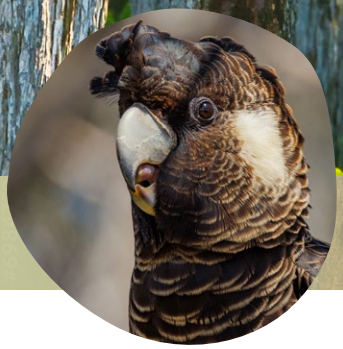
Strategic opportunities for environmental offsets in the Northern Jarrah Forest



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Acknowledgement of Country

We acknowledge the traditional custodians throughout Western Australia and their continuing connection to, and deep knowledge of, the land and waters. We pay our respects to Elders both past and present.

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Contents

Executive summary

The Northern Jarrah Forest (NJF) in Western Australia is of environmental, cultural, social and economic significance. With competing existing uses of the region, and plans for the expansion of development areas, strategic approaches are required to mitigate the impacts of development and ensure a meaningful contribution to sustainable developments through biodiversity offsets.

This report is the fourth and final stage of the research project "Biodiversity Offsets in the Northern Jarrah Forest Strategy" (Research Project) and consolidates information gathered in the three preceding stages:

1. Literature review "The identification of gaps in knowledge, management and conservation in the Northern Jarrah Forest" (Abdo & Young, 2025) that identifies knowledge gaps and opportunities for offsets in the NJF.
2. Stakeholder engagement to provide context to the data analysis. The information gathered during this stage was also used as the "acceptability" component of the risk assessment of offset options during Stage 3.
3. Spatial data analysis to identify strategic areas for offset opportunities to be implemented. The results of the spatial analysis were risk assessed, and the information gathered during this stage was also used to inform the "confidence" component of the risk analysis.

Four key offset opportunities were identified from the literature review during Stage 1:

1. **Protection** – legal protection to prevent (or hinder) clearing of land.
2. **Restoration** – activities that assist a degraded area towards a trajectory of recovery of natural values (biodiversity, ecosystem functions and ecosystem services) with the aim of forming a persistent, adaptive and resilient ecosystem.
3. **Invasive species and disease management** – use of various activities (spraying, trapping/baiting, etc.) to reduce to occurrence and prevent further spread of plant pathogens and invasive fauna.
4. **Management for improved water balances (ecological thinning)** – reduction in vegetation to reduce vegetation-based draw down of waterways, streams and groundwater.

Spatial analysis of relevant Geographic Information System (GIS) data sets was undertaken using publicly available and restricted access data sourced from government repositories and industry partners, and mapping of suitable and priority locations for the offset opportunities identified in Stage 1 was undertaken.

Areas where offsets would be less likely to meet broadly agreed criteria such as permanence and additionality (i.e. higher risk areas for offsets) were also identified, and in doing so, an overall paucity of available land was found. Therefore, flexible approaches involving enabling offset opportunities within conservation and planning areas were found to be necessary. Strategic approaches to offsets opportunities, including ecological linkages, collaborative approaches and coordinated approaches were also investigated.

Restoration offsets were found to provide the greatest extent of opportunity across the NJF and also presented the lowest risk in terms of confidence in meeting government and best practice offset criteria as well as regulator and stakeholder acceptability. However other offset opportunities appeared to be less strategic for the NJF. There were few opportunities for protection offsets, and both invasive species and disease management and the management of water balances through ecological thinning were found to be largely unsuitable offset solutions unless implemented through a coordinated approach such as a suite of offset activities.

Several gaps in knowledge were also identified through the various stages of the Research Project. Addressing these knowledge gaps through offsets could improve conservation outcomes (including offsets) in the NJF.

Given the paucity of land available for offsets in the NJF, if further development is to occur, the following recommendations for offsets in the NJF are provided on the basis of this research:

1. Offsets must be applied strategically through collaborative and coordinated approaches.
2. Offsets should be preferentially delivered in priority and low risk areas where permanency of offset actions can be reasonably assured, regardless of existing land tenure.

Further, with the increasing severity of the predicted impacts of climate change on the NJF, it is further recommended that the piecemeal approach to compensation of individual environmental values for offsets be instead replaced with focussing of offset activities towards key regional scale priorities.

The approach represented by this research can not only improve the capacity of offsets in the NJF to meet the needs of sustainable development but has broader applicability to other regions with high levels of development both within Australia and globally.

Introduction

Purpose

The Northern Jarrah Forest (NJF) has been identified to be at serious risk of loss due to historical and ongoing usage, compounded by the impacts of climate change (Calver & Dell, 1998a; Lawrence et al., 2022; Malcolm et al., 2006). There are several industries that rely on the NJF for economic purposes, with benefits to the broader Western Australian economy, and it is imperative to support the resilience and health of the forest to facilitate the economic, social and cultural priorities for the region. Finding solutions that will ensure that these environmental, economic, social and cultural priorities can be balanced will be the key to ensure the ongoing longevity and resilience of the NJF.

Australia has the second highest loss of mean species abundance globally (BioInt, 2024). With the impacts of climate change increasing in Australia (CSIRO & BOM, 2024), and the additional pressure that this places on biodiversity, the assurance of persistent and resilient natural values is becoming increasingly important. Recent data has shown that around 80% of Western Australians are supportive of greater consideration of natural values (CCWA, 2024; WWF, 2024). Australia's Strategy for Nature 2024–2030 (DCCEEW, 2024a) and commitment to global biodiversity targets (for example, as aligned with the Kunming-Montreal Global Biodiversity Framework (CBD, 2022)), are in recognition of this increasing importance. Biodiversity offsets (also known as environmental offsets) are a tool that can compensate for the impacts of development, and where strategically implemented, may also contribute to these goals and targets.

This report constitutes the final stage of the research project "Biodiversity Offsets in the Northern Jarrah Forest Strategy" that seeks to identify strategic opportunities, in recognition of sustainable development, for environmental offsets within the NJF (Research Project). The Research Project was conducted in four stages:

1. Literature review "The identification of gaps in knowledge, management and conservation in the Northern Jarrah Forest" (Abdo & Young, 2025) that identifies knowledge gaps and opportunities for offsets in the Northern Jarrah Forest (NJF).
2. Stakeholder engagement to provide context to the data analysis. The information gathered during this stage was also used as the "acceptability" component of the risk assessment of offset options during Stage 3.
3. Spatial data analysis to identify areas potentially suitable for offset opportunities to be implemented. The results of the spatial analysis were risk assessed and the information gathered during this stage was also used to inform the "confidence" component of the risk analysis.
4. Consolidation of information gathered in the three preceding stages and final recommendations (this report).

The strategic approach utilised by the Research Project is aligned with the Western Australian Environmental Protection Authority's Public Advice (EPA, 2024), the National Objectives within the Commonwealth Governments draft National Environmental Standard for Regional Planning (DCCEEW, 2024b) and the recommendations of the Independent Review of the EPBC Act – Final Report (Samuel, 2020). In addition, this strategy is aligned with Australia's Strategy for a National Reserve System 2009–2030 (NRMMC, 2010), enabling the outcomes of this Research Project to have further applicability to conservation activities more broadly.

The scope of the Research Project is focused on biodiversity offsets, the final stage in the mitigation hierarchy of avoid, mitigate, rehabilitate and offset (BBOP, 2024). Research has been conducted under the assumption that environmental approvals for development in the NJF are certain. This report does not make commentary on the appropriateness or feasibility of development in the NJF or the process surrounding Environmental Impact Assessments (EIA), acknowledging EIA and the design of offsets often occur simultaneously in practice.

Offset requirements

Environmental offsets are used throughout Australia to compensate for the impacts of development and to provide a contribution to Australia's goals for sustainable development (Abdo, 2023). In Western Australia, offsets are required by the Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW) for impacts to Matters of National Environmental Significance; the Western Australian Department of Biodiversity, Conservation and Attractions (DBCA) for the taking of flora, fauna, and impacts to ecological communities; and the Western Australian Department of Water and Environmental Regulation (DWER) for native vegetation clearing and environmental protection (Figure 1).

Significant residual impacts in the Northern Jarrah Forest[1]

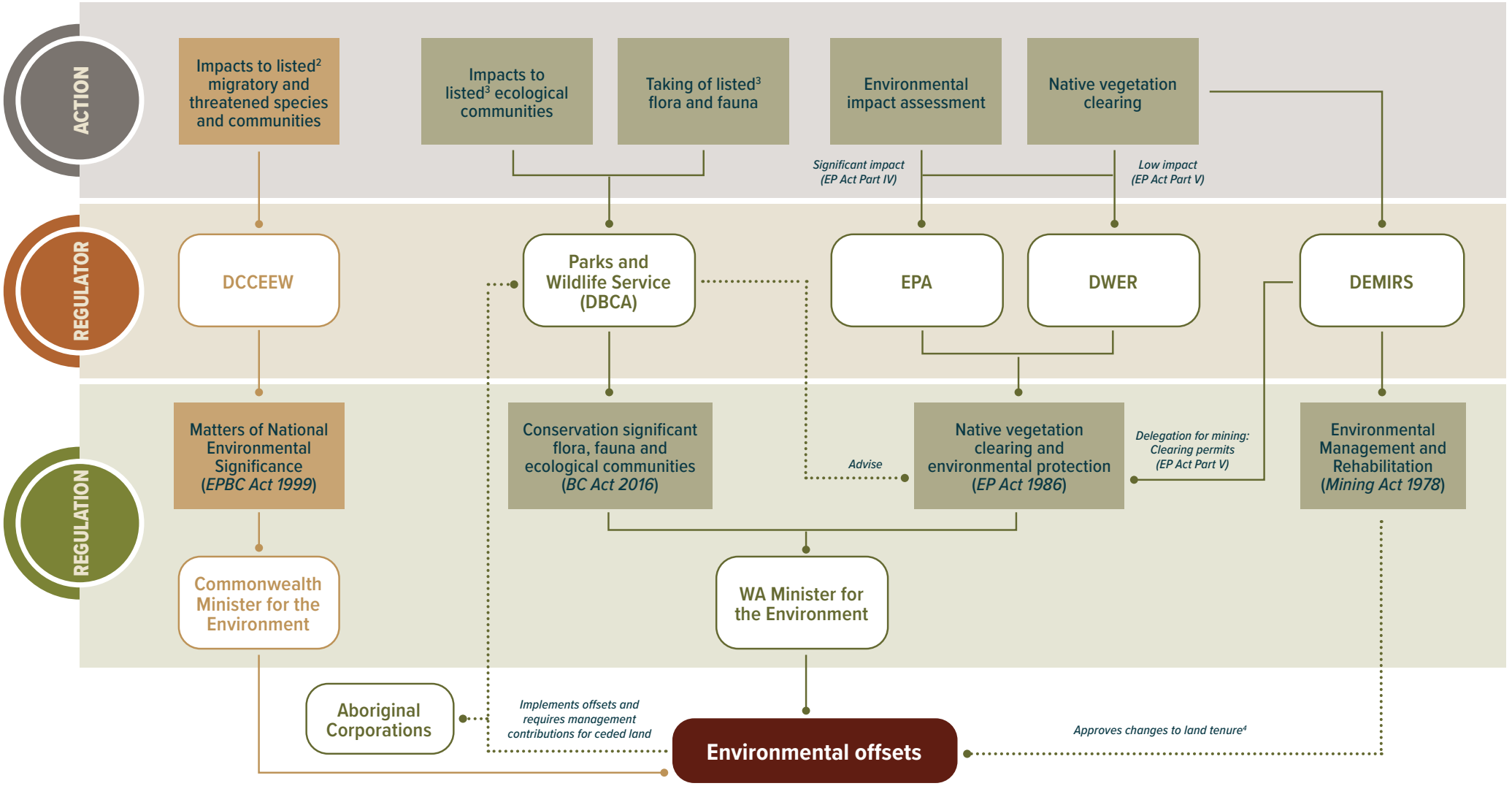


Figure 1: Overview of regulatory requirements for environmental offsets in the NJF taken from Abdo and Young (2025). Solid lines represent a dedicated process. Dotted lines represent an indicative/voluntary process. Square boxes indicate a document/requirement. Rounded boxes indicate a government department/minister.

1. Significant residual impacts means environmental impact remaining after all avoidance and mitigation measures have been fully explored and is consistent with both the description of "Significant Residual Impacts" in the WA Environmental Offset Guidelines (EPA, 2014) and the description of "Residual Significant Impacts" in the *Environment Protection and Biodiversity Conservation Act 1999* Environmental Offsets Policy (DSEWPaC, 2012a).
2. Species and ecological communities listed as Matter of National Environmental Significance in the *Environment Protection and Biodiversity Conservation Act 1999*.
3. Threatened and priority flora, fauna and ecological communities, and critical habitat as listed in the *Biodiversity Conservation Act 2016*.
4. The Department of Energy, Mines, Industry Regulation and Safety (DEMIRS) has a role in the approval of changes to land tenure (e.g. covenants) that are often required to provide legal protection of offset areas.

Background

The NJF subregion is classified by the Interim Biogeographic Regionalisation for Australia (Thackway & Cresswell, 1995). Located to the south and east of Perth along the Darling Scarp, it covers an area of 1,898,799 hectares[1], and is typified by mild wet winters and hot dry summers (Climate Change in Australia, 2024; Rundel et al., 2016; Thackway & Cresswell, 1995). The NJF is of environmental significance occurring within the South West Biodiversity Hotspot and containing three nationally important waterways; the Wannamal Lake System (WA094) in the Swan-Avon catchment, the Avon River Valley (WA045) and the Chittering-Needonga Lakes (WA047) (DBCA, 2019; DCCEEW, 2024b).

The NJF has geologically stable soils with deeply weathered profiles (Wardell-Johnson et al., 2015). Vegetation, geomorphology and soil variations across the NJF are driven by an east to west gradient of rainfall (Abdo & Young, 2025).

Several conservation significant fauna listed under the Western Australian *Biodiversity Conservation Act 2016* and Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) occur in the region as referred to in Table 1.

Many threatened and priority flora species listed under the BC Act have been recorded in the NJF including 13 critically endangered species, 23 endangered species and 16 vulnerable species. In addition, more than 180 priority species[2] have been recorded. There have been 19 different threatened ecological communities recorded within the NJF, including four that are listed under the BC Act as critically endangered and three that are listed as endangered[3].

Aboriginal people have managed the South West of Australia for thousands of years (Flynn & Ugle, 2023; Lullfitz et al., 2017; SWALSC, 2024), however, since European occupation in 1836 (Pearce, 1982), the South West of Western Australia, including the NJF, has been subject to very high levels of development from multiple industries (Neugarten et al., 2024). Initially clearing in the NJF was for agriculture and timber for the construction of Perth (Mills, 1989). Broader harvest of timber soon followed and continued until commercial logging of native forest ceased in 2024 (GWA, 2024). Mining, first commenced in the NJF in the mid-1960s (Gardner & Bell, 2007) with mining tenements now covering most of the region (Abdo & Young, 2025).

Table 1: Conservation significant fauna recorded in the NJF (GHD, 2021a, b)

Common name	Scientific name	Western Australian listing (BC Act)	Commonwealth listing (EPBC Act)	International Union for Conservation of Nature listing (IUCN Red List)
Baudin's black cockatoo	*Zanda baudinii*	Endangered	Endangered	Critically endangered
Carnaby's black cockatoo	*Zanda latirostris*	Endangered	Endangered	Endangered
Chuditch	*Dasyurus geoffroii*	Vulnerable	Vulnerable	Near threatened
Forest red-tailed black-cockatoo	*Calyptorhynchus banksii naso*	Vulnerable	Vulnerable	Least concern
Numbat	*Myrmecobius fasciatus*	Endangered	Endangered	Endangered
Quokka	*Setonix brachyurus*	Vulnerable	Vulnerable	Vulnerable
Red-tailed phascogale	*Phascogale calura*	Conservation dependent	Vulnerable	Near threatened
Woylie	*Bettongia penicillata*	Critically endangered	Endangered	Critically endangered

[1] Data source: IBRA Subregion Australia Version 7.0 - PED

[2] Data sources: DBCA_59_0724-1, DBCA_59_0724-2

[3] Data source: DBCA_39_0724

Key threats

Habitat loss, alteration and fragmentation from clearing, altered fire regimes, diseases such as *Phytophthora* dieback and invasive species such as feral cats, foxes and pigs present key threats to several threatened species or specially protected species in the NJF including quokkas and red-tailed phascogales (DEC, 2013; TTSC, 2016), Carnaby's, Baudin's and forest red-tailed black cockatoos (DEC, 2008a; DPaW, 2013), Muir's corella (DEC, 2008b), chuditch (DEC, 2012a), woylie and numbats (DEC, 2012b; DPaW, 2017).

Vegetation clearing and associated fragmentation and modification of habitat has a large impact on native species in Australia (Murphy & van Leeuwen, 2021; Nelder, 2018). Similarly, loss and modification of habitat through altered fire regimes and diseases such as *Phytophthora* dieback can negatively impact native species. Altered fire regimes may have further negative impact on native species by changing species composition, as well as the diversity and richness of native vegetation (CPC, 2023; Pekin et al., 2011; Robinson et al., 2023).

Invasive species including the rabbit (*Oryctolagus cuniculus*), fox (*Vulpes vulpes*), cat (*Felis catus*), black rat (*Rattus rattus*), house mouse (*Mus musculus*) and pig (*Sus scrofa*) exist across almost the entire south west, including the NJF (DoE, 2015), with corresponding negative impacts on native species throughout the region. Further, other key threats such as altered fire regimes, habitat clearing and fragmentation, *Phytophthora* dieback and climate change are likely to exacerbate the impacts of invasive species on native fauna, particularly those that are dependent on dense understory vegetation.

The climate of the southwest of Australia is becoming hotter and overall drier with significantly reduced streamflow (CSIRO & BOM, 2024; DJTSI, 2023). Rainfall recorded over the last 30 years in the NJF represents the lowest on record (1900–2024) (CSIRO & BOM, 2024). Comparing the periods 1910–1999 and 2000–2019 shows a change in average rainfall from more than 800 mm per year to between 450–800 mm per year (DPIRD, 2020).

There are many species that overlap the NJF that will be at threat from the effects of climate change. For example, the effects of climate change are expected to cause the extinction of Muir's corella (*Cacatua pastinator pastinator*), Darling Range southwest ctenotus (*Ctenotus delli*) and long-eared bat (*Nyctophylis major*) (Cook et al., 2016). In addition, the forest red-tailed black-cockatoo, minnow (*Galaxias truttaceaus*), and barking owl (*Ninox connivens connivens*) will be significantly threatened due to climate change (Cook et al., 2016).

Climate change is likely to cause structural change of the NJF from single stemmed individuals to multi-stemmed with accompanying increased water requirements (Prof. Giles Hardy 10/10/2024 pers comm.). Climatic changes, such as hotter conditions with longer periods of drought interspersed with larger rainfall events, will cause stress to trees and encourage pathogens such as *Phytothphora* dieback and marri canker to flourish. This can further increase stress to tree species and encouraging individuals to choose a multi-stemmed morphology over a single-stemmed. Given that multi-stemmed individuals have higher water usage needs, this will have further impacts on water availability and wetlands through the NJF, affecting aquatic species such as the vulnerable Carter's freshwater mussel and the western trout minnow (DEC, 2008c; TTSC, 2017), and threatened species including quokkas (DEC, 2013).

The altered climate is also likely to increase stress to trees and therefore increase both the prevalence and effects of existing and new pathogens and invasive species (Prof. Giles Hardy 10/10/2024 pers comm.), with consequences for the health, resilience and extent of the NJF. Further consequences from the impacts of declining forest health may be seen in fauna such as Carnaby's, Baudin's and forest red-tailed black cockatoos that utilise jarrah and marri trees as a key food and nesting source (DEC, 2008a; DPaW, 2013).

Methodology

The Research Project was completed in four stages, with each stage utilising the outcomes of the previous stage, culminating in this final report.

Stage 1 – Literature review

The Literature review "The identification of gaps in knowledge, management and conservation in the Northern Jarrah Forest" (Abdo & Young, 2025) was undertaken to:

- set the context for the subsequent stages of the Research Project
- identify gaps in knowledge management and conservation for the NJF
- identify priorities for the NJF that could present opportunities for the delivery of environmental offsets.

Documents (for example, policies, reports, positions statements) relevant to the NJF were collated, reviewed and utilised in the analysis. Although the literature reviewed identified several priorities for the NJF, some priorities were not able to demonstrate a potential for environmental gain over existing requirements and therefore were not explored further as opportunities for offsets.

Stage 2 – Stakeholder engagement

Stakeholder engagement was undertaken to provide further context to information gathered in the spatial data analysis phase (Stage 3) of the Research Project. Stakeholders relevant to the NJF were identified and then categorised into different sectors. A review of publicly available information about the NJF from stakeholders was undertaken and, where no publicly available information could be sought, stakeholders were invited to discuss the Research Project. Discussions with stakeholders, while informal and unstructured, were centred around projects planned and undertaken in the NJF, and opinions on key priorities for the NJF. While offsets were raised by stakeholders in some cases, offsets were not a key focus of these discussions.

A summary of sectors and number of stakeholders engaged from each sector is presented in Table 1. The publicly available information along with information gathered from these discussions was used to refine key priorities for the NJF, identify potential new sources of opportunities for offsets and contributed to the analysis of risk associated with implementation of the offset opportunities (see Stage 3). The list of stakeholders and a summary of relevant key perspectives are found in Appendix A.

Table 2: Summary of sectors investigated and stakeholder information collected

Sector	No. of documents reviewed	No. of stakeholders identified for engagement	No. of stakeholders met
Regulator/Government	31	9	5
Aboriginal Corporation	0	4	4
Catchment group	0	5	4
Agriculture	0	3	0
Carbon farmer/agroforestry	0	1	0
Forestry	1	0	0
Land development	3	0	0
Subject matter expert	9	6	3
Local government	9	1	1
Conservation group	2	3	3
Forestry group	2	0	0
Tourism	3	0	0

Stage 3 – Spatial data analysis

Spatial data were sourced from Western Australian and Commonwealth government repositories and included both publicly available and restricted access data sets. In addition, some data was provided by industry partners. Data layers were used to identify locations suitable for offset opportunities within, and near to, the NJF. These data layers were then displayed in maps (see "Results and discussion"). Maps of the data layers at a finer scale were also prepared; these maps are available as supplementary materials.

Data sets sourced were of variable quality and used to provide a broad-scale indication of suitable locations for various strategic opportunities for biodiversity offsets. Note that the spatial analysis was not designed to identify specific offset locations and ground-truthing and/or further research would be required to infer specific locations for offset projects. A list of data layers used is provided in Appendix B.

To compare, contrast and prioritise offset opportunities, a risk assessment was undertaken using the level of confidence in the achievement of the offset requirement for a particular offset opportunity, and the level of stakeholder acceptability[4]. The metrics utilised for the confidence aspect of the risk analysis were derived from Western Australian Government and Commonwealth Government offset requirements, including:

- Draft National Environmental Standard for Restoration Actions and Restoration Contributions (DCCEEW, 2024c)
- *Environment Protection and Biodiversity Conservation Act 1999* Environmental Offsets Policy (DSEWPaC, 2012a)
- Public Advice: Considering environmental offsets at a regional scale (EPA, 2024)
- WA Environmental Offsets Policy (EPA, 2011)
- WA Environmental Offsets Guidelines (EPA, 2014).

A brief search of literature was then conducted to confirm if these metrics also represented best practice. A summary of metrics used, including references to best practice elements identified in literature, are presented in Figure 2.

Scores were applied to each metric in terms of confidence and acceptability for each offset opportunity. The scoring rubric and the risk matrix utilised is presented in Figure 3.

Scores for confidence and acceptability were averaged (non-weighted) to provide an overall assessment for acceptability and confidence. The risk was determined using these averaged scores[5] within the risk matrix (Figure 3).

Stage 4 – Final report

The final stage of the Research Project is to use the information gathered during the previous three stages to draw conclusions and make further recommendations for the strategic use of offsets in the NJF (this report).

[4] Note stakeholders were not specifically surveyed for opinions on the offset opportunities presented and therefore level of acceptability was based on insights provided through generic discussions as part of stakeholder engagement and/or information made publicly available by relevant stakeholders (polices, reports, position statements).

[5] Averaged scores were rounded where required prior to utilisation of the risk matrix.

		Metric
Reflects best practice	in **both** WA and Commonwealth requirements	**Data quality** *What level of confidence in the accuracy of the data?*
		Permanence *Will the outcomes be long-term in the face of climate change?* (BBOP, 2012; Laitila et al., 2014; Moilanen & Kotiaho, 2021; Noga. 2014; Rosa et al., 2016)
		Measurable *Can benefits be measured?* (Abdo et al., 2019; BBOP, 2012; Koh et al., 2014; Kujala et al., 2015; Maron et al. 2010; Maron et al. 2012; Maron et al, 2016; Niner et al, 2021)
		Additional *Is it additional to existing efforts?* (BBOP, 2012; Laitila et al., 2014; McKenney & Kiesecker, 2010; Yu et al., 2018)
	in Commonwealth or WA requirements	**Efficient** *Is it cost effective?* (Abdo et al., 2019; Carwardine et al., 2014; Niner et al, 2021; Noga, 2014)
		Effective *Can it make a meaningful improvement for the NJF?* (Abdo et al., 2019; BBOP, 2012; Koh et al., 2014; Niner et al, 2021)
	EPA advice	**Strategic** *Can it be delivered in an optimal way?* (Abdo et al., 2019, Andrello et al., 2015; Koh et al., 2014; Lukey et al., 2017; Takeda et al., 2021; Underwood, 2011)

Figure 2: Metrics used for the risk analysis of offset opportunities. Shading represents how reflective the opportunity is of government requirements or best practice, with darker green included in best practice and both Commonwealth and Western Australian government requirements

	Accuracy/confidence			
	Measure	**Low**	**Medium**	**High**
Data quality *What level of confidence in the accuracy of the data?*	Aggregate of data sets used for the layer and a function of both: • data accuracy (scale of collection, reliability) and • data age (where age is relevant to accuracy)[6]	Data is unreliable/ coarse scale **AND** data is not recent and age is relevant	Data is reliable/fine scale **OR** data is recent/age irrelevant	Data is reliable/fine scale **AND** data is recent/age irrelevant
Permanence *Will the outcomes be long-term in the face of climate change?*	Resilience of the benefits of the offset activity	Benefits are at high risk of reversal following the end of the activity and/or loss from other processes	Offset is designed to persist BUT other mechanisms may reverse its benefits	Benefits from the offset are resilient and long lasting
Measurable *Can benefits be measured?*	• Proportion of the outcome that can be measured • Quality of the baseline (see data quality)	Data can only be feasibly collected for a small proportion (e.g. <50%) of the offset benefit **AND** baseline data is unavailable or of low quality	Data can feasibly be collected for most of offset benefit (e.g. >50%) **OR** baseline data is high quality	Data can feasibly be collected for most of offset benefit (e.g. >50%) **AND** baseline data is high quality
Additional *Is it additional to existing efforts?*	• Requirement for management • Level of management	Offset is in an area that has a mandate for management **AND** is currently managed	Offset is in an area that has a mandate for management **OR** is currently unmanaged	Offset is in an area that does not have a mandate for management **AND** is currently unmanaged
Effective *Can it make a meaningful improvement for the NJF?*	Level of risk from other processes (including policies/legislative instruments)	Benefits are at high risk of loss from other processes	Offset is effective in delivering meaningful outcomes **BUT** benefits are at high risk of loss from other processes	Offset is effective in delivering meaningful outcomes **AND** benefits are at low risk of loss from other processes
Efficient *Is it cost effective?*	• Cost of implementation/ regulation • Likelihood of achieving offset benefit	Offset is costly to implement/regulate **AND** cannot facilitate adaptive management	Offset is inexpensive to implement/regulate **OR** facilitates adaptive management	Offset is inexpensive to implement/regulate **AND** facilitates adaptive management
Strategic *Can it be delivered in an optimal way?*	Scale across landscape: • contribution to ecological linkages • Contribution to co-benefits	Offset does not link fragmented areas **AND** co-benefits are not possible	Offset provides ecological linkages across the landscape **OR** provides additional environmental/socio-economic co-benefits	Offset provides ecological linkages across the landscape **AND** provides additional environmental/socio-economic co-benefits

Figure 3: Definitions of risk used during the risk assessment of offset opportunities. Shading represents how reflective the opportunity is of government requirements or best practice, with darker green included in best practice and both Commonwealth and Western Australian government requirements

[6] The assessment of data accuracy and age has been undertaken using metadata for the data sets used. This assessment is available as supplementary information to this report.

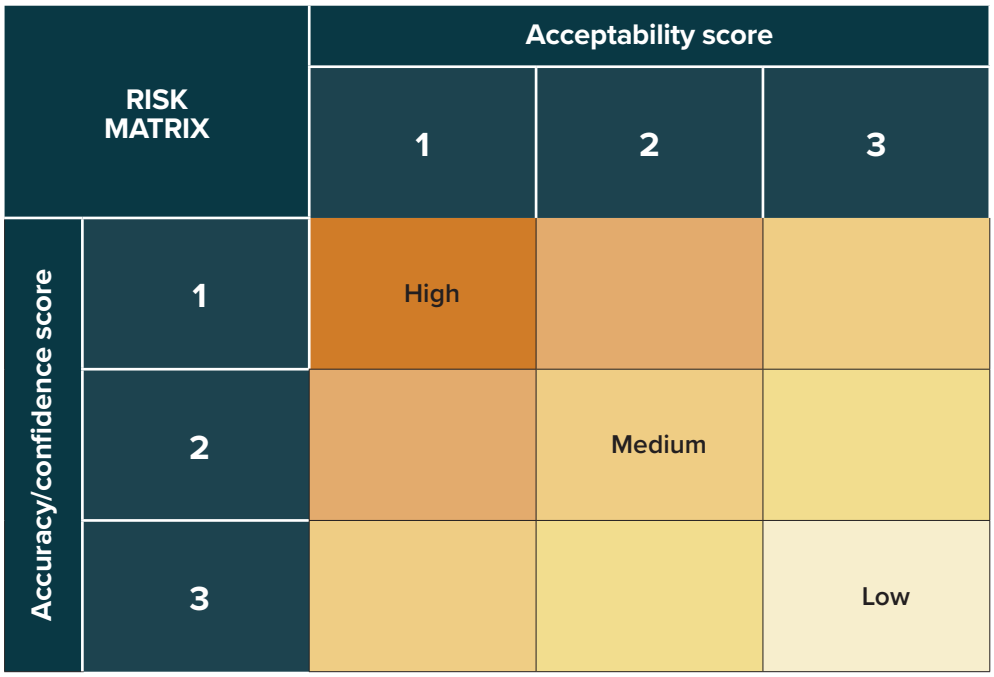


Figure 4: Risk matrix utilised to determine the overall risk for different offset opportunities

Results and discussion

Information collected through the literature review and stakeholder engagement, identified four broad opportunities for offsets in the NJF:

1. Protection
2. Restoration
3. Invasive species and disease management
4. Management for improved water balances (ecological thinning)

The mapping and analysis identified areas of high and low risk for offsets, as well as strategic approaches for an offset model. These are discussed below.

Higher risk areas for offsets

Potential resource (mining tenements, extraction sites, significant basic raw materials), referral (EPA significant referrals) and conservation areas (DBCA reserves, Collaborative Australian Protected Areas Database (CAPAD)) were mapped to indicate areas that would be higher risk to undertake offsets (Figure 4).

Potential resource areas

Offsets require placement offsite from development areas and given that mining tenements and resource extraction sites are onsite (i.e. where development occurs), offsets by definition cannot be placed within these areas. The implementation of offsets within potential resource areas (mining tenements, resource extraction sites, areas identified with significant basic raw materials) poses a higher risk of offset failure due to the inability to secure long-term protection from further development and offset benefits.

Where there are known minerals, protection measures to secure land tenure for conservation purposes, such as conservation covenants, can be reversed to allow for exploration and mining. Both the Western Australian and Commonwealth governments require the long-term security of offsets. The Western Australian offsets guidance states that "Offsets for clearing permits require long-term security of the outcome (whether land acquisition or on-ground management)" (EPA, 2014). The Commonwealth offset policy states that it will consider "current land tenure of the offset and the proposed method of securing and managing the offset for the life of the impact" (DSEWPaC, 2012a). Therefore, it is unlikely that potential resource areas within and surrounding the NJF would be considered suitable for the implementation of offsets.

Mining tenements are provided in blocks, and while developers may not choose to mine the entire block, the tenement itself enables the developer to utilise the whole area even if that is not their intention. While it may be possible for a conservation covenant and mining tenement to be issued over the same area, a conservation covenant cannot exclude mining activity within the Western Australian regulatory framework. On these bases, the security of offset outcomes would be considered uncertain and therefore it would be difficult to justify the use of an existing mining tenement as an offset site. A potential solution to this issue would be to enable a section of mining tenement block to be cleaved off for offset purposes. While some areas can be declared as exempt from mining (under Section 19 of the *Mining Act 1978*), this exemption is only valid for a period of two years, therefore a new legal mechanism may be needed to be explored.

The proximity of development activity to offsets within potential resource areas is also of concern due to possible impacts on offset outcomes from development activities, habitat fragmentation and edge effects. This could compromise the ability of the offset to achieve required environmental outcomes in an efficient and cost-effective manner as required by the EPA offset guidelines (EPA, 2014) and the Commonwealth offset policy (DSEWPaC, 2012a). The placement of an offset within a mining area would also restrict the opportunity to derive co-benefits as suggested by the EPA's public advice (EPA, 2024) and the Commonwealth's draft National Environmental Standards (DCCEEW, 2024b). A new type of covenant could be explored; one that excludes any activity that jeopardises offset outcomes. However, this would also require new legal solutions.

Referral areas

Referral areas include areas to be cleared for development and areas under planning regimes for management (including under the Forest Management Plan (FMP). Similar to potential resource areas, referrals for development areas would not be considered suitable for offsets due to the increased risk of offset failure from future development and potential impacts due to the proximity to development, as well as having a restricted ability to deliver co-benefits.

Referrals for planning areas include areas to be managed for conservation purposes, such as those identified in the FMP. The FMP incorporates a vast area (2.5 million hectares) of the South West of Western Australia and provides the framework with which DBCA will protect and manage forests on public land. Given that both the Commonwealth (DSEWPaC, 2012a) and Western Australian (EPA, 2014) governments require offsets to demonstrate additionality, land within planning areas, including the FMP, is unlikely to be considered suitable for offsets under a strict application of these offset requirements.

Conservation areas

Conservation areas are intended to be managed for conservation purposes and are therefore compromised in their ability to demonstrate additionality as offsets. Adhering to a strict definition of offset requirements by both the Commonwealth (DSEWPaC, 2012a) and the Western Australian (EPA, 2014) governments, conservation areas are typically not considered suitable to be utilised for offsets.

Summary

Resource, referral and conservation areas cover almost 90% (1,701,433 hectares) of the NJF and much of the surrounding area, with little remaining area available for biodiversity offsets (Figure 5). However, the NJF is at high risk of loss, including from climate change (Lawrence et al., 2022). Loss of the NJF would result in a large impact on biodiversity, ecosystem functions and ecosystem services including the loss of cultural and socio-economic benefits from industries that rely on these natural values (like tourism, bee keeping). Therefore, for development in the NJF to continue, innovative and flexible approaches to offsets are required to retain natural values of the region and prevent the transition or collapse of the forest as predicted by the IPCC (Lawrence et al., 2022). A flexible approach to offsets is consistent with the recommendations of a recent review of the Pilbara Environmental Offset Fund (Impactseed, 2024).

The conservation estate is vast, and management requirements are increasing in accordance with growing socio-economic requirements and the impact of a changing climate. Enabling offsets to occur within referral planning areas and conservation areas could further support management efforts and improve the extent and resilience of natural values. The identification of priorities for these conservation actions should be considered in the context of future referrals for development and mining, particularly within priority management areas.

There is precedence of offsets being permitted in areas where there are existing referrals, resource and/or conservation areas (Figure 6). Further, the EPA's public advice encourages a strategic and flexible approach to offsets (EPA, 2024). Therefore, the data analysis presents offset opportunities that overlap designated planning areas (Figure 7). In these locations, offsets could contribute to the further management and resilience of areas planned for conservation.

Offset opportunities have also been presented within development areas (Figure 8). However, with the presence of mining and the existence of referrals for development in these areas, offset outcomes are high risk. Therefore offsets should be implemented with caution, and with a strong justification of how they align with offset criteria and the potential co-benefits.

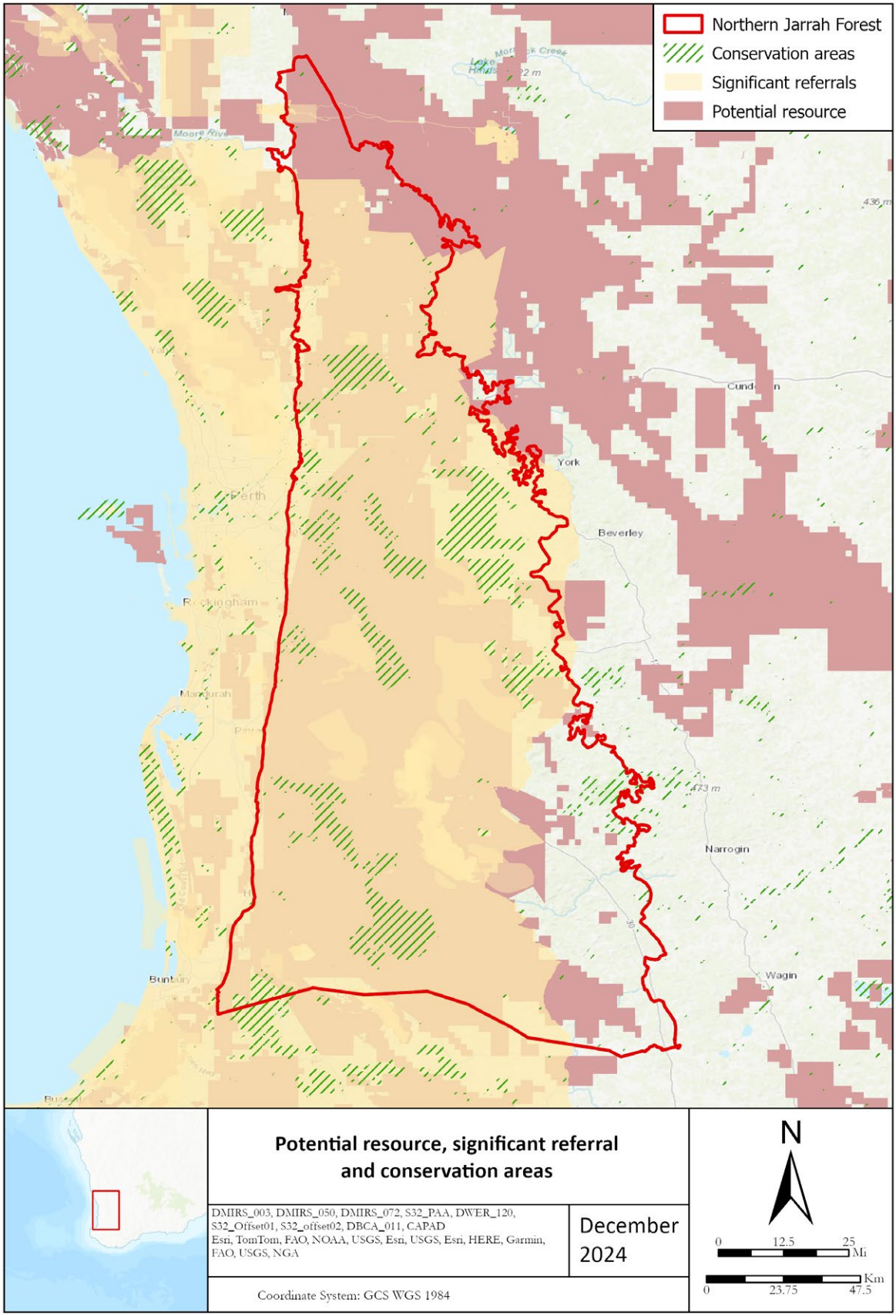


Figure 5: Potential resource (mining tenements, extraction sites, significant basic raw materials), referral, and conservation areas (DBCA reserves, Collaborative Australian Protected Areas Database (CAPAD))

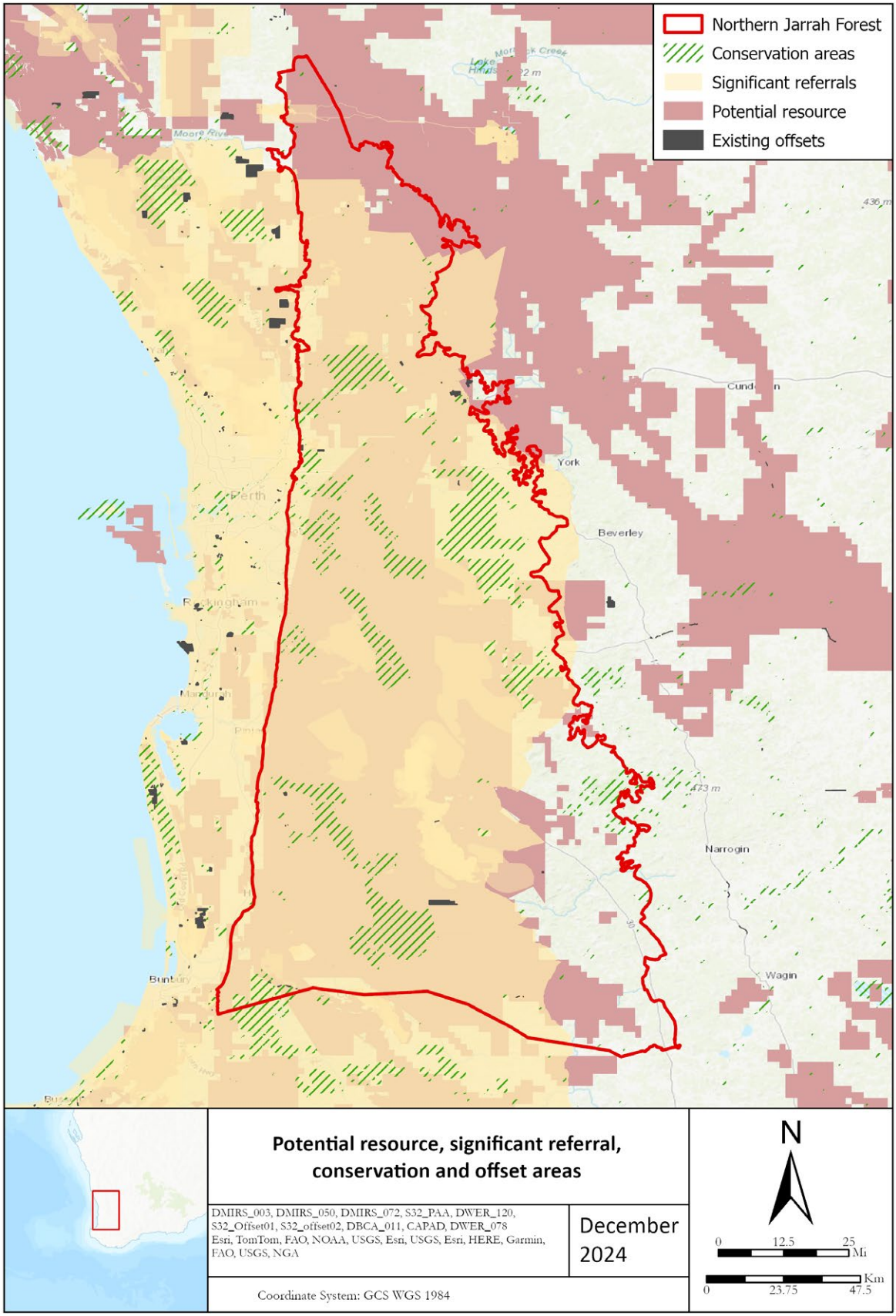


Figure 6: Mapped environmental offsets (as per the EPA register) previously approved within and adjacent to resource (mining tenements, extraction sites, significant basic raw materials), referral and conservation areas (DBCA reserves, Collaborative Australian Protected Areas Database (CAPAD))

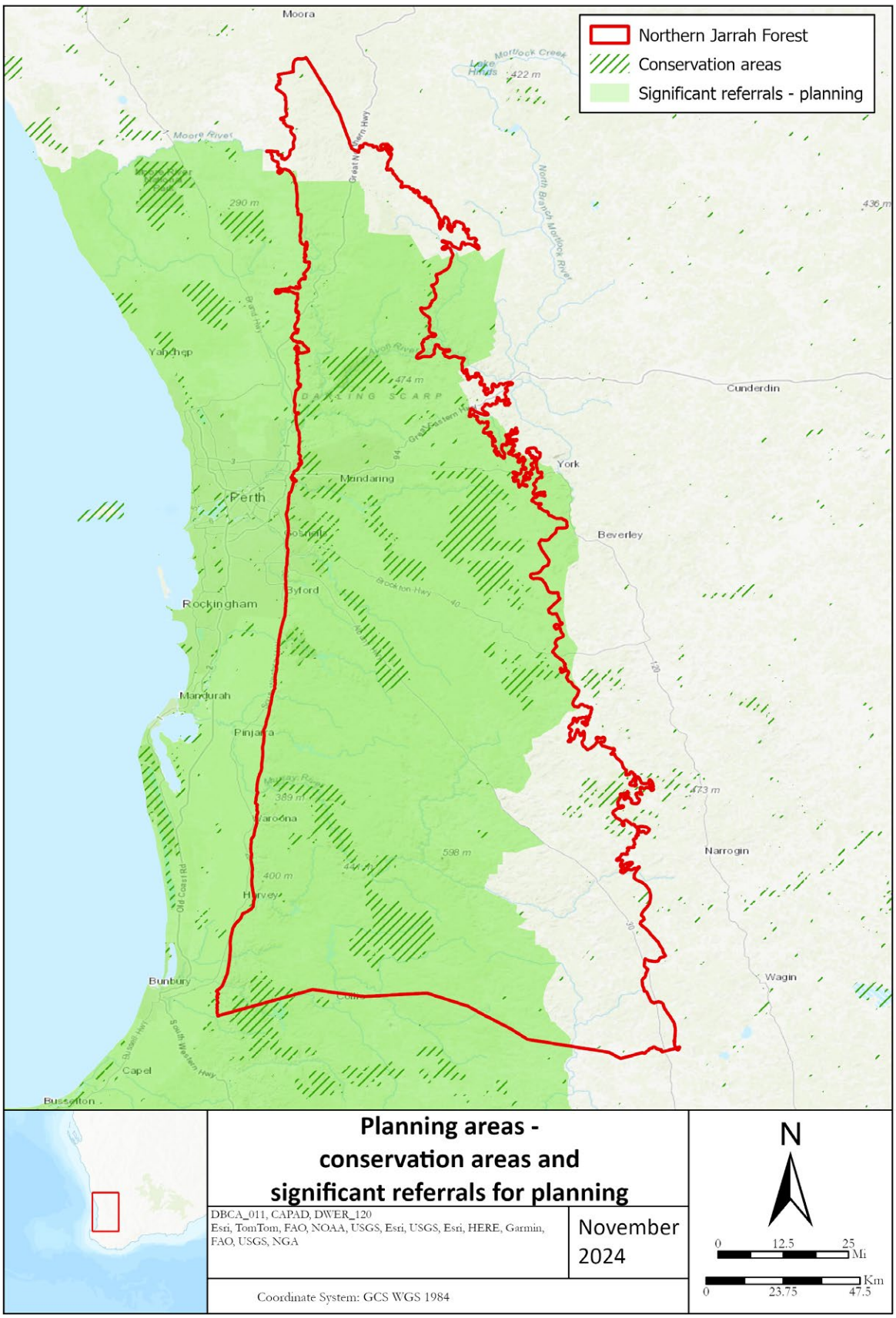


Figure 7: Planning areas — where offsets could be applied in addition to existing management actions on conservation areas (DBCA reserves, Collaborative Australian Protected Areas Database (CAPAD)) or within areas that have referrals for planning purposes

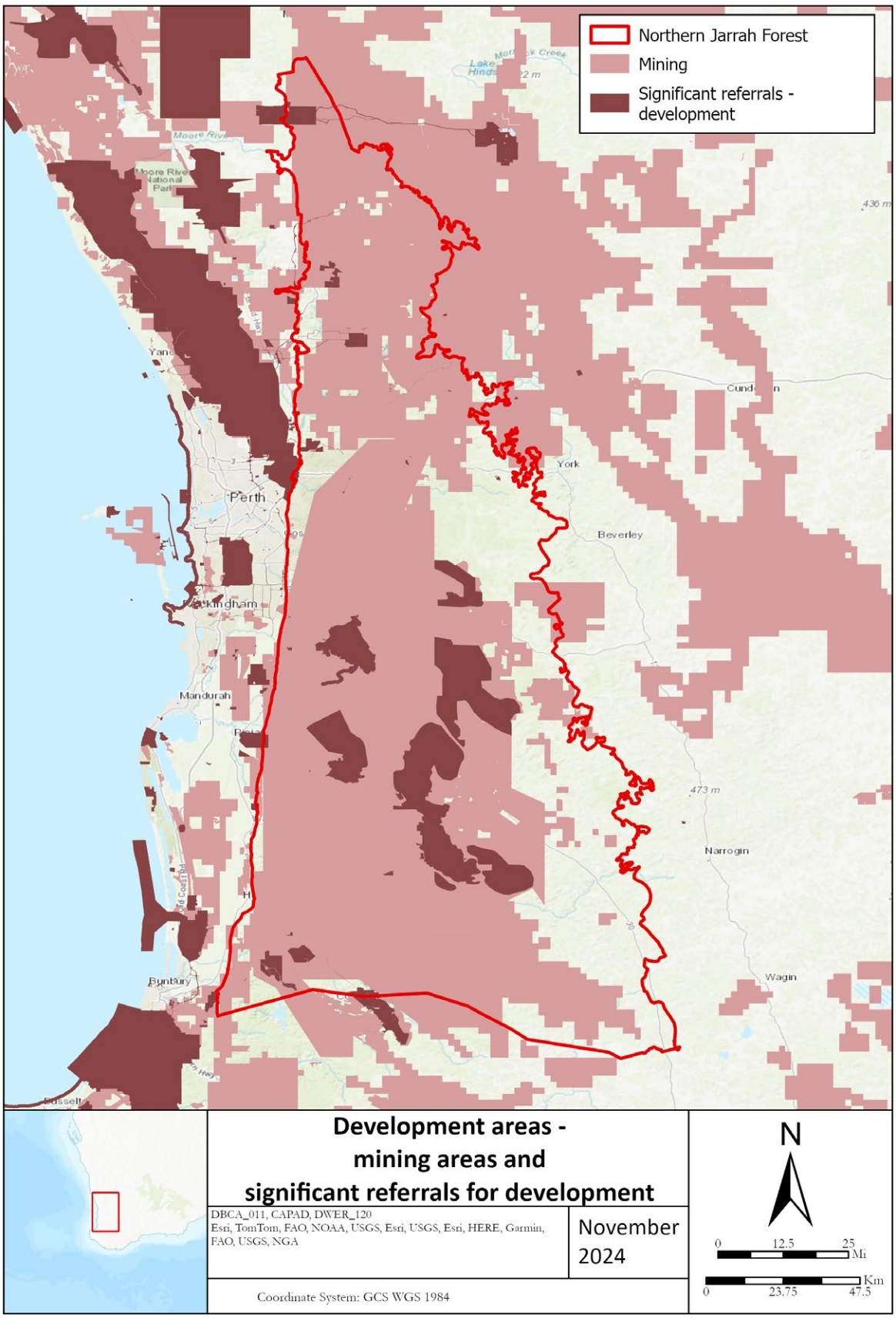


Figure 8: Development areas — where offsets should be applied with caution as development is expected due to potential resources (mining tenements, extraction sites, significant basic raw materials) or referrals for development purposes

Strategic approaches

Historically, the use of offsets has been focused on the delivery of compensation for specific environmental values (such as the conservation of significant flora, fauna and ecological communities) and the placement of offsets within this context has been based on the availability and cost of land and proximity to development. This has created a piecemeal approach to the delivery of offsets that provides only localised, small-scale benefits. Instead, if offsets have a strategic focus towards conservation priorities across the region, greater conservation gains can be realised and risks and costs minimised (IUCN, 2022, Strassburg et al., 2019, Bonnot et al 2013). In addition to improved efficiency and effectiveness a strategic approach can also enable flexibility and support decision making for conservation (Cook et al. 2014).

In their recent public advice (EPA, 2024), the EPA has recognised the importance of flexible approaches, ecological linkages, and co-benefits with heritage, cultural, and social values. Similarly, the draft National Environment Standards (DCCEEW, 2024c) highlight the importance of community engagement and consultation as well as the benefits of providing offsets through a coordinated approach such as a strategic fund. These values can be used to inform strategic approaches to offsets in the NJF, with greater co-benefits and better regulator and stakeholder acceptability.

Prioritisation of ecological linkages

Clearing for development in the NJF may cause fragmentation of habitat for threatened species across the region (WAFA & CCWA, 2022). Therefore, the prioritisation of strategic continuous habitat and/or 'stepping stones' to create ecological linkages for these species across the landscape is of primary importance (Molloy et al., 2009). Prioritising ecological linkages can enable clearing for development to continue, whilst minimising the loss of natural values across the landscape (Mastrantonis et al., 2022). This is consistent with the EPA's public advice that has a guiding value of connectedness whereby "offsets that demonstrate connectedness of the physical or ecological function values with those being impacted should be prioritised" (EPA, 2024).

Ecological linkages can provide access to core habitat and climate refugia for threatened species (Marsh & Carwardine, 2023). Linkages can reduce fragmentation and the loss of biodiversity, especially in the context of climate change (Molloy et al., 2009). Given that open areas provide predatory invasive species, such as cats and foxes, a greater efficiency of predation, reducing habitat fragmentation through ecological linkages can also ease pressures of predation on native fauna (Brennan et al., 2005). Maintenance of ecological linkages can assist in the persistence and recovery of threatened species and facilitate genetic flows over larger distances (DEC, 2012a).

Mapping of ecological linkages in the NJF has occurred under three different projects: Chittering Ecological Linkages (WALGA, 2008), Perth Regional Ecological Linkages (WALGA, 2004) and South West Regional Ecological Linkages (Molloy et al., 2009). These linkages were identified to link "patches of remnant vegetation judged to be of regional significance by retaining the best (condition) and/or most contiguous patches available to act as stepping stones for flora and fauna between regionally significant areas" (Molloy et al., 2009). Waterways and associated vegetation have also been included as part of the ecological linkage data sets (Molloy et al., 2009; WALGA, 2004; 2008). Although the ecological linkage data is older, given that the identified linkages were predominantly created to join conservation areas or follow waterways neither of which would be likely to change over time, the data is still considered relevant. However, research that reviews and updates these linkages is recommended. In particular, linkages along waterways should be also prioritised given that wetlands, waterways and other hydrographically important areas create linkages across the landscape and are also important as sites of Aboriginal cultural heritage (DPLH, 2024) and priority for protection and conservation (Luxton, 2000).

In areas where there are competing priorities for ecosystem services, such as the NJF, managing the landscape to deliver multiple benefits can provide socio-economic benefits and reduce conflict over land use (Neyret et al., 2023). Previously cleared areas are often restricted in access for cultural and social purposes (for example, hiking and mountain biking) (Forestry Australia, 2022). However, if combined with ecological linkages and impacts are carefully managed, additional cultural and socioeconomic benefits including connection to nature and improved mental and physical health can be realised (CGT, 2020; CGT, 2022; WestCycle, 2023). The WA Strategic Trails Blueprint 2022–2027 recognises the value of sustainable design, community engagement and collaborative planning (CGT, 2022); values which are also aligned with the planning and design of strategic offsets. Collaborating with groups that promote cultural and recreational use, such as Aboriginal businesses and hiking and mountain biking groups, to improve visual amenity of areas surrounding key trails such as the Bibbulmun and Munda Biddi has been identified as a priority (Lynch, 2024). Offsets may also provide an opportunity to develop new trails within restoration areas and/or ecological linkages with high potential social/cultural and heritage amenity such as the Balmoral Track and Tullis Bride walking trail.

Collaborative approaches

The knowledge of local stakeholders has not been effectively incorporated into offsets and restoration to date (Peel Alliance, 2023). Ensuring ongoing, equitable and effective engagement increases the likelihood of success of restoration (Nelson et al, 2024). Developers should better align with community expectations

and priorities, undertaking ongoing engagement in transparent and collaborative ways, effectively integrating scientific, local and Indigenous knowledge and encouraging local buy-in (Peel Alliance, 2023, Wardell-Johnson et al., 2024).

The EPA encourages collaborative approaches with co-benefits for social surroundings as a guiding value in their public advice (EPA, 2024). Collaborative approaches are also consistent with DBCAs approach to managing lands and waters (DBCA, 2019) and align with the draft National Environmental Standard for Regional Planning (DCCEEW, 2024a), that describes the use of collaborative approaches to deliver net positive outcomes, identify regional values and guide future protection conservation, restoration and development.

Collaborative approaches can reduce the risk of offset failure and improve cost effectiveness (Abdo & Young, 2025). The Standards of Practice to Guide Ecosystem Restoration (Nelson et al., 2024) describes five principles (out of 10) that explicitly refer to collaboration and/or social and cultural benefits:

- **Principle 2:** Ecosystem restoration promotes inclusive and participatory governance, social fairness and equity from the start and throughout the process and outcomes.
- **Principle 4:** Ecosystem restoration aims to achieve the highest level of recovery for biodiversity, ecosystem health and integrity, and human well-being.
- **Principle 6:** Ecosystem restoration incorporates all types of knowledge and promotes their exchange and integration throughout the process.
- **Principle 7:** Ecosystem restoration is based on well-defined short-, medium- and long-term ecological, cultural and socioeconomic objectives and goals.
- **Principle 8:** Ecosystem restoration is tailored to the local ecological, cultural and socioeconomic contexts, while considering the larger landscape or seascape.

A large proportion of the NJF is potentially arable land (Abdo & Young, 2025) and the integration of restoration into an active and changing agricultural landscape can be complex (WABSI, 2025). Collaboration with farmers on the restoration of surplus/less productive farmland can assist in overcoming these challenges and has been identified as having environmental benefits for biodiversity and ecosystem services, as well as socio-economic benefits such as improved food security increased farm yields and productivity, increased employment and further economic opportunities through carbon credits or biodiversity certificates (Ansell et al., 2016; AFPA, 2022; Newton et al., 2021; UNEP, 2023).

Collaboration with Aboriginal people also presents a strategic opportunity for the delivery of offsets that deliver improved co-benefits. Aboriginal Corporations are recognised as the authority on land matters for Aboriginal people across the South West of Western Australia. There are four Aboriginal Corporations with lands that overlap the NJF: Ballardong Aboriginal Corporation, Gnaarla Karla Booja Aboriginal Corporation, Whadjuk Aboriginal Corporation and Yued Aboriginal Corporation. Staff from these four Aboriginal Corporations were invited to a workshop held with The Western Australian Biodiversity Science Institute on 30/10/2024 to discuss biodiversity offsets on Aboriginal land. At this workshop, the attendees identified three key messages around collaboration with Aboriginal people on offsets:

- the need for resourcing of Aboriginal Corporations to enable their participation in offset planning, development and implementation;
- the need for consultation and collaboration with Aboriginal people for both developers and regulators; and
- the need for Aboriginal Corporations to derive economic benefit from offsets from non-impactful activities (like hunting kangaroo and emu, bee keeping) on offset land.

Aboriginal Corporations will be provided land through the South West Settlement which may provide a further opportunity to partner with Aboriginal Corporations on offset implementation. However, the identification of specific land parcels is yet to be confirmed. Therefore, data analysis of collaboration opportunities with Aboriginal people has utilised cultural heritage sites (which are already protected under other legal mechanisms) which could be extended and/or buffered as offset opportunities through collaboration with Aboriginal people.

Aboriginal Corporations have a focus on community (Garvey, 2024), so any participation in offsets will require significant social co-benefits such as employment opportunities and income generation and/or equity shares. Further, given that the Aboriginal Corporations that intersect the NJF are relatively new and are poorly resourced, further support may be required to enable their participation in offsets, although meaningful early engagement can ensure that benefits for Aboriginal people can be effectively realised (Monte & Coakes, 2024, Swords & Godwell, 2024).

The land provided to Aboriginal people has several constraints that may need to be overcome prior to its use (Garvey, 2024). Offset protection mechanisms, such as conservation covenants, exclude income generating activities on offsets lands, effectively restricting the participation of Aboriginal Corporations in offsets. Early engagement can enable the incorporation of exemptions within these protection mechanisms to enable income generating activities to take place without compromising the benefits of the offset. The support of Aboriginal people in the restoration economy is a priority (Young, in prep.) and offsets can be a mechanism to achieve this.

Coordinated approaches

Coordinated approaches for the delivery of offsets, such as delivery through a regional offset fund, can better address cumulative impacts and changing ecological needs across a region. Regional offset funds can facilitate strategic offsets, particularly when inclusive of relevant stakeholders and governed by an independent body with transparent and adaptable management (Abdo, 2023).

Regional offset funds can increase the efficiency of offsets, and where offsets are provided in advance, replicate an ecological savings bank which can be lower risk and more cost effective, especially in ecosystems with longer recovery times such as the NJF (Abdo, 2023; Drechsler, 2024). Regional offset funds can be targeted towards key priorities for natural values across a region and provide early detection and rapid response capabilities, improving environmental protection (Abdo, 2023; Wardell-Johnson et al., 2024). The longevity of offset activities can also be increased (Abdo, 2023), which is consistent with the EPA's public advice that encourages regional scale management that addresses long-term needs (EPA, 2024). This is particularly important for threatened species whose recovery is reliant on management solutions (Leseberg et al., 2023). The concept of payments into a fund for restoration actions in lieu of the delivery of offsets has also been developed by the Commonwealth as part of the new Nature Repair Market (DCCEEW, 2024c).

Research by Abdo (2023) assessed seven offset funds[7] for their alignment with a holistic model for biodiversity offsets and found that all were lacking elements that would to contribute to sustainable development. In order to improve alignment with sustainable development, a number of changes to offset funds were suggested including that offset funds be region-specific, are governed by an independent expert committee and are sufficient (including through the use of bonds), perpetual and directed towards key strategic priorities across the whole region (Abdo, 2023).

Under a strategic approach, changes to regulatory process for offsets would be required to enable funds such as these. Suggestions to better ensure the inclusions of collaborative and coordinated approaches to offsets are displayed in Figure 9.

Protection opportunities

Protection is defined as legal protection to prevent (or hinder) clearing of a parcel of land. Although protected areas within the NJF meet previous targets under the national conservation reserve system[8], these protected areas have been found to be lacking in representativeness (Luxton et al., 2021). There are unprotected areas of high quality[9] forest and high rainfall in the NJF that would be suitable as reserves (Forestry Australia, 2022), providing an opportunity for land protection offsets.

Data identifying the quality of vegetation across the NJF was not available. Therefore, protection opportunities for offsets were identified using areas outside of the conservation estate with increasing woody density as a proxy for higher quality vegetation for strategic approaches (Figure 9). However, as stated in "Methodology", ground truthing of areas identified for protection would be required prior to the use of these areas within offset design and planning purposes.

Priority areas for protection were identified as areas where threatened species and/or priority ecological communities have been observed, and where potential for new conservation reserves have been identified. However, many of the areas identified as protection opportunities intersect development and/or planning areas (Figure 10). Given that land within development areas cannot be protected and that conservation areas are already protected, protection opportunities in the NJF are restricted to a small area in the south east of the NJF, which is not near identified ecological linkages (Figure 11). This area does, however, intersect with potentially arable land and some Aboriginal cultural heritage sites (Figure 12), which could represent collaborative opportunities for the delivery of land protection offsets.

[7] Offset funds researched included: Biodiversity Conservation Trust (New South Wales), Environmental Offsets Fund (Queensland), Native Vegetation Fund (South Australia), Environmental Revegetation and Rehabilitation Fund (Western Australia), Pilbara Environmental Offsets Fund (Western Australia), Great Victoria Desert Biodiversity Trust (Western Australia) and Gunduwa Regional Conservation Association (Western Australia).

[8] Previous targets for the national conservation reserve system were to meet Aichi Biodiversity Target 11 under the Convention of Biological Diversity for at least 17% of terrestrial areas. In Western Australia, this is implemented under the States reserve system through percentage-based targets (15%) using Forest ecosystem units, which are largely based on forest structure (and not floristic diversity). Note that newer targets are for the protection of 30% of all terrestrial areas under the Global Biodiversity Framework, which replaced the Aichi Biodiversity Targets in December 2022.

[9] High quality is not defined in the cited notation but is assumed to refer to areas with natural values reflective of a jarrah forest ecosystem.

Significant residual impacts in the Northern Jarrah Forest[10]

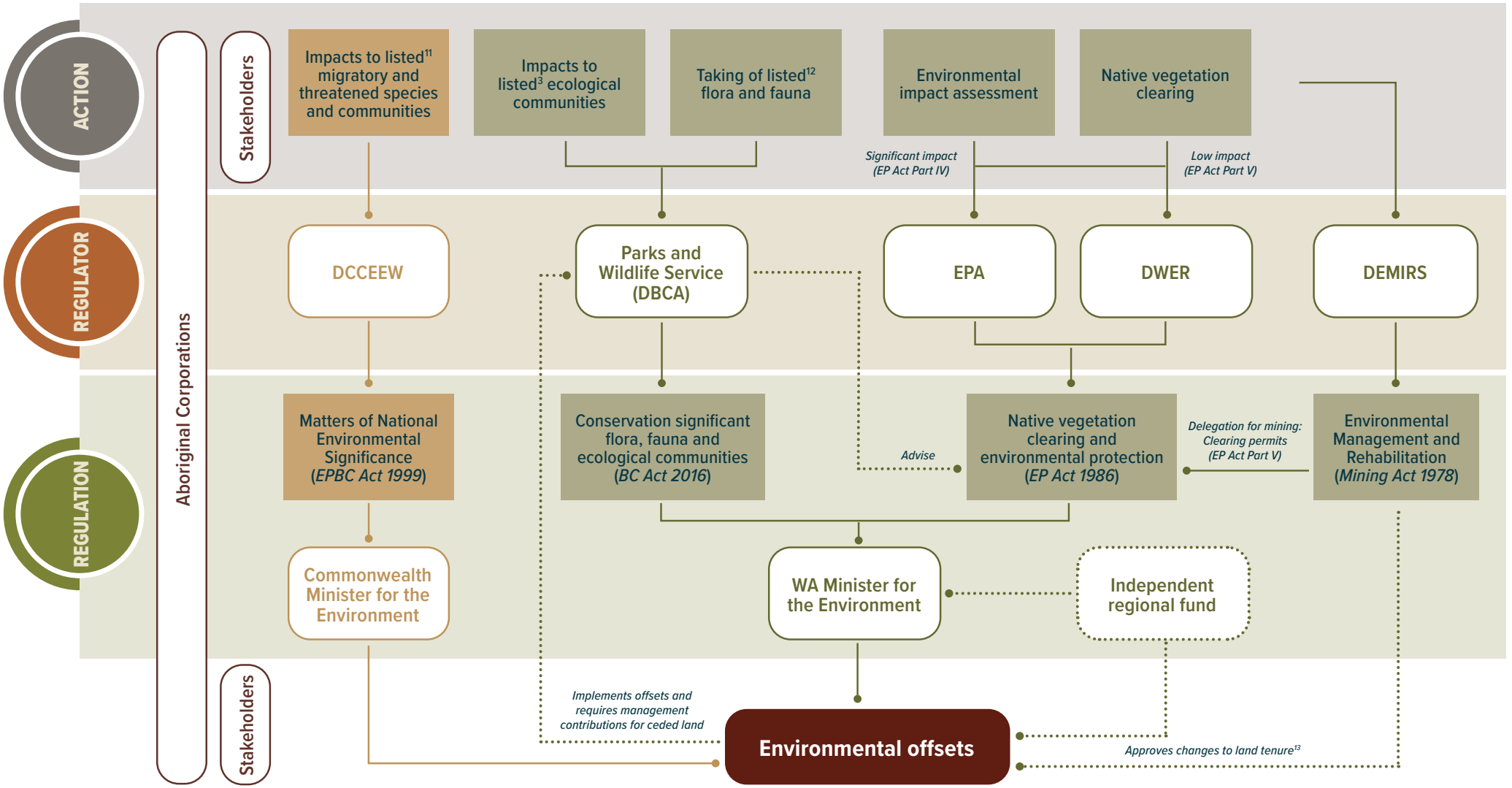
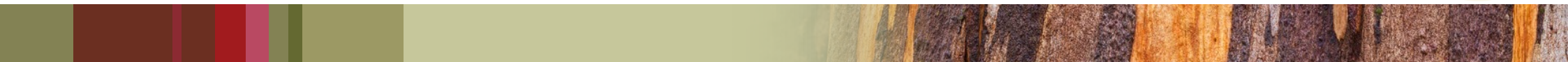


Figure 9: Suggested changes to the regulatory process for the approval of environmental offsets 'Figure 1: Overview of regulatory requirements for environmental offsets in the NJF taken from Abdo and Young (2025)'. Solid lines represent a dedicated process. Dotted lines represent an indicative/voluntary process. Square boxes indicate a document/requirement. Rounded boxes indicate a government department/minister.

10. Significant residual impacts means environmental impact remaining after all avoidance and mitigation measures have been fully explored and is consistent with both the description of "Significant Residual Impacts" in the WA Environmental Offset Guidelines (EPA, 2014) and the description of "Residual Significant Impacts" in the *Environment Protection and Biodiversity Conservation Act 1999* Environmental Offsets Policy (DSEWPaC, 2012a).
11. Species and ecological communities listed as Matter of National Environmental Significance in the *Environment Protection and Biodiversity Conservation Act 1999*.
12. Threatened and priority flora, fauna and ecological communities, and critical habitat as listed in the *Biodiversity Conservation Act 2016*.
13. DEMIRS has a role in the approval of changes to land tenure (e.g. covenants) that are often required to provide legal protection of offset areas.



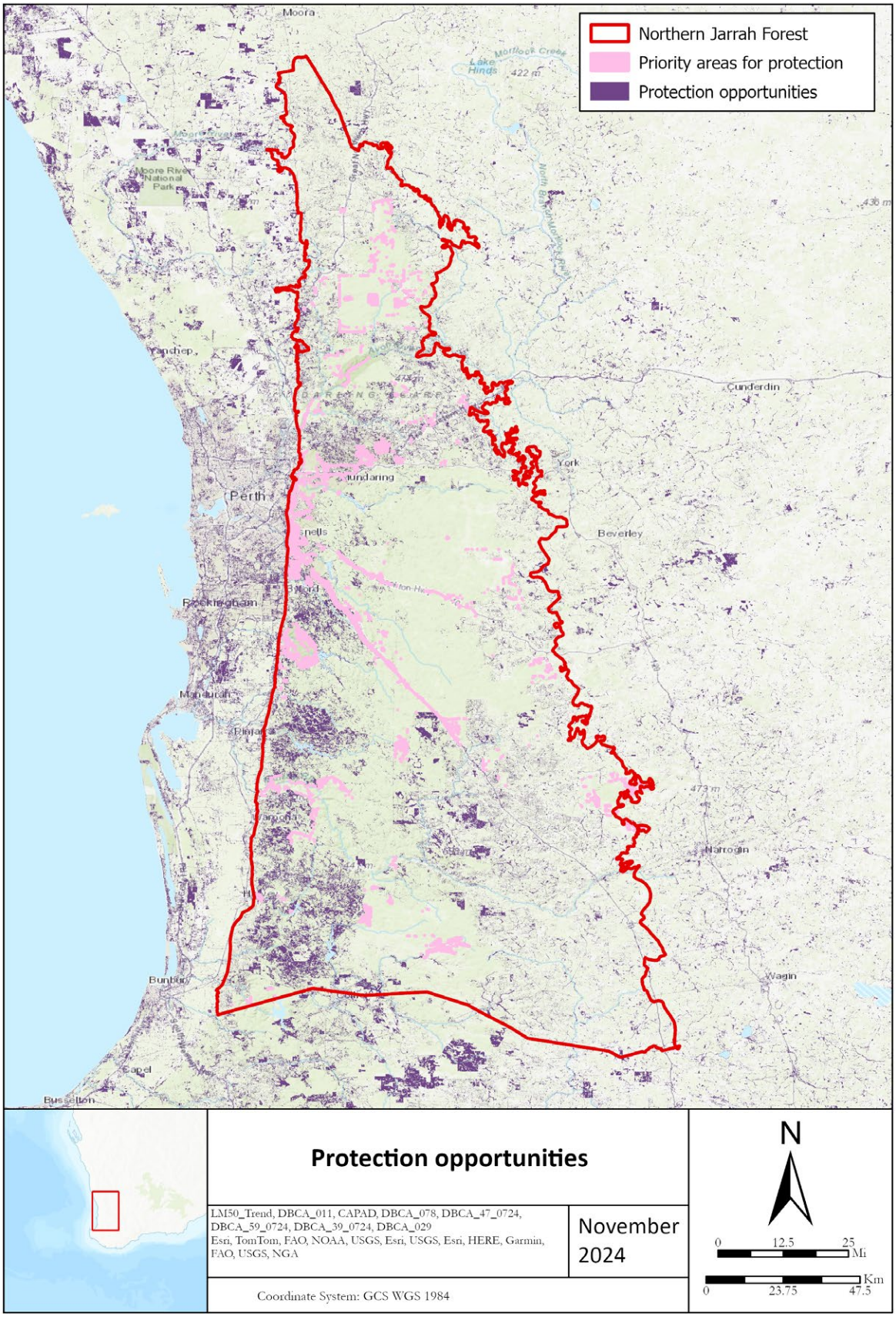


Figure 10: Areas with increasing woody density between 1990 and 2023 that are outside of conservation areas (DBCA Legislated Lands and Waters, Collaborative Australian Protected Areas Database (CAPAD)) and therefore, represent protection opportunities

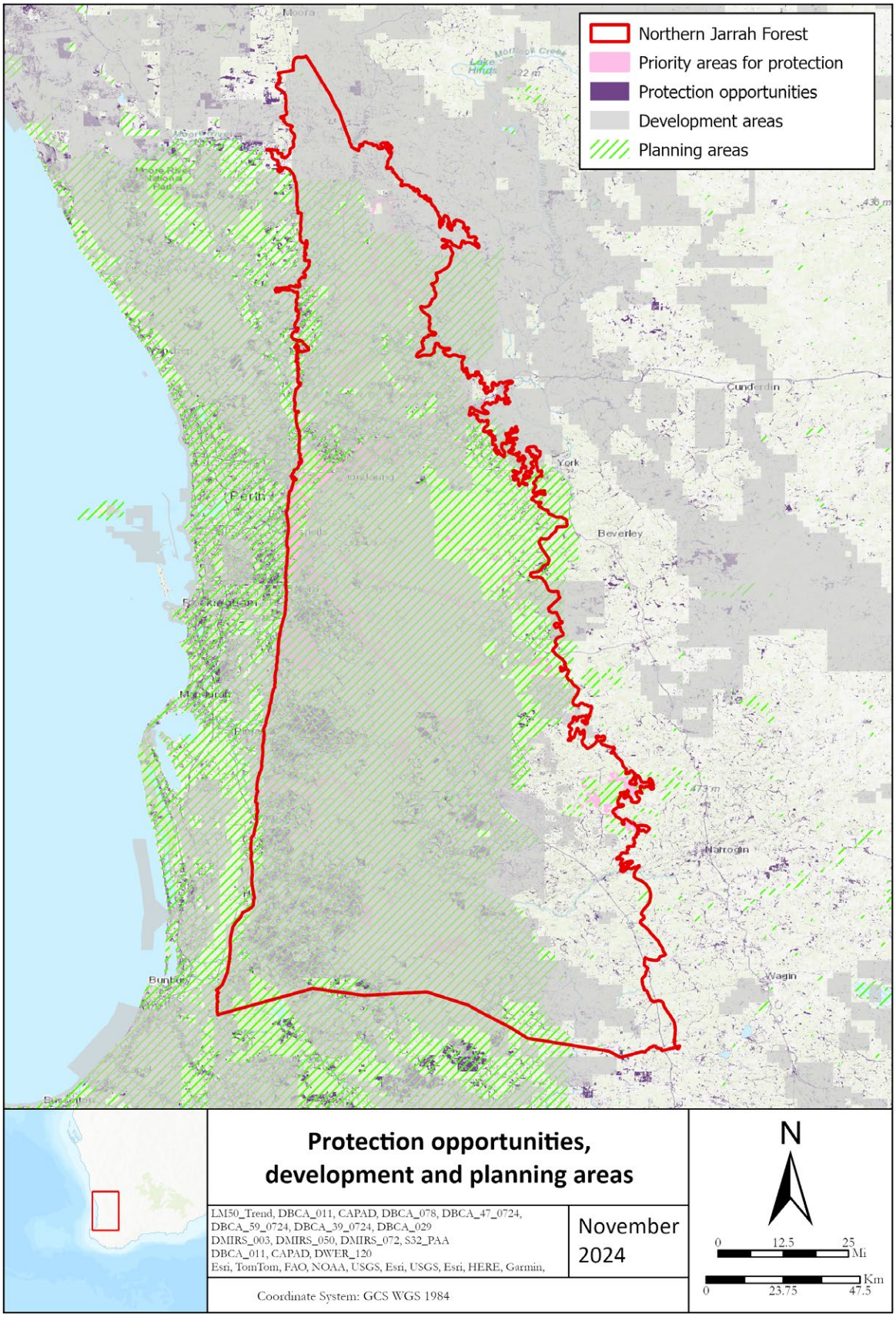


Figure 11: Protection opportunities, planning areas and development areas in the NJF

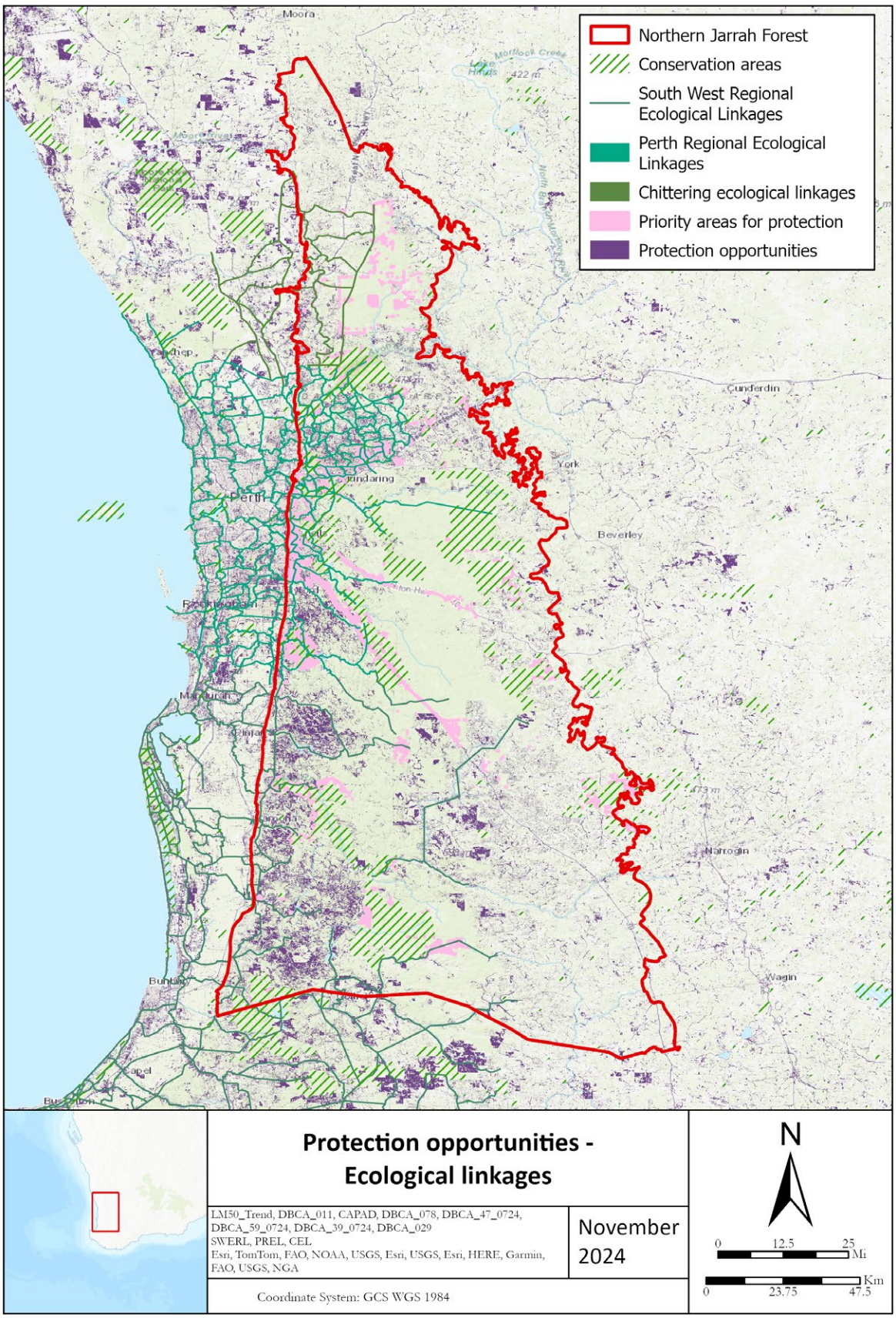


Figure 12: Protection opportunities and identified ecological linkages and conservation areas that represent strategic approaches to land protection

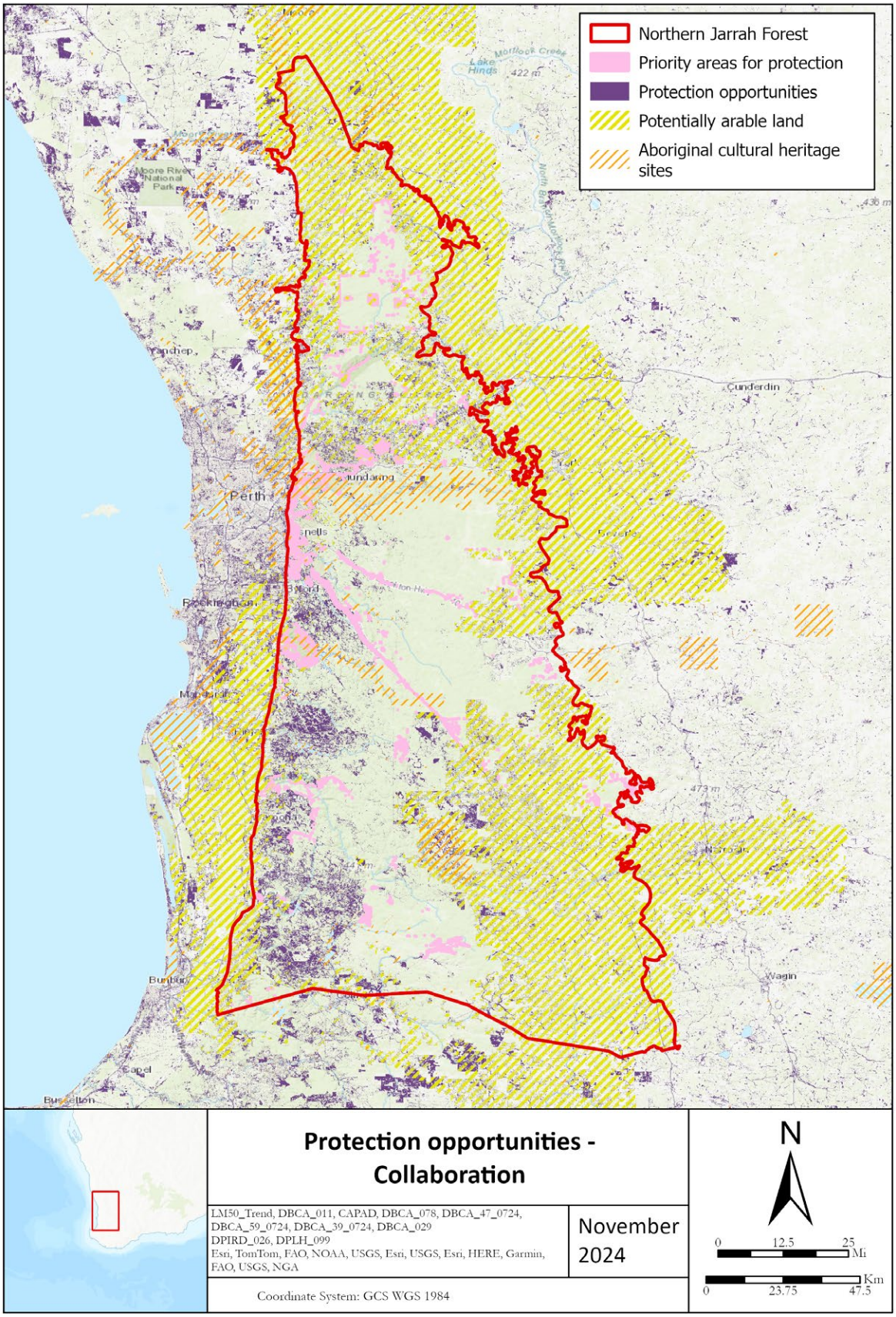


Figure 13: Protection opportunities and indicative areas for collaboration (subject to engagement) that represent strategic approaches to land protection

Table 3: Summary of risk assessment for protection opportunities in the NJF

	Protection opportunities	Priority areas for protection	Strategic approaches
Accuracy/confidence score	2	2	3
Acceptability score		2	
OVERALL RISK	Medium	Medium	Low-medium

Risk assessment

Despite only a small proportion of the NJF being identified as suitable for protection by offsets (Figure 10), a risk assessment was conducted on the suitability of protection opportunities as offsets within the NJF. A summary of the risk assessment is presented above in Table 3. A full outline of the risk assessment undertaken is provided in Appendix C.

The risk associated with protection opportunities was medium, although this was reduced when strategic approaches, such as the use of ecological linkages and/or collaborative approaches, were applied. Ensuring that land protection offsets cannot be cleared, and that recreational access can be maintained would further reduce this risk (Appendix C).

Research to identify, and protect, refugia from the impacts of climate change and changing fire regimes would ensure that land protection offsets were representative and resilient (Luxton et al., 2021). This is aligned with Australia's Strategy for a National Reserve System 2009–2030 (NRMMC, 2010).

Restoration opportunities

Restoration is defined as activities that assist a degraded area towards a trajectory of recovery of natural values (biodiversity, ecosystem functions and ecosystem services) with the aim of forming a persistent, adaptive and resilient ecosystem (Gann et al., 2019). Restoration is required to change the usage of the NJF from an extractive model towards a sustainable model that includes a resilient ecosystem (Wardell-Johnson et al., 2024). Restoration of native vegetation cover to more than 30% pre-European levels of each vegetation type and mitigation of threats to native species is required to substantially repair Australia's degraded landscapes (WGCS, 2024). Restoration of wetlands and waterways could offer additional benefits to improved water quality, biodiversity and carbon sequestration, especially given the coincidence of registered Aboriginal sites with wetlands and rivers in the NJF.

Data identifying the quality of vegetation across the NJF was not available. Therefore, restoration opportunities were identified as areas outside of the conservation estate or urban land use with decreasing woody density as a proxy for degraded vegetation for strategic approaches (Figure 14). However, as stated in "Methodology", ground truthing of areas identified for restoration would be required prior to the use of these areas within offset design and planning purposes.

Priority areas for restoration were identified as areas where threatened species and/or ecological communities have been observed. Many of the areas identified for restoration were outside of the development and/or planning areas (Figure 14), demonstrating that the implementation of offsets through restoration would be a preferred option for the delivery of offsets in the NJF. However, much of the area identified for restoration opportunities does not intersect with existing ecological linkages (Figure 15), but does intersect with potentially arable land and some Aboriginal cultural heritage sites (Figure 16), which could represent collaborative opportunities for the delivery of restoration as offsets.

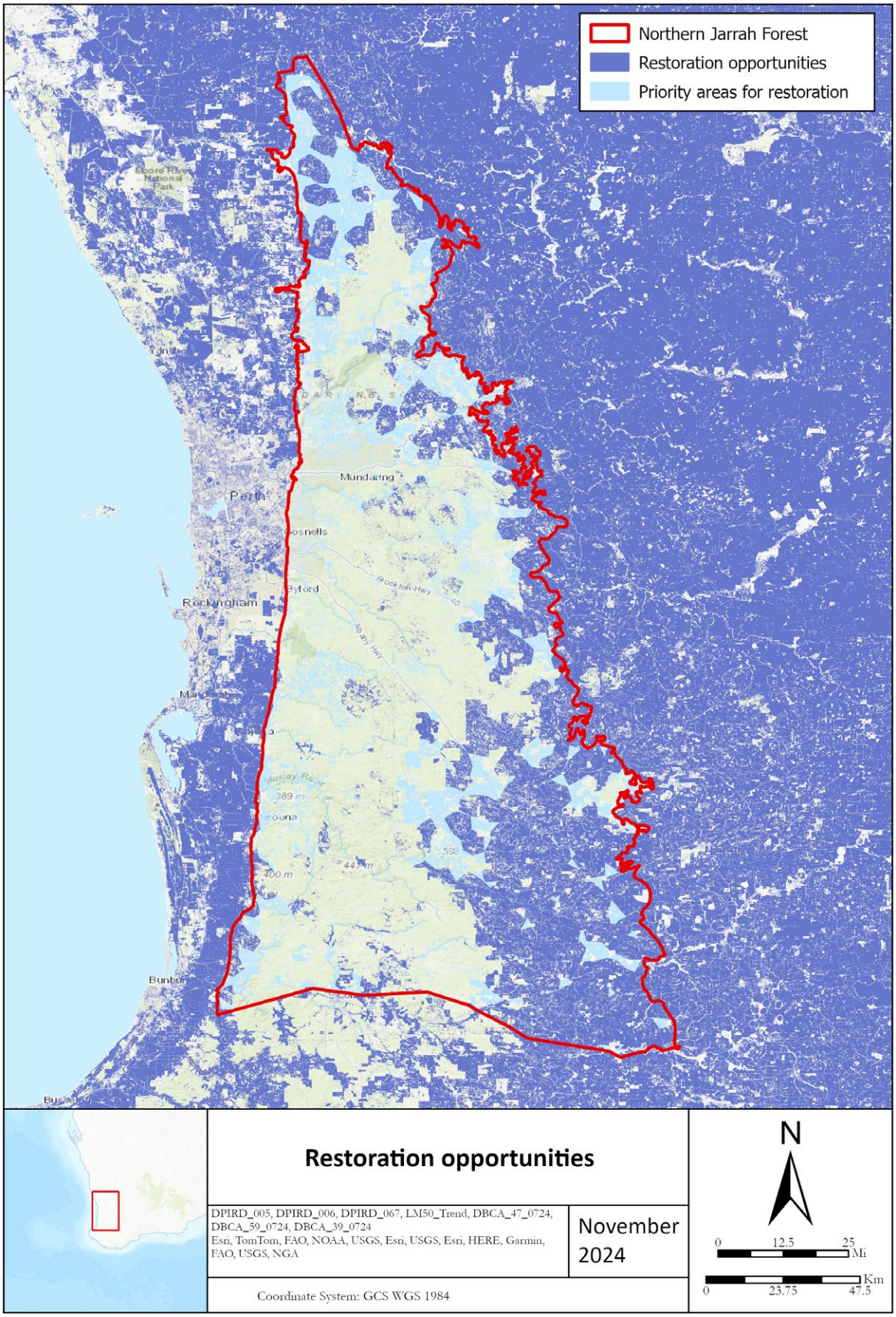


Figure 14: Areas with decreasing woody density between 1990 and 2023 that are outside of urban (rural restoration) and conservation areas (DBCA Legislated Lands and Waters, Collaborative Australian Protected Areas Database (CAPAD)) and therefore, represent restoration opportunities

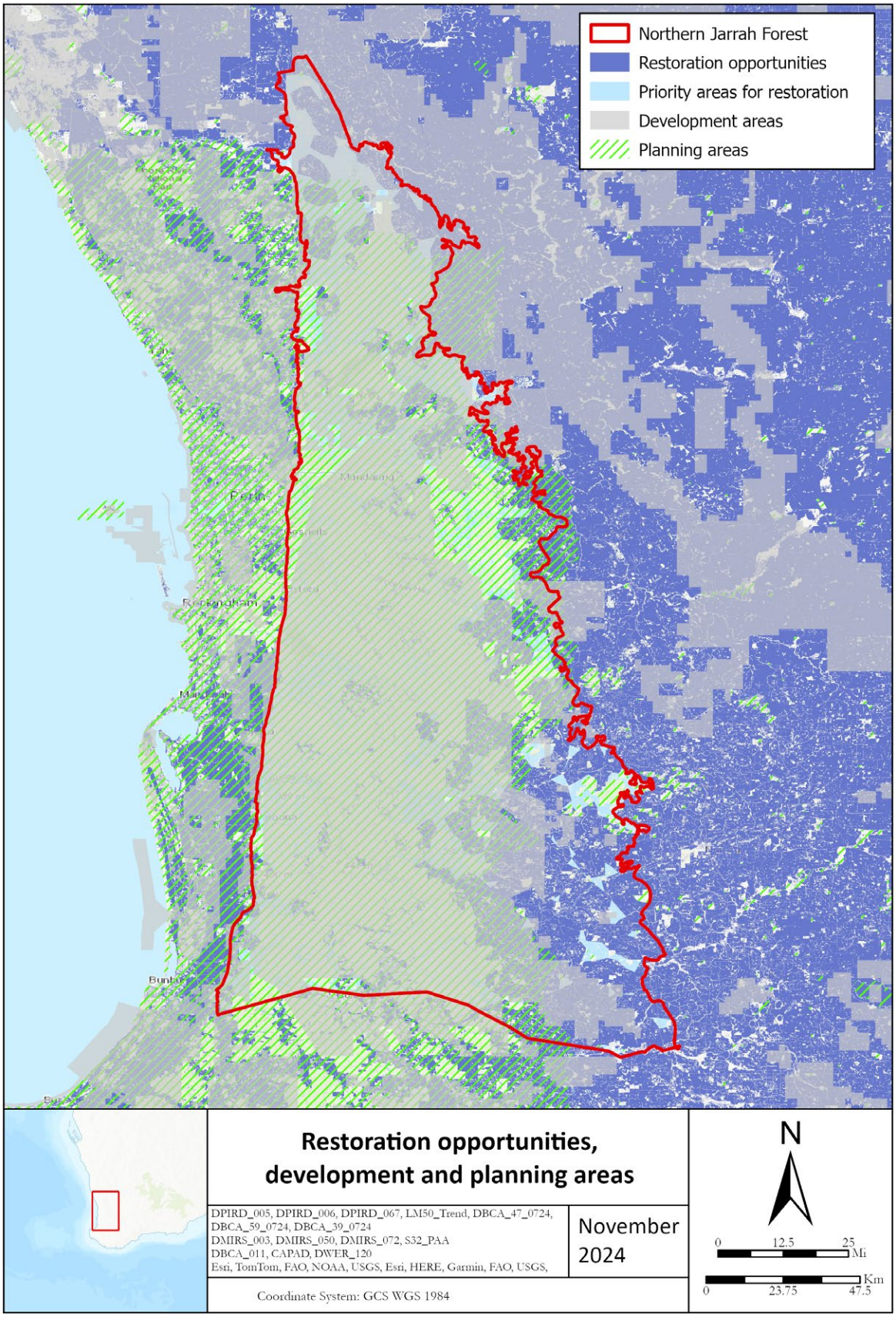


Figure 15: Restoration opportunities, planning areas and development areas in the NJF

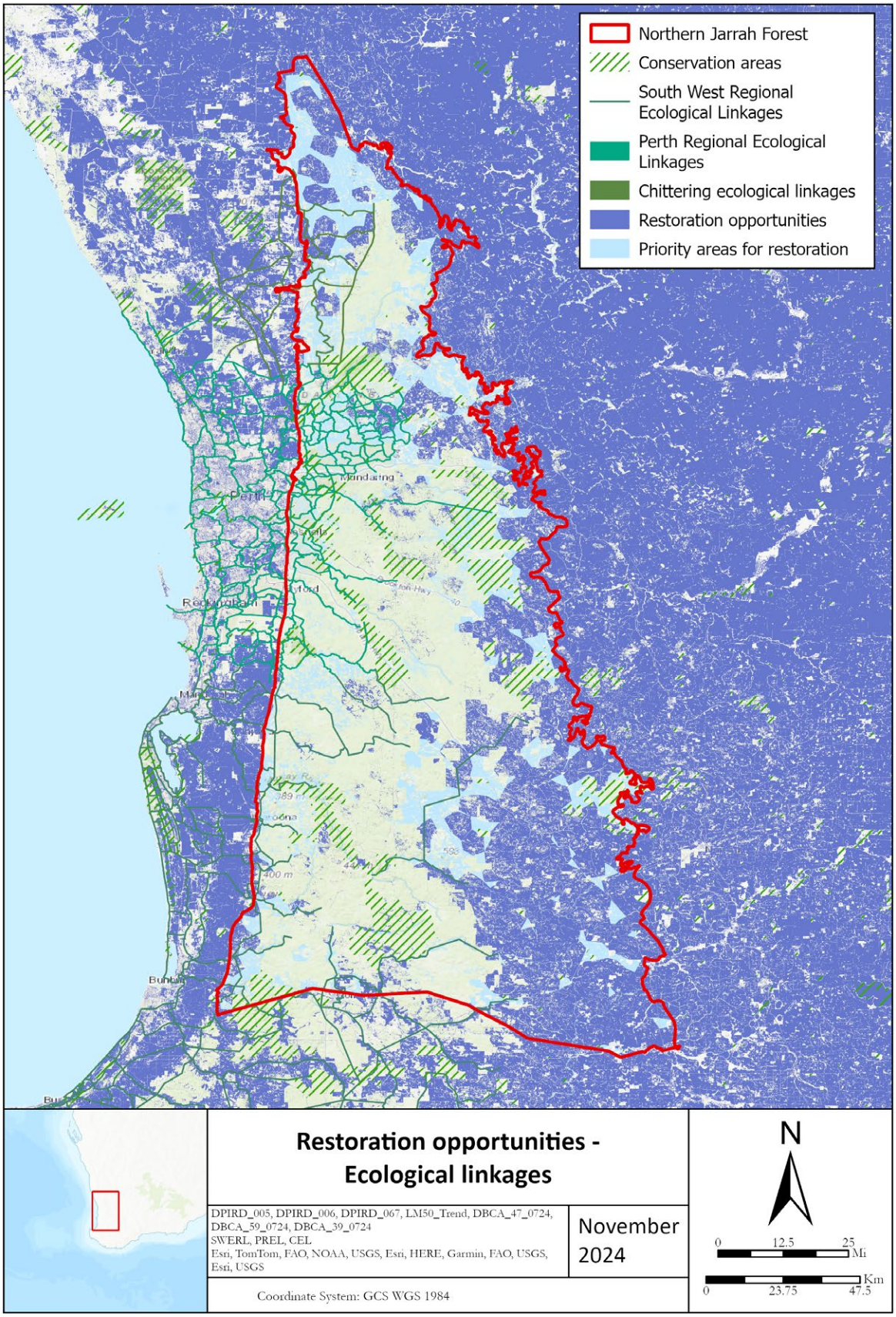


Figure 16: Restoration opportunities and identified ecological linkages and conservation areas that represent strategic approaches land restoration

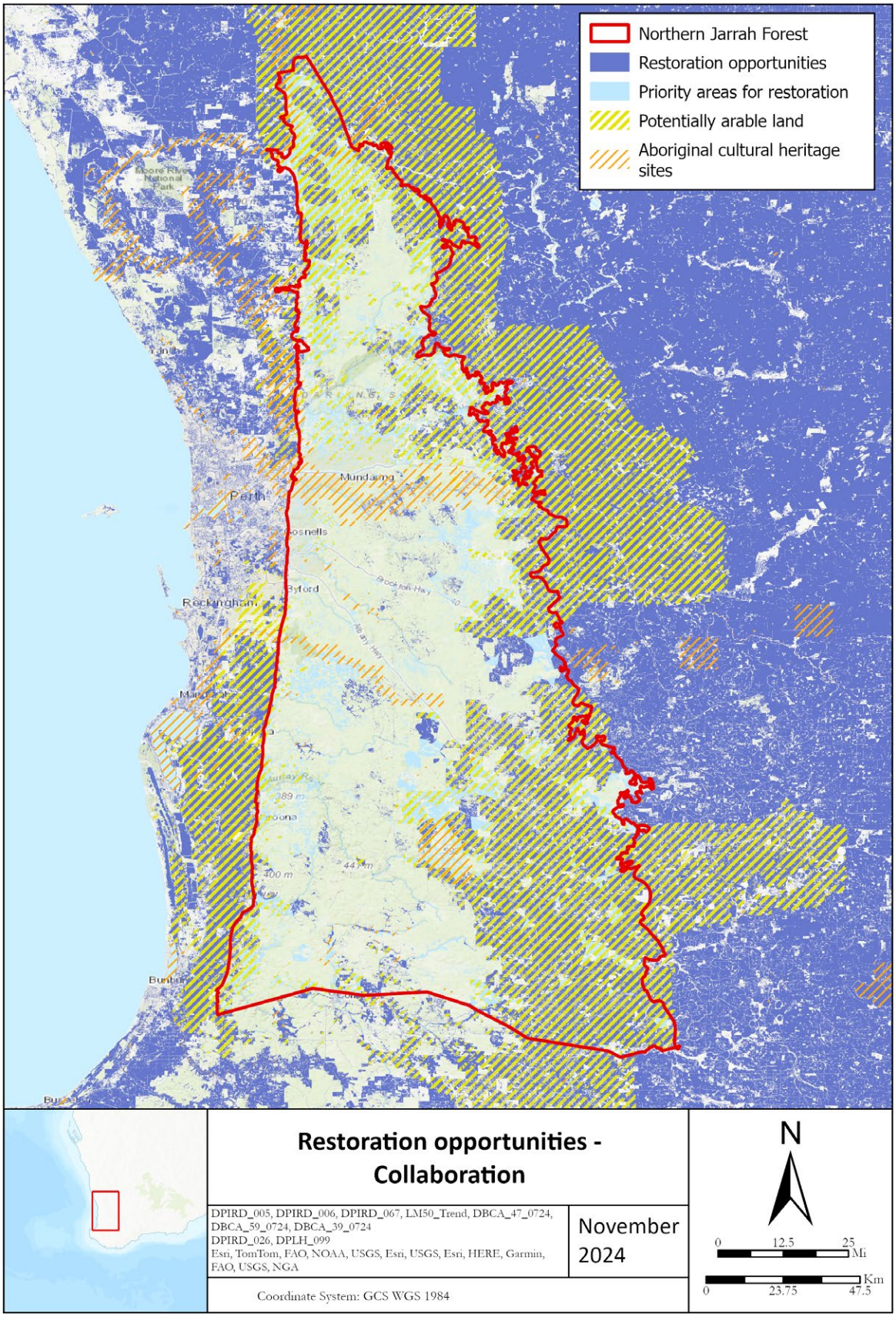


Figure 17: Restoration opportunities and indicative areas for collaboration (subject to engagement) that represent strategic approaches to land restoration

Table 4: Summary of risk assessment for restoration opportunities in the NJF

	Restoration opportunities	Priority areas for restoration	Strategic approaches
Accuracy/confidence score	2	2	3
Acceptability score	3		
OVERALL RISK	Low-medium	Low-medium	Low

Risk assessment

A summary of the risk assessment for restoration opportunities is presented above in Table 4. A full outline of the risk assessment undertaken is provided in Appendix C.

The risk associated with restoration opportunities was low-medium, which was reduced to low when strategic approaches, such as the use of ecological linkages and/or collaborative approaches, were applied. Improving the quality of baseline data and identifying mechanisms to produce more cost-effective seed at scale would further reduce this risk (Appendix C).

Invasive species and disease management

Reducing the abundance and distribution of weeds, pests and diseases within the NJF is a priority management action (Abdo & Young, 2025; Wardell-Johnson et al., 2024). Control of invasive species is one of the easiest and most effective measures to improve the recolonisation of fauna to a disturbed area (Brennan et al., 2005). However, invasive species control must be undertaken across several species of predators, and/or in conjunction with the restoration of habitats to avoid the loss of native species to other predators (de Tores et al., 2008). For example, research in the NJF found cascading effects on shared prey species from the control or removal of one or more predator types, which could result in a longer term declines in the abundance of some species of native fauna due to increased predation by other exotic (like feral cats) or native predators (such as. goannas, chuditch and pythons) (de Tores et al., 2008).

There was a paucity of available data related to invasive species and disease management in the NJF. While invasive species such a cats and foxes are found throughout the NJF, information regarding the extent of disease was only available for the disease *Phytophthora* dieback caused by the pathogen *Phytophthora cinnamomi*. Data on existing management measures for the management of invasive species and disease in the NJF was also unavailable. Therefore, the data analysis for disease opportunities presented reflects only the known and expected extent of *Phytophthora* dieback and does not consider any existing management measures (Figure 17).

Phytophthora dieback has the greatest effect on species richness and abundance in the first five years following fire (Barrett et al., 2024; Moore et al., 2015; Regan et al., 2011). Therefore, priority disease (*Phytophthora cinnamomi*) management areas were identified as areas burnt within the last five years and areas where threatened species and/or ecological communities have been observed. Within the NJF, almost all disease management opportunity areas were found within development areas, although there was some overlap with planning areas (Figure 18). Disease management opportunities corresponded well with ecological linkages (Figure 19). Although disease management opportunities did not overlap potentially arable land, there was some overlap with Aboriginal cultural heritage sites, which could present some collaborative opportunities (Figure 20).

Assuming the prevalence of invasive species across the NJF, priority management areas for invasive species were identified as those recently burnt and where conservation significant species have been observed (Figure 22). Within the NJF, almost all invasive species management opportunity areas were found within development areas, although there was some overlap with planning areas (Figure 23). Invasive species management opportunities corresponded well with ecological linkages (Figure 24). Although there was only a small overlap between invasive species management opportunities and potentially arable land, there was some additional overlap with Aboriginal cultural heritage sites, which could present some collaborative opportunities (Figure 25).

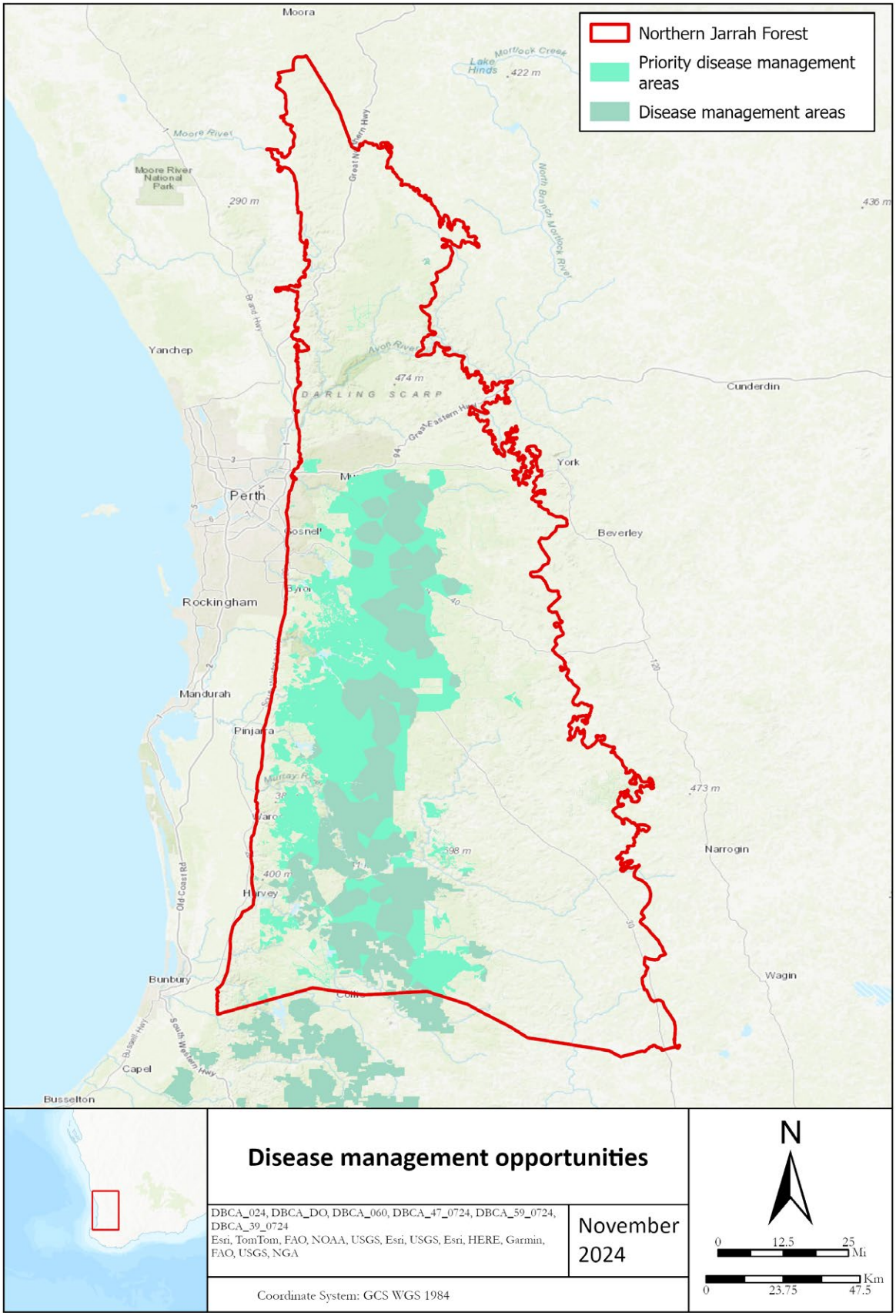


Figure 18: Areas of the NJF that would benefit from the management of *Phytophthora cinnamomi*

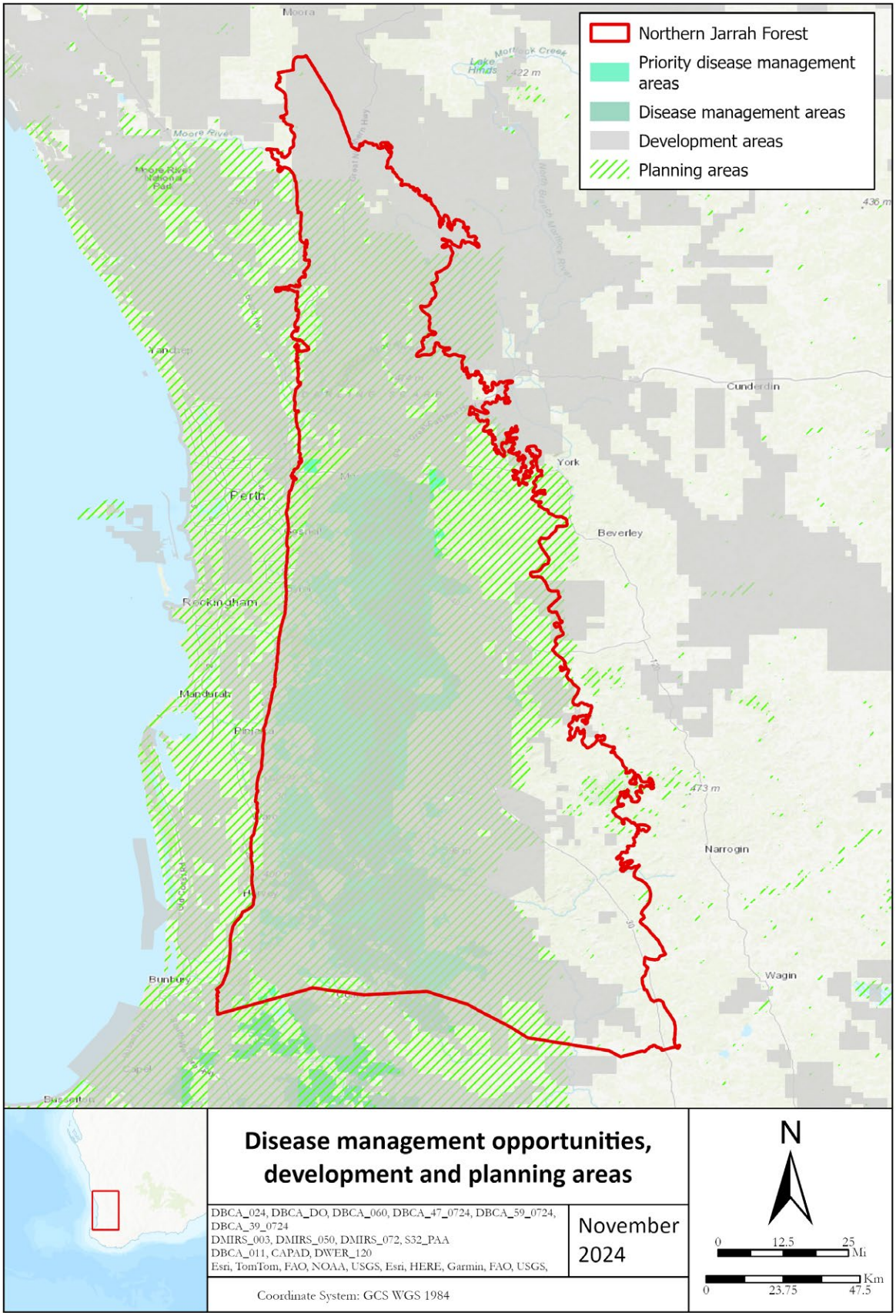


Figure 19: Disease management opportunities, planning areas and development areas in the NJF

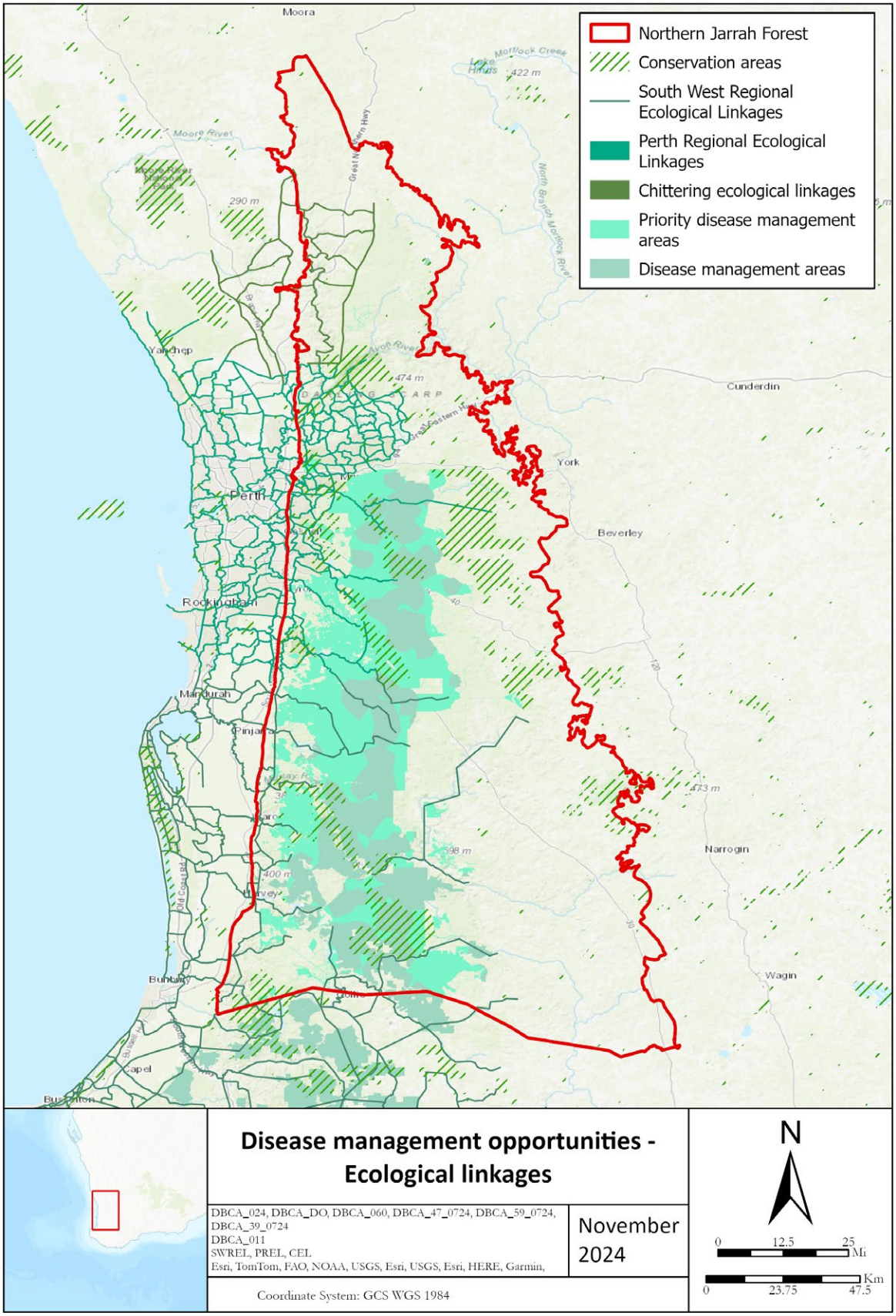


Figure 20: Disease management opportunities and identified ecological linkages and conservation areas that represent strategic approaches to disease management

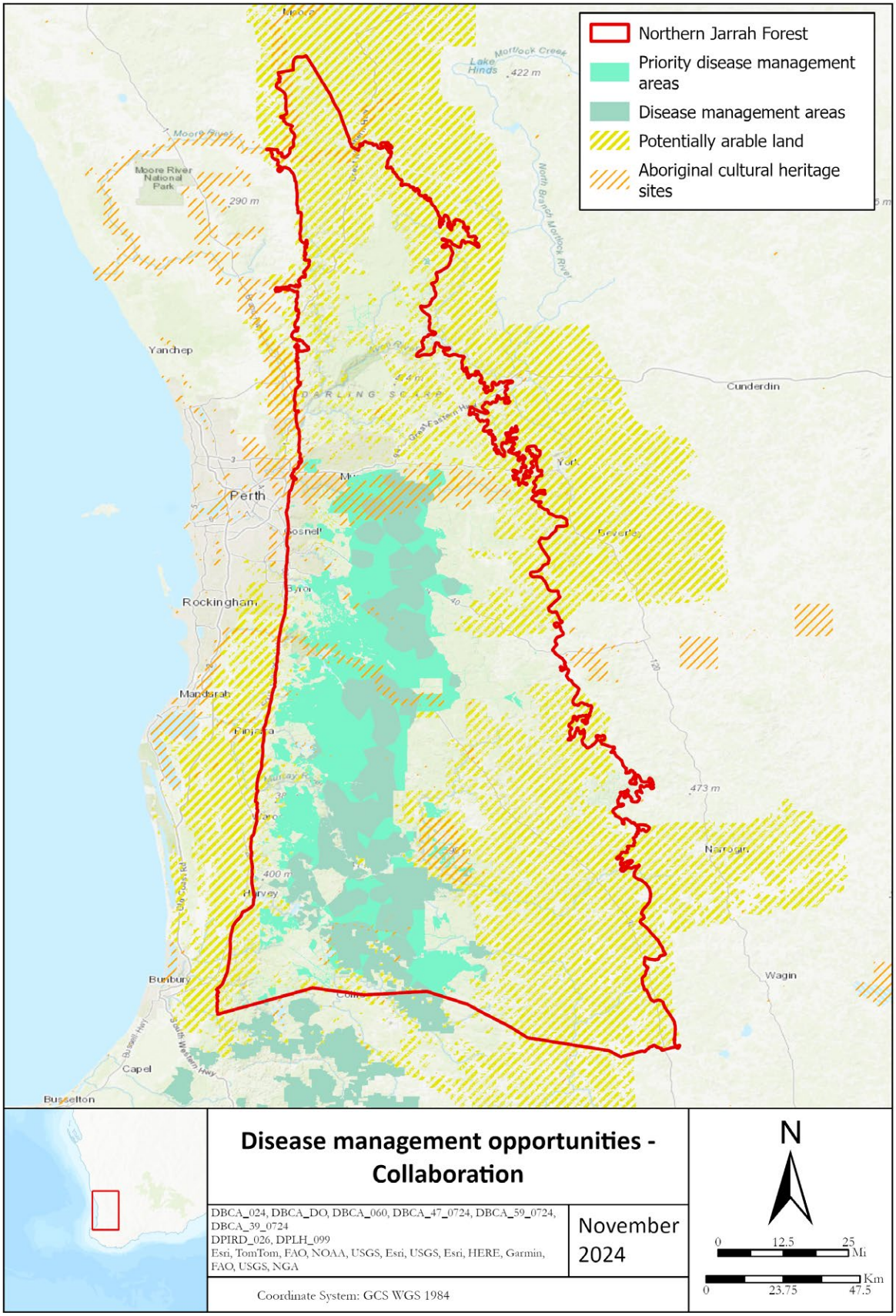


Figure 21: Disease management opportunities and indicative areas for collaboration (subject to engagement) that represent strategic approaches to disease management

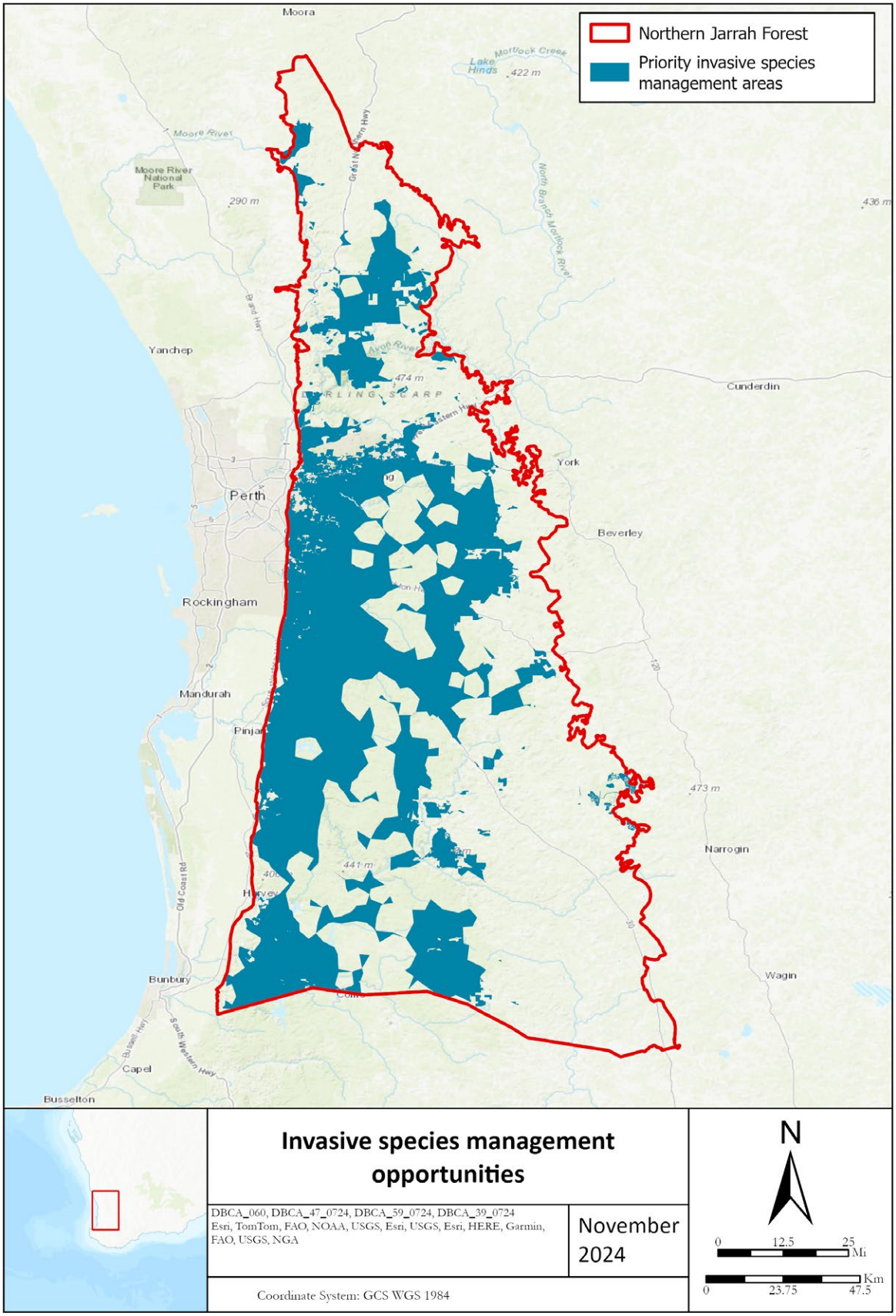


Figure 22: Areas of the NJF that would benefit from the management of invasive species

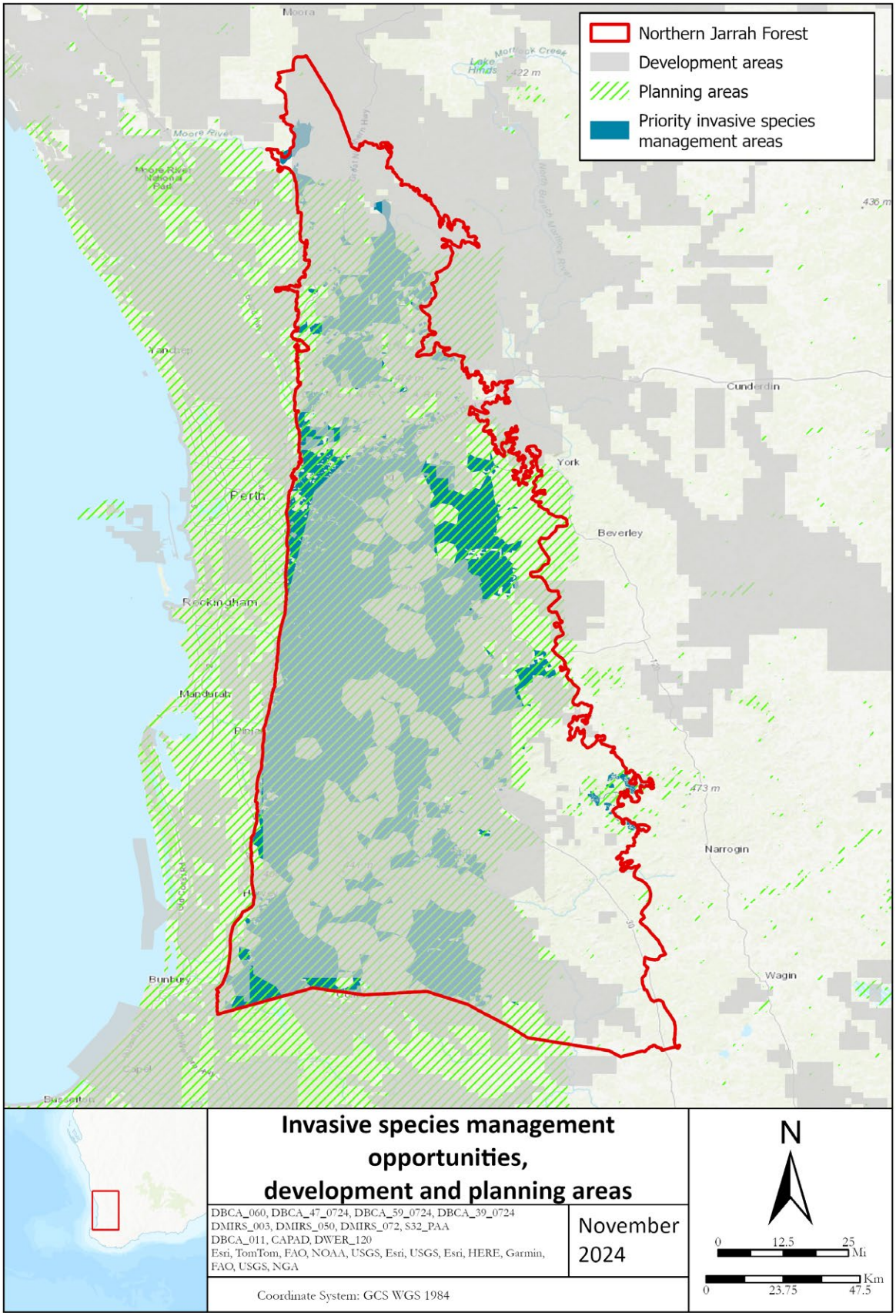


Figure 23: Invasive species management opportunities, planning areas and development areas in the NJF

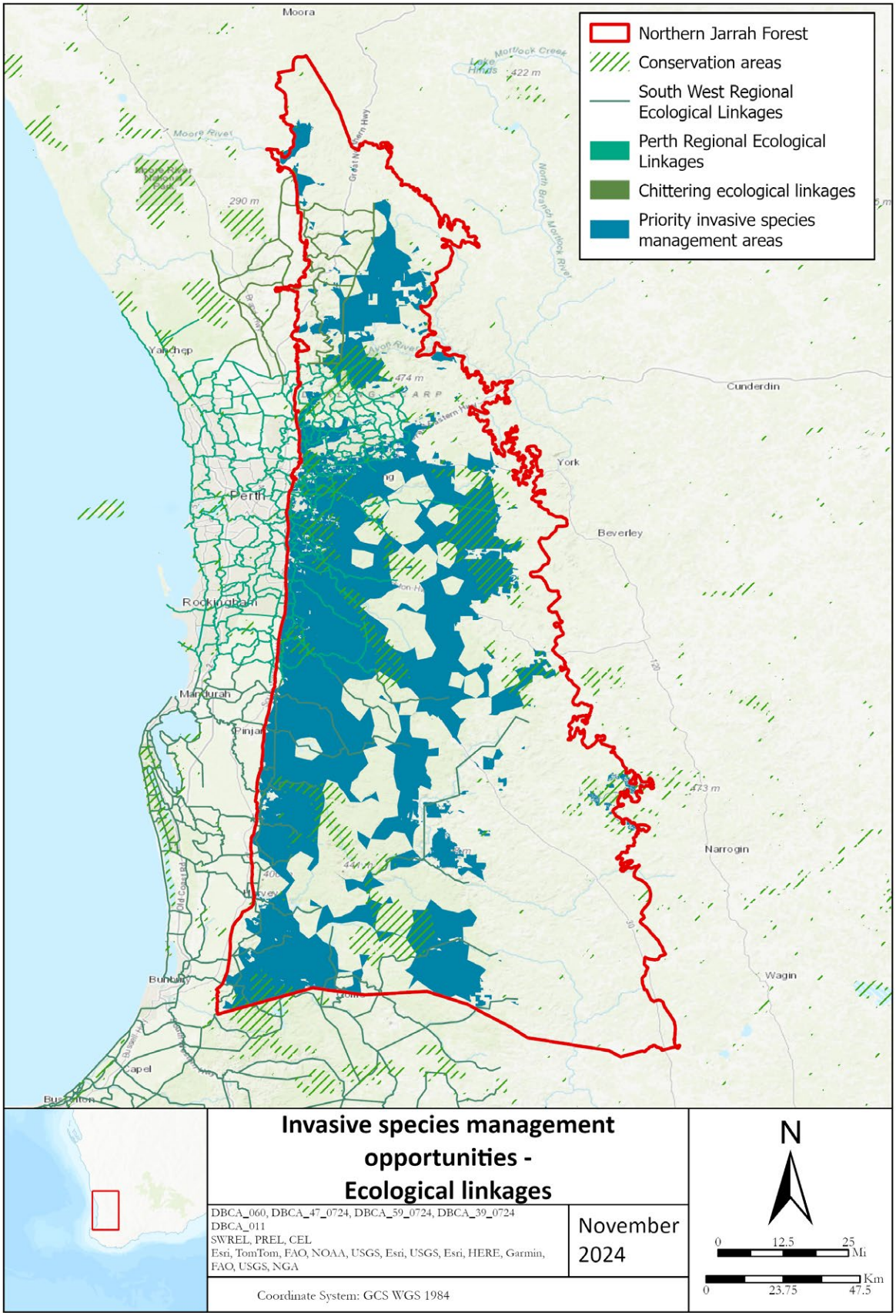


Figure 24: Invasive species management opportunities and identified ecological linkages and conservation areas that represent strategic approaches to disease management

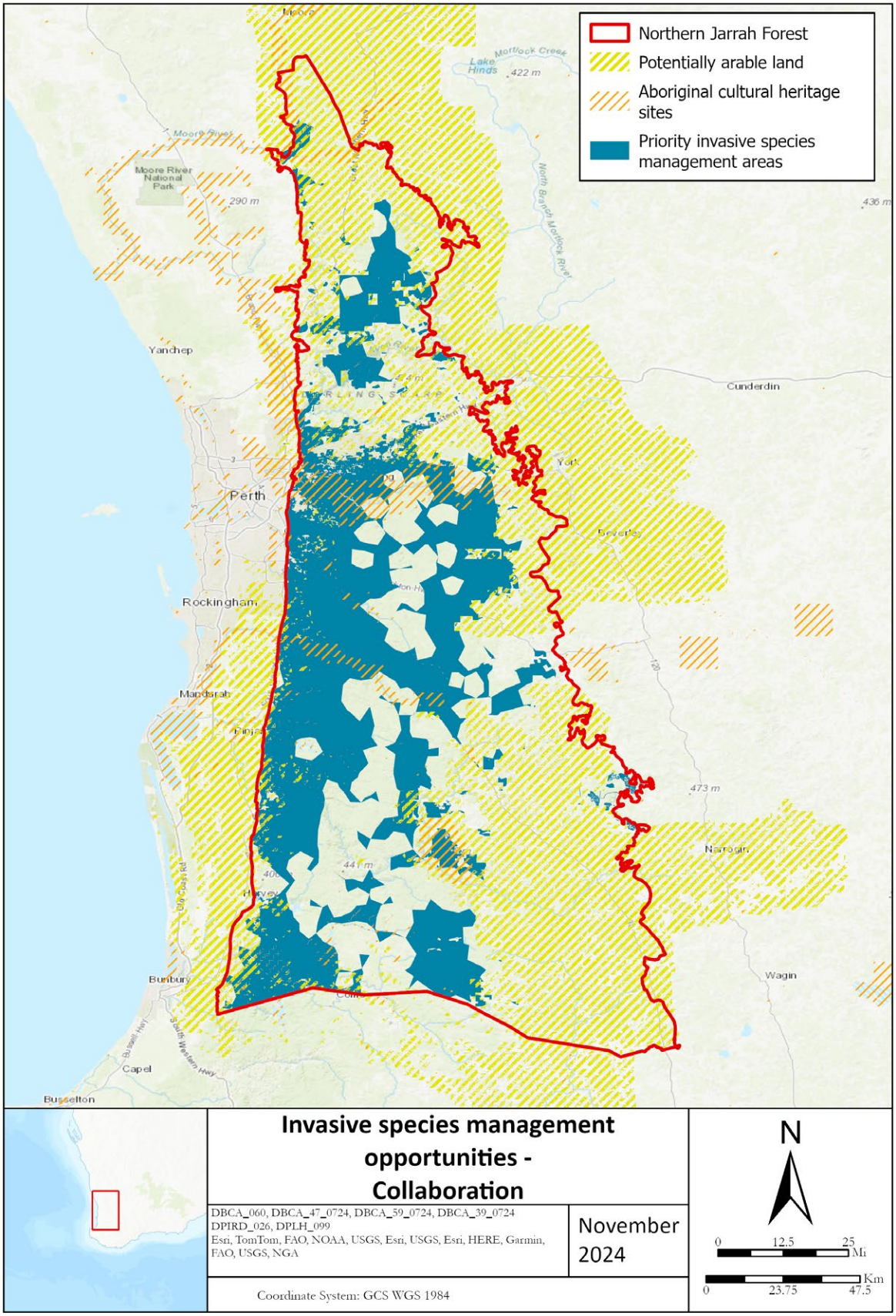


Figure 25: Invasive species management opportunities and indicative areas for collaboration (subject to engagement) that represent strategic approaches to disease management

Table 5: Summary of risk assessment for disease (*Phytophthora cinnamomi*) and invasive species management opportunities in the NJF

	Disease and invasive species opportunities	Priority disease and invasive species management areas	Strategic approaches
Accuracy/confidence score	1	1	1
Acceptability score	3		
OVERALL RISK	Medium	Medium	Medium

Risk assessment

A summary of the risk assessment for disease (*Phytophthora cinnamomi*) and invasive species management opportunities is presented above in Table 5. A full outline of the risk assessment undertaken is provided in Appendix C.

The overall risk associated with the disease and invasive species management in the NJF was medium. While acceptability was high, and many stakeholders identified this as a key priority for the NJF (Appendix A), the accuracy of data and confidence in the offset outcomes were low, even for strategic approaches (Appendix C). Therefore, while identified as key management actions for the NJF, the management of invasive species and disease are not recommended to be delivered through offsets. However, the use of offsets to improve the accuracy of data related to the management of invasive species and disease would be of benefit.

Management for improved water balances

Ecological thinning is the selective removal of tree species within a densely vegetated area to provide ecological benefits. Ecological thinning, with careful management of associated impacts, may be a potential solution to the improved management of water balances in the NJF (Abdo & Young, 2025; Bari & Ruprecht, 2003; Bhandari, 2021; Grigg & Grant, 2009; Macfarlane et al., 2010). Thinning opportunities were identified as areas that had increased in woody density and had been unburnt for 10 years (Figure 26). Priority areas for thinning were identified as areas free from *Phytophthora* dieback and where threatened species and/or ecological communities have been observed.

Thinning opportunities were found completely within development areas in the NJF (Figure 27). Given that development areas are at higher risk of clearing, it may not be possible to use ecological thinning as an offset activity within these areas. Under the assumption that some existing areas within mining tenements may not be used for development and instead could be excised for offset purposes, analysis of strategic opportunities were further investigated. Thinning opportunities corresponded well with ecological linkages (Figure 28) but only overlapped with potentially arable and Aboriginal land in small discrete areas (Figure 29).

Figure 26: Areas with increasing woody density between 1990 and 2023 that have been unburnt for 10 years or more and therefore, represent thinning opportunities

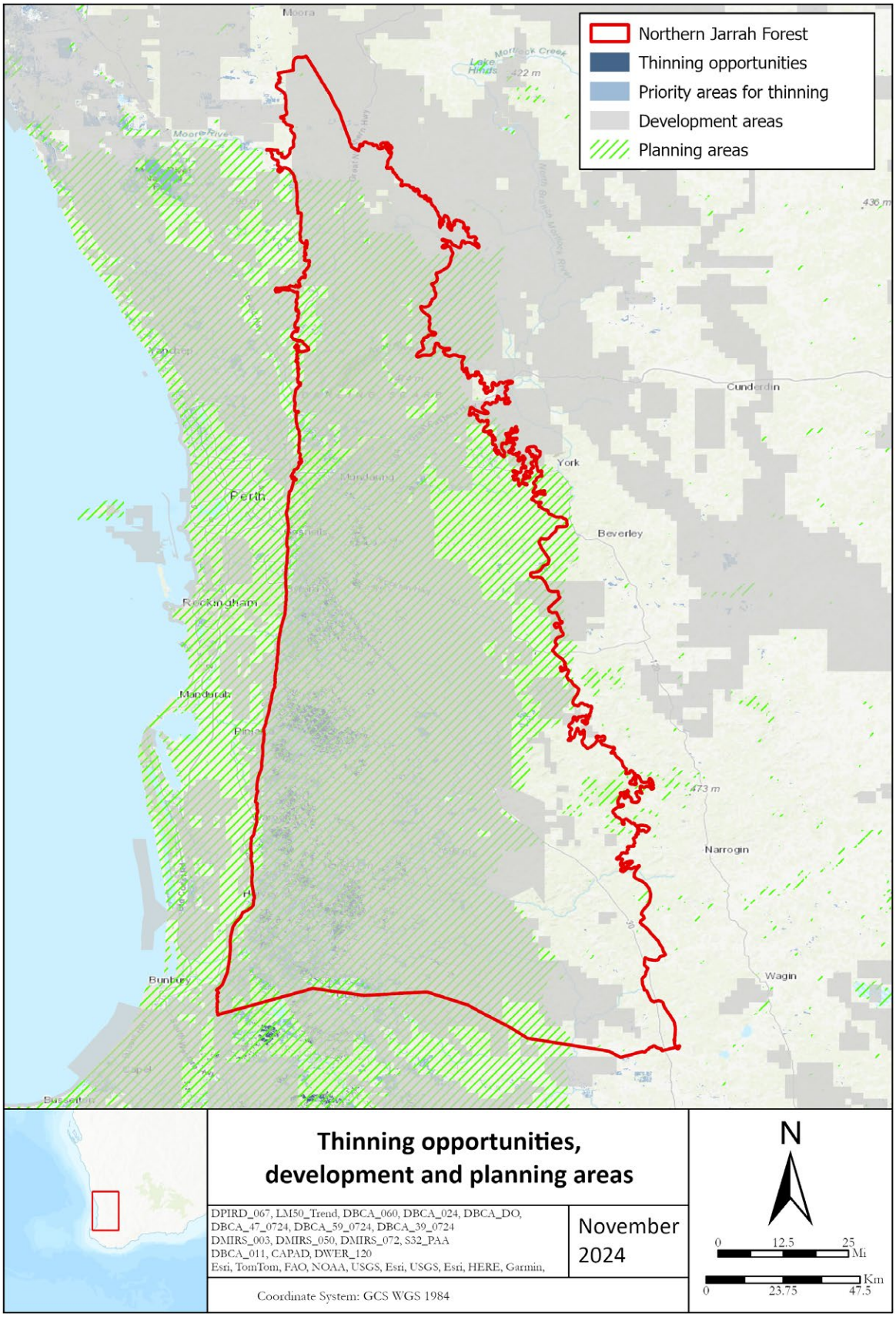


Figure 27: Thinning opportunities, development areas and planning areas

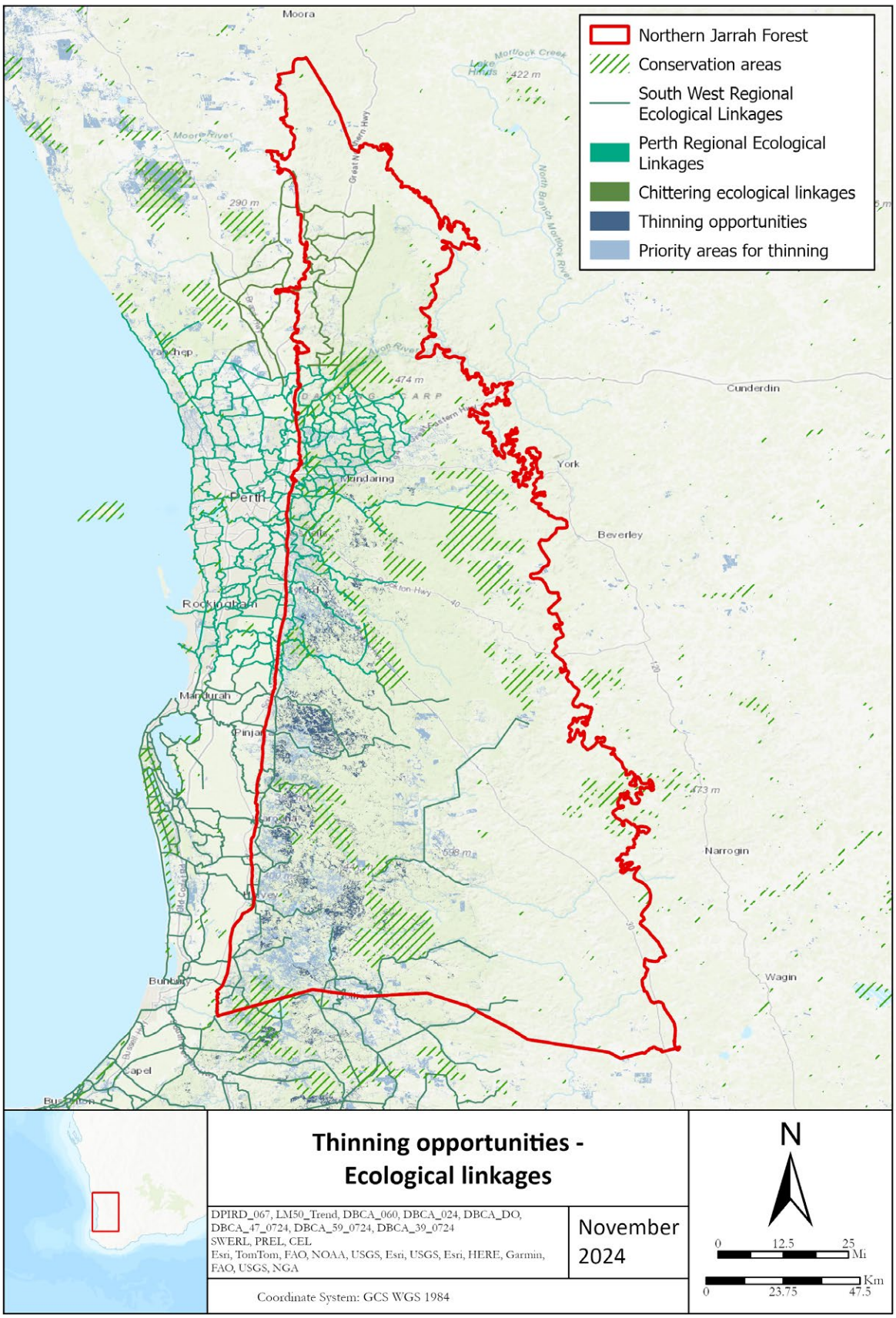


Figure 28: Thinning opportunities and identified ecological linkages and conservation areas that represent strategic approaches to ecological thinning

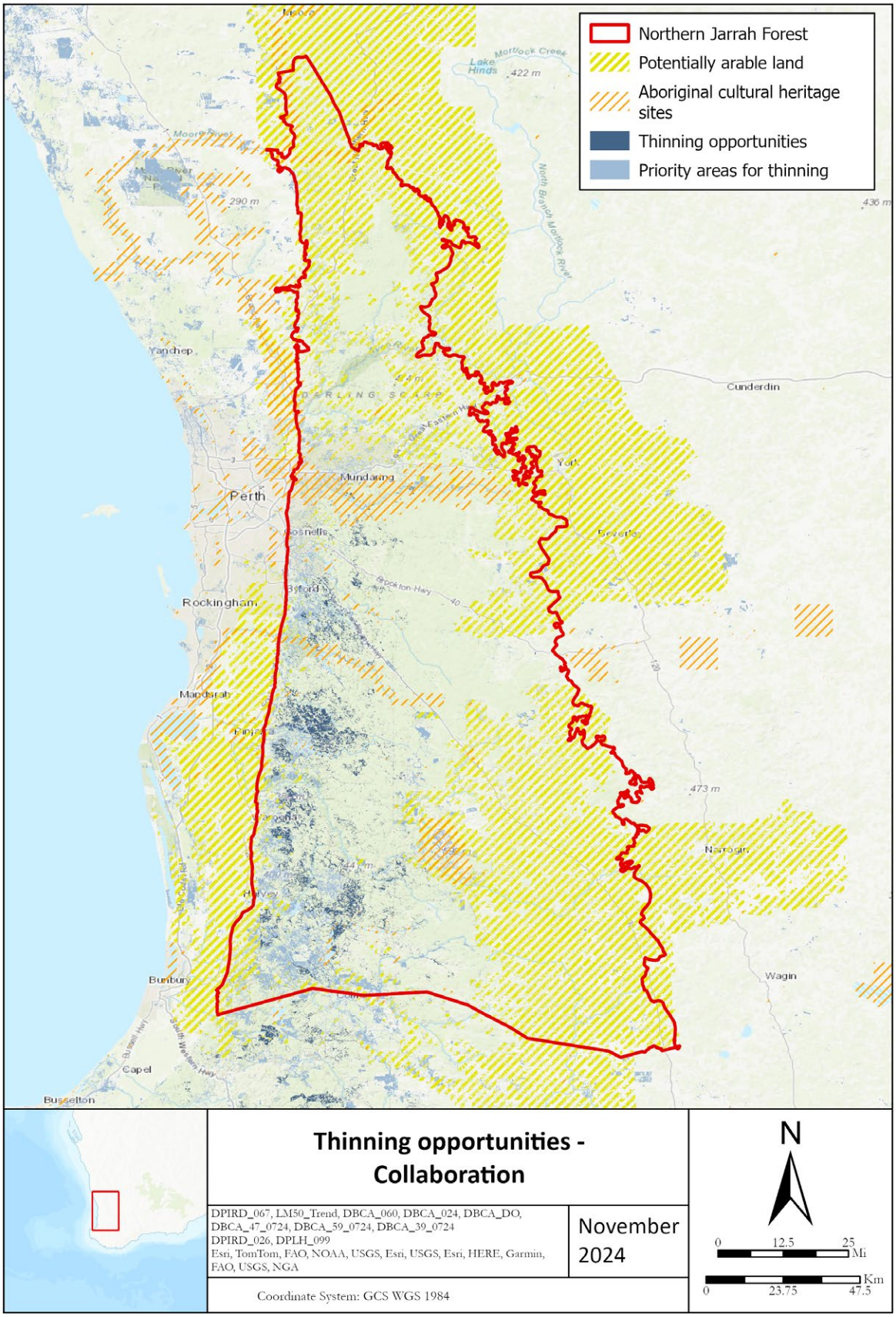


Figure 29: Thinning opportunities and indicative areas for collaboration (subject to engagement) that represent strategic approaches to ecological thinning

Table 6: Summary of risk assessment for thinning opportunities in the NJF

	Thinning opportunities	Priority areas for thinning	Strategic approaches
Accuracy/confidence score	2	2	2
Acceptability score	3		
OVERALL RISK	Low-medium	Low-medium	Low-medium

Risk assessment

A summary of the risk assessment for thinning opportunities is presented above in Table 6. A full outline of the risk assessment undertaken is provided in Appendix C.

The risk associated with thinning opportunities was low-medium regardless of approach. While acceptability was high, and water management and hydrology were identified by several stakeholders as a key priority for the NJF (Appendix A), the permanence and measurability of thinning was low (Appendix C). Improving the permanence of thinning activities (such as planting thinned areas with native understory species) would improve the use of thinning as an offset opportunity.

Contribution to knowledge gaps

Knowledge gaps, including natural disturbance patterns and climate resilient restoration; levels of recovery in terms of vegetation composition and fauna recolonisation in disturbed areas; indicator species for the assessment of recovery; further knowledge of invertebrates and reptiles; and legal mechanisms for improved protection, were all identified for the NJF in Abdo and Young (2025). Further research to support offset opportunities within the context of this report were also identified in Table 7.

Addressing these knowledge gaps could improve offset (and other conservation) outcomes in the NJF and is consistent with the EPA's expectation that offsets should "contribute to the ecological knowledge of a region" (EPA, 2024). Further, the Commonwealth offsets calculator (DSEWPaC, 2012b) incentivises research that reduces the uncertainty of offset outcomes (Miller et al. 2015). Using a collaborative and coordinated approach to the prioritisation and delivery of research projects could ensure their strategic use to improve management and conservation (including offsets) in the NJF.

Table 7: Research topics to address knowledge gaps identified during the Research Project and examples of potential research questions

Research topic	Example research topics
Strategic use of land at a regional scale	• Should offsets for developments in the NJF be permitted in other ecosystems? • Should areas with altered soil profiles be planted for an alternative purpose (i.e. timber), enabling existing plantations with a more complete soil profile to be restored instead? (Campbell et al., 2024; Forestry Australia, 2022; Dr George Matusick 28/10/2024 pers comm) • How can recreational uses and socio-economic land uses be implemented on offset land without impacting natural values? (CGT, 2020; 2022) • The identification of priority ecological linkages across the NJF and surrounding regions
Improved resilience of restoration	• Development and maintenance of a publicly accessible central record of native vegetation extent and condition (Molloy et al., 2009, Peel Alliance, 2023) • Monitoring of understory establishment and levels of recovery (Stantec, 2023) • Improved understanding of wildfire and the susceptibility of restored areas to dieback and drought (Stantec, 2023) • Use of coated seed as a solution in dieback infested areas for restoration using dieback resistant species (Prof. Giles Hardy 10/10/2024 pers comm.) • Understanding the ideal forest structure for the NJF (Dr George Matusick 28/10/2024 pers comm.) • How can younger areas of the NJF be adapted into a structure more resemblant of old growth forest? (Dr George Matusick 28/10/2024 pers comm.) • Has historical use shifted the perceived baseline standards for restoration in the NJF? • How will the structure and natural values of the NJF be altered by climate change? • Should restoration focus on species and the return of natural values most resilient to climate change, or should restoration be focused on the return of all natural values of excellent quality remnant vegetation types?
Landscape scale conservation of threatened species	• Creation of an integrated balanced landscape conservation value model for all threatened species across the NJF to better inform regional prioritisation for the prevention of species loss
Management of disease and invasive species	• The extent of forest diseases in the NJF • What is the change in forest diseases in response to climate change across the NJF? • The extent and effectiveness of management regimes for forest diseases and invasive species • Can a benefit from the time-lag in clearing and restoration be justified if development occurs in an area with confirmed dieback?

Comparison of offset opportunities

Planning areas represent an opportunity for the delivery of offsets utilising a flexible approach. Planning areas were found to cover 80% (1,517,624 hectares) of the NJF, although most of this planning area, 83% (1,265,576 hectares; 67% of the NJF), intersected with development areas.

Development areas, which present a high risk for offsets, were found to cover 76% (1,444,917 hectares) of the NJF. Given that offsets often require a greater area of implementation (multiplier) to compensate for the reduced quality and time lags between development and the implementation of offsets, then insufficient land is available for the compensation of development in the NJF. It should also be noted that if all areas currently identified for development (i.e. significant referrals and mining tenements) across the NJF were cleared, then less than 30% of vegetation would remain, accelerating species loss, and negatively impacting the viability of ecological communities and the retention of ecosystem functions (DEC, N.D.; EPA, 2000; Mappin et al., 2022; Nelder, 2018). Further, it would be inconsistent with Australia's Strategy for Nature 2024-2030 and hinder the Commonwealth's ability to meet international commitments under the Kunming-Montreal Global Biodiversity Framework (CoA, 2017; DCCEEW, 2024d; DER, 2014). Restoration presented the lowest risk and greatest extent of opportunity for offsets in the NJF; with the largest area identified outside of development areas, opportunities adjacent to conservation areas and ecological linkages, and opportunities for collaboration. However, the analysis does not provide an assessment of land availability for restoration in the NJF. In locations where there is a paucity of land, it may be difficult to provide offsets without contributing to negative socio-economic outcomes. However, the delivery of offsets through a strategic approach such as in collaboration with existing land holders and/or through a strategic regional fund can mitigate these issues (Abdo, 2023).

While far more limited in area, protection also presented an opportunity for offsets with some opportunities available outside of development areas, and adjacent to conservation areas and ecological linkages, as well as opportunities for collaboration. The risk of protection opportunities was medium to low-medium. The analysis only assessed the protection of land through conservation covenants or reserves. Protection as 'other effective area-based conservation measures (OECMs)' may be a solution to the issues related to permanence as conservation reserves/under conservation covenants. OECMs are defined as an area "other than a Protected Area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the in-situ conservation of biodiversity, with associated ecosystem functions and services and where applicable, cultural, spiritual, socio–economic, and other locally relevant values" (IUCN-WCPA Task Force on OECMs, 2019). These areas include pastoral leases, other covenanted areas not currently protected for conservation, and the Indigenous (Aboriginal) land estate (Fitzsimons et al., 2024). While these land tenures are not currently recognised formally as protection for the purposes of offsets, under a strategic approach consideration of protection in this regard should be examined. However, protection offsets can only be of benefit where legal protection will prevent the imminent loss of natural values. Therefore, unless protection can be legally achieved in areas already identified for development (including within potential resource areas), protection opportunities are unlikely to present suitable offsets.

Opportunities for invasive species and disease management and thinning were entirely found within development areas and, whilst adjacent to ecological linkages, only provided small opportunities for collaboration. However, the involvement of relevant Aboriginal people is of key importance as management actions, while informed by scientific knowledge, should be guided by local and tradition knowledge (Wardell-Johnson et al., 2024). Therefore, other opportunities for collaboration through knowledge sharing and planning may exist. While the acceptability was high and specifically identified as a priority for the NJF by several stakeholders, accuracy and confidence was much lower and posed an increase to the risk of implementing these management actions as offsets.

There was a paucity of data on disease and invasive species management, which was restricted to *Phytophthora* dieback and, as such, the viability of management of other diseases is unknown. However, given the ubiquitous extent of invasive species in the NJF (DoE, 2015), strategic approaches to the delivery of invasive species management as offsets are likely to exist, although the risk associated with these approaches is likely to represent low confidence in permanence, measurability, additionality, effectiveness and strategic criteria.

There is some conjecture over whether thinning represents an appropriate action for the management of water balances in the NJF, with concerns over its effect on evaporative cooling, atmospheric moisture and cloud cover (Pugh, 2017) and the need for ongoing maintenance (Stantec, 2023; Wardell-Johnson et al., 2024); meaning that this solution may not be viable as an offset. Further research to understand the benefits and impacts of thinning in areas of the NJF are thus recommended.

The delivery of management actions such as thinning, and disease and invasive species management through a coordinated approach such as a regional offset fund could improve confidence in permanence, measurability, efficiency and strategic criteria, particularly when utilised as part of a broader suite of long-term offset actions. A coordinated approach to management actions could present further strategic opportunities for offsets in the NJF.

Conclusion and recommendations

This Research Project has identified opportunities for offsets within the NJF using literature review, stakeholder engagement and spatial data analysis, concluding:

1. There is a paucity of land available for offsets under existing interpretation of offset requirements and therefore flexibility, through strategic approaches, is required to ensure adequate compensation can be achieved if future development is to be permitted in the NJF.
2. Offsets cannot be implemented in development areas in the NJF unless assurance of protection from further development (both legally and in practice) can be achieved and risks to offset success can be overcome.
3. Offsets could be undertaken in areas currently identified for planning if legal protection of offset areas can be achieved and additionality can be demonstrated.
4. Collaborative approaches with existing land holders (for example, agricultural land holders, Aboriginal people) are key to ensuring the success of offsets, particularly in landscapes such as the NJF where there is a paucity of land available for offsets.
5. Early and ongoing collaboration should be undertaken with relevant stakeholders, and through appropriate mechanisms, to support the inclusion of Aboriginal people in offsets (such as the ability to generate income from offset areas) be identified and implemented.
6. Restoration should be prioritised for the implementation of offsets in the NJF.
7. Coordinated approaches (i.e. an independent regional offset fund) should be utilised for the strategic implementation of management offsets such as invasive species and disease management and ecological thinning as well as the prioritisation and delivery of further research projects that overcome to knowledge gaps for the NJF and improve the accuracy and effectiveness of strategic approaches.

Given the paucity of land available for offsets in the NJF, if further development is to occur, the following recommendations for offsets in the NJF are provided on the basis of this research:

- Offsets must be applied strategically through collaborative and coordinated approaches.
- Offsets should be preferentially delivered in priority and low risk areas where permanency of offset actions can be reasonably assured, regardless of existing land tenure.

Given the severity of the predicted impacts of climate change on the region it is further recommended that the piecemeal approach to compensation of individual environmental values for offsets should instead be replaced with a focus on offset activities towards regional scale priorities.

The inclusion of cultural, social and economic concerns into the consideration of offsets can enable strategic and cost-effective offsets that could provide greater co-benefits. However, for this approach to be truly effective, these aspects should also be considered in EIA. This is especially important in areas such as the NJF, a depleted, highly impacted ecosystem that may be difficult to replicate and is at high risk of loss (Campbell et al., 2024; Maron et al., 2012).

This research represents a novel approach to the strategic use of offsets at a regional scale to guide sustainable development in the NJF. Further consideration of the values of sustainable development within a regional scale framework, such as the one presented here, across Western Australia, would present an equitable and effective approach to EIA and offsets across the state. There is increased recognition by the Commonwealth and other regulators, and in best practice, of the benefits of region scale planningfor EIA and offsets. The approach proposed in this report therefore has broad applicability to other regions with similar competing demands.

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Appendix A

List of stakeholders identified

	Organisation
Aboriginal Corporations	Ballardong Aboriginal Corporation
	Gnaala Karla Booja
	Whadjuk Aboriginal Corporation
	Yued Aboriginal Corporation
Agriculture	WA Farmers
	Wide Open Agriculture
	Growers Group Alliance
Catchment groups/ conservation managers	South West NRM
	Peel Harvey Catchment Council
	Leschenault Catchment Council
	Perth NRM
	Wheatbelt NRM
Conservation group	Daniel Jan Martin
	Peel Alliance
	WA Forest Alliance
Local government	Western Australian Local Government Association
Regulator/Government	DWER
	DPIRD
	Water Corporation
	JSTI
	DCCEEW
	DPLH
	DMIRS
	DBCA
Subject matter experts	Joe Fontaine
	John Bailey
	Giles Hardy
	George Matusick
	Rachel Standish
	Grant Wardell-Johnson

Stakeholder perspectives

	Protection
	Meetings
Aboriginal Corporations	Limit damage to environment and culture
Conservation groups	Potential way forward with Beyond 2024 report
	Concern around protection of recreational areas and how they will be protected into the future
	New conservation areas
	New conservation areas
Catchment groups	Not supportive of further clearing
	Have been discussing a strategic assessment for protection of the NJF with EPA
	Want to protect biodiversity and ecosystems
	Intact areas are important investments for resilience. Focus on protecting intact patches in the Perth hills area
Forestry group	Conservation
	Include high-rainfall high quality northern Jarrah Forest areas in reserves
	Some high-quality areas should be retained for recreational purposes
Regulator/Government	Vegetation communities underrepresented in the conservation estate
	Maintain environmental values, biodiversity and ecosystem function
Subject matter experts	Longevity and better legislation
Tourism	Maintain public access for recreational purposes through quality vegetation
	Maintain public access for recreational purposes through quality vegetation
	Literature
Local government	Goal to retain and protect natural areas
	One of the significant proposals in this draft Strategy is that natural areas be protected where possible, rather than just retained.
	Local Biodiversity Strategy has a goal to formalise the long-term protection of Local Natural Areas
	Council adopted as a 10-year priority, 'Shire-led conservation, protection and retention of natural areas'
	Protection and restoration to improve ecological linkages
	Have targets to protect specific biodiversity features
Regulator/Government	Protect remnants from clearing
	Strategic goal in state planning strategy for conservation including the protection of natural habitat
	Undertake protection of MNES as part of the regional forest agreement

	Restoration
	Meetings
Aboriginal Corporations	Want to limit damage to environment and culture
Catchment groups	Want further restoration. Lots of value socially but lots of misinformation regarding social value and land use associated with development
	Want to protect biodiversity and ecosystems
Forestry group	Include management of mined areas in the Forest Management Plan
	Planting of trees provides carbon sequestration
Local government	Prioritise conservation of identified areas
Regulator/Government	Most of the Jarrah Forest is continuous, but linkages to Perth/Peel and/or wheatbelt
	Literature
Local government	Protected areas are to be established so as to be ecologically resilient in the long term. This may require restoration and management of the natural area (and revegetation in some cases)
	Manages and restore Local Natural Areas and revegetate new areas to increase native fauna habitat
	The city restores natural area reserves
	Support and encourage restoration works by other parties (landholders, conservation groups etc.)
	Protection and restoration to improve ecological linkages
	Focus on restoration and management of remaining natural areas
Regulator/Government	With the right statewide and regional policy settings, the State Government can better enable all sectors to contribute to a net gain in native vegetation and landscape scale conservation and restoration
	State planning strategy aspires to implement catchment protection and restoration programs

	Disease and invasive species management
	Meetings
Catchment group	High priorities are dieback and feral pigs. Also foxes
Local government	Dieback is a big issue
Regulator/Government	Western Shield as per FMP
Subject matter expert	Likely to increase with climate change (as will other pathogens and invasive species). Forest is likely to transition from single stemmed individuals to multistemmed with accompanying increased water requirements
	Literature
Local government	Management of Local Natural Areas for conservation is a priority once they have been protected. Standard management practices include access control, fencing, environmental weed and feral animal control, fire planning and dieback management
	Management of natural area reserves includes weed management
	Dieback management priorities and advocate for improved feral animal control
	Support invasive species management
Regulator/Government	In South Western Australia Temperate Eucalyptus open forests with a shrubby understorey vegetation profile: • Maintain strict hygiene protocols to avoid spreading *Phytophthora* • Manage Bridal Creeper and Blackberry • Undertake fox and rabbit baiting and shooting, and feral cat trapping
	State planning strategy aspires to effectively manage threats such as invasive species (weeds, pests, ferals)

	Thinning	
	Meetings	
	Hydrology	**Thinning**
Catchment group	Lots of issues with hydrology and gaps in information	
Conservation group	Mines are large users of potable water	
	Impacts on ground water allocations to other areas and environmental impacts and health of the rivers (including in adjacent areas)	
Local government	Management of catchment and improving water quality	
Forestry		Ecological thinning
Forestry group	Water use of revegetation and economic loss of water usage	Thinning of rehabilitated areas
	Literature	
Local government	Supportive of limited thinning	
Regulator/Government	Complement the Forest Management Plan through improved coordination of mechanisms for managing South West forests and woodlands (including thinning)	

Appendix B

List of spatial data analysed

Data name	Data code	Last updated	Link
39-0724_TEC_NJF_buffers	DBCA_39_0724	19/07/2024	Supplied by DBCA and used under agreement
47-0724_BlackCockatoo_ roosts	DBCA_47_0724-2	22/07/2024	Supplied by DBCA and used under agreement
47-0724_FRTBC_ BreedingTrees	DBCA_47_0724-4	22/07/2024	Supplied by DBCA and used under agreement
47-0724_ TheatenedPriorityFauna	DBCA_47_0724-1	22/07/2024	Supplied by DBCA and used under agreement
47-0724_WhiteTailBC_ BreedingTrees	DBCA_47_0724-3	22/07/2024	Supplied by DBCA and used under agreement
59-0724FL_TPFL	DBCA_59_0724-1		Supplied by DBCA and used under agreement
59-0724FL_WAHerb	DBCA_59_0724-2		Supplied by DBCA and used under agreement
Aboriginal Cultural Heritage - Register	DPLH-099	6/05/2024	https://catalogue.data.wa.gov.au/dataset/aboriginal-cultural-heritage-register
Chittering Ecological Linkages	CEL	1/06/2008	https://catalogue.data.wa.gov.au/dataset/chittering-ecological-linkages
Collaborative Australian Protected Areas Database (CAPAD) 2022 - Terrestrial	CAPAD	3/09/2024	https://fed.dcceew.gov.au/datasets/ec356a872d8048459fe78fc80213dc70_0/explore?location=-10.479124%2C28.201442%2C16.97
DBCA - Legislated Lands and Waters	DBCA-011	19/10/2023	https://catalogue.data.wa.gov.au/dataset/dbca-legislated-lands-and-waters
DBCA Fire History	DBCA-060	1/07/2023	https://catalogue.data.wa.gov.au/dataset/dbca-fire-history
dieback-occurrence-njf	DBCA_DO	31/12/2023	Supplied by DBCA and used under agreement
EPA Redbook Recommended Conservation Reserves 1976-1991	DBCA-029	2/10/2017	https://catalogue.data.wa.gov.au/dataset/epa-redbook-recommended-conservation-reserves-1976-1991
EPA Referred Significant Proposals	DWER-120	30/06/2024	https://catalogue.data.wa.gov.au/dataset/epa-referred-significant-proposals
fmp24-map13-indicative-protection-areas-njf	FMP24_Map13	30/06/2023	Supplied by DBCA and used under agreement
Forest Disease Risk Areas	DBCA-024	19/02/2019	https://catalogue.data.wa.gov.au/dataset/forest-disease-risk-areas
Forest Management Plan (FMP) 2024 - 2033	DBCA-078	16/01/2024	https://catalogue.data.wa.gov.au/sl/dataset/forest-management-plan-fmp-2024-2033-dbca-078
IBRA Subregion Australia Version 7.0 - PED	IBRA_NJF	13/04/2022	https://data.gov.au/data/dataset/e5a6d60a-009c-4fc3-b27d-67ed108b38ba
LM50_ TrendClass_1990-2023_ everwoody.tif	LM50_Trend	1/02/2024	Supplied by Pawsey Data centre

Data name	Data code	Last updated	Link
Mining Tenements	DMIRS-003	16/05/2024	https://catalogue.data.wa.gov.au/dataset/mining-tenements-dmirs-003
Native Vegetation Extent	DPIRD-005	19/06/2023	https://catalogue.data.wa.gov.au/dataset/native-vegetation-extent
Offsets Register - Offsets	DWER-078	27/08/2024	https://catalogue.data.wa.gov.au/dataset/offsets-register-offsets/resource/26b0b92b-dee9-461e-aa8c-43860f721050
Perth Regional Ecological Linkages	PREL	1/06/2004	https://catalogue.data.wa.gov.au/dataset/perth-regional-ecological-linkages
Potentially Arable Land	DPIRD-026	23/05/2018	https://catalogue.data.wa.gov.au/dataset/potentially-arable-land-dpird-026
Pre-European Vegetation	DPIRD-006	23/07/2019	https://catalogue.data.wa.gov.au/dataset/pre-european-dpird-006
Regionally significant basic raw materials 1:100 000	DMIRS-050	18/10/2019	https://catalogue.data.wa.gov.au/dataset/regionally-significant-basic-raw-materials-1-100-000
S32_WAPL_ERD_RtS_PAA_Regions_20231005_SPECIES_Dissolved_GDA94z50_SHP	S32_PAA		Supplied by South32
S32_WAPL_ERD_RtS_PAA_REVISED_20230920_UNION_GDA2020_MGAz50_poly	S32_PAA		Supplied by South32
S32_WAPL_OIP_DirectOffset01_20231110_HabitatType_GDA94z50_SHP	S32_Offset01		Supplied by South32
S32_WAPL_OIP_DirectOffset02_20231109_HabitatType_GDA94z50_SHP	S32_Offset02		Supplied by South32
South West Regional Ecological Linkages Axis Lines	SWREL	1/09/2009	https://catalogue.data.wa.gov.au/dataset/south-west-regional-ecological-linkages-axis-lines
SPP_2_4_Extraction_Sites_DMIRS_072	DMIRS-072	17/08/2021	https://catalogue.data.wa.gov.au/dataset/state-planning-policy-2-4-extraction-sites-dmirs-072
WA_CLUM_August2018	DPIRD-067	31/12/2017	https://catalogue.data.wa.gov.au/dataset/catchment-scale-land-use-mapping-for-western-australia-2018

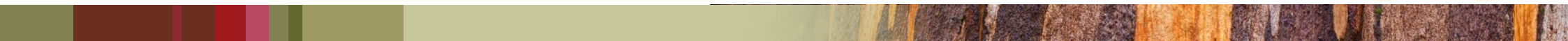
Appendix C

Risk matrices

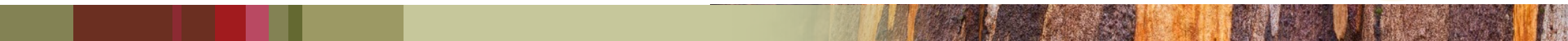
Protection

	ACCURACY/CONFIDENCE				
Criteria	Measure	Score			
		Comment	Thinning opportunities	Priority areas for thinning	Strategic approaches
Data quality	Aggregate of data sets used for the layer and a function of both: • data accuracy (scale, reliability) • data age (where relevant)	• Confidence of data used for the mapping of protected areas is moderate, although for priority areas this was high[14]	2	3	3
Permanence	Resilience of the benefits of the offset activity	• If protected areas are impacted by development, an alternative offset must be provided elsewhere. Implementation of offsets using strategic approaches such as collaboration or coordinated approaches can mitigate this risk by ensuring ongoing use (management etc.)	2	2	3
Measurable	• Proportion of the outcome that can be measured • Quality of the baseline	• Given that permanence is achieved through a legal change in tenure, measurement of this type of offset is simple to achieve. However, in order to achieve a benefit, management measures must also be implemented	1	1	2
Additional	• Requirement for management • Level of management	• Protection of an offset can only be achieved on land that has no formal prior legal protection and therefore this type of offset is additional by definition	3	3	3
Effective	Level of risk from other processes	• Legal protection of an area only provides protection from approval of clearing and other negative impacts to the area may cause the loss of natural values. Strategic approaches may ensure better protection through the reduction in risk and incorporation of other protective mechanisms (such as ongoing management)	1	1	2

14. Analysis of data quality is available as supplementary information to this report.



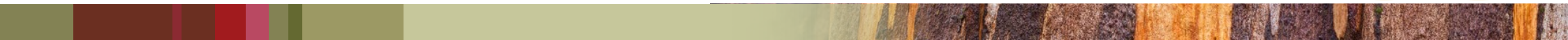
ACCURACY/CONFIDENCE					
Criteria	Measure	Score			
		Comment	Thinning opportunities	Priority areas for thinning	Strategic approaches
Efficient	• Cost of implementation/ regulation • Likelihood of achieving offset benefit	• Implementation and assurance of protected areas is cost-effective. However, adaptive management is not possible. Strategic approaches may ensure better protection through the reduction in risk and incorporation of other protective mechanisms (such as ongoing management)	1	1	2
Strategic	Scale across landscape: • contribution to ecological linkages • Contribution to co-benefits	• Suggested areas for protection include areas with increasing woody vegetation outside of urban areas, that are additional to the current conservation estate. Protection areas and priority areas can contribute to ecological linkages, but strategic approaches are able to better contribute to co-benefits	2	2	3
		Total Accuracy/confidence score	**1.7**	**1.9**	**2.6**
ACCEPTABILITY					
Response to protection was mixed with 14 stakeholders across eight sectors supportive of the concept, but concerns raised around the maintenance of recreational access, which is not always available when land protection offsets are implemented. Acceptability would therefore be high for protection offsets that enable recreational activities, but low for those that do not. Thus, an overall score of medium has been applied			2		
		OVERALL RISK	Medium	Medium	Low-medium



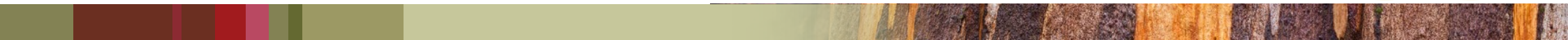
Restoration

Criteria	Measure	ACCURACY/CONFIDENCE			
		Score			
		Comment	Thinning opportunities	Priority areas for thinning	Strategic approaches
Data quality	Aggregate of data sets used for the layer and a function of both: • data accuracy (scale, reliability) • data age (where relevant)	• Confidence of data used for the mapping of restoration areas is moderate • Data sets for the priority areas have an overall high confidence[15]. Assuming a strategic approach (focussing on priority areas), score has been set as high	2	3	3
Permanence	Resilience of the benefits of the offset activity	• Completion of restoration offsets should ensure a moderately resilient ecosystem, enabling the persistence of offset benefits. Strategic approaches can ensure ongoing management following offset completion through collaboration with other parties	2	2	3
Measurable	• Proportion of the outcome that can be measured • Quality of the baseline	• Data of the outcomes of restoration can be measured, but how reflective this of actual benefits achieved can be mixed • There is a paucity of data related to some aspects of the NJF, but high-quality data available for other aspects (see Abdo & Young, 2024). Therefore quality of the baseline is assumed to be moderate	2	2	2
Additional	• Requirement for management • Level of management	• Areas identified for restoration either do not have a mandate for management or are unmanaged (based on decrease in woody vegetation) and are therefore additional to existing restoration activities	3	3	3
Effective	Level of risk from other processes	• Threats of climate change and disease and invasive species to offset outcomes are high. Collaborative/coordinated approaches can provide greater certainty against issues with land tenure	2	2	3

15. Analysis of data quality is available as supplementary information to this report.



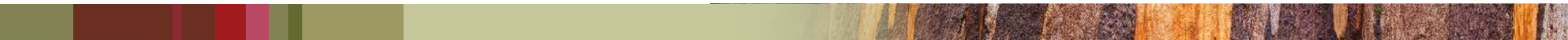
Criteria	Measure	Score			
		Comment	Thinning opportunities	Priority areas for thinning	Strategic approaches
ACCURACY/CONFIDENCE					
Efficient	• Cost of implementation/ regulation • Likelihood of achieving offset benefit	• The cost of seed, planting and management is high, as is monitoring adaptive management is possible and regularly implemented	2	2	2
Strategic	Scale across landscape: • contribution to ecological linkages • Contribution to co-benefits	• Restoration can be strategic, providing both ecological linkages and co-benefits when implemented in conjunction with a regional plan	2	2	3
		Total accuracy/confidence score	**2.1**	**2.3**	**2.7**
ACCEPTABILITY					
No concerns raised and support from 15 stakeholders across five sectors			3		
		OVERALL RISK	Low-medium	Low-medium	Low



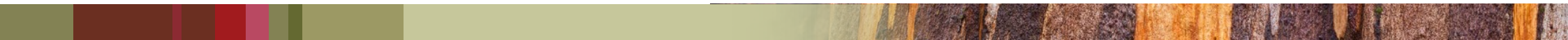
Invasive species and disease management

	ACCURACY/CONFIDENCE				
Criteria	**Measure**	**Score**			
		Comment	**Thinning opportunities**	**Priority areas for thinning**	**Strategic approaches**
Data quality	Aggregate of data sets used for the layer and a function of both: • data accuracy (scale, reliability) • data age (where relevant)	• Confidence of data used for the mapping of *Phytophthora* dieback is high[16] • While invasive species are known to be ubiquitous throughout the NJF, data is not available for other diseases or areas where existing management of invasive species occurs	1	1	1
Permanence	Resilience of the benefits of the offset activity	• Given that invasive species and diseases are far more widely spread than the NJF and that the NJF cannot be isolated, any activities that aim to manage invasive species or diseases are temporary	1	1	1
Measurable	• Proportion of the outcome that can be measured • Quality of the baseline	• There are many factors that contribute to the effects of disease and invasive species on natural values, as such, the benefits attributable to activities that manage disease and invasive species can be difficult to measure	1	1	1
Additional	• Requirement for management • Level of management	• Government departments including DBCA and DPIRD have a mandate to manage the environment and prevent the spread of invasive species and disease, however, the cost of management is extremely high, especially given the large area over which disease and invasive species have an impact. Therefore, under a strategic approach, it may be possible to consider this activity as additional	1	1	2
Effective	Level of risk from other processes	• Given the widespread nature of invasive species and disease across WA and the inability to isolate the NJF from incursion from surrounding areas, management activities are unable to provide a persistent outcome	1	1	1

16. Analysis of data quality is available as supplementary information to this report.



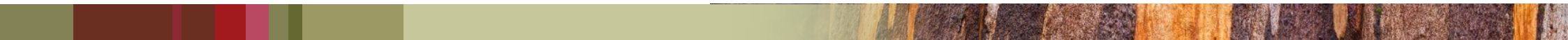
Criteria	Measure	Score			
		Comment	Thinning opportunities	Priority areas for thinning	Strategic approaches
ACCURACY/CONFIDENCE					
Efficient	• Cost of implementation/ regulation • Likelihood of achieving offset benefit	• The offset may be costly to implement but can facilitate adaptive management	2	2	2
Strategic	Scale across landscape: • contribution to ecological linkages • Contribution to co-benefits	• Invasive species and disease management do not contribute to co-benefits and are unlikely to provide a significant and long-lasting contribution to ecological linkages	1	1	1
		Total accuracy / confidence score	**1.1**	**1.1**	**1.3**
ACCEPTABILITY					
No concerns raised and support from ten stakeholders across four sectors			3		
		OVERALL RISK	Medium	Medium	Medium



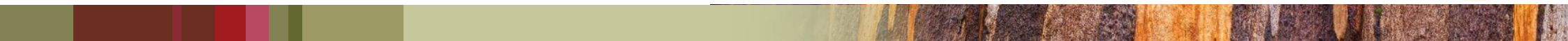
Management for improved water balances

	ACCURACY/CONFIDENCE				
Criteria	Measure	Score			
		Comment	Thinning opportunities	Priority areas for thinning	Strategic approaches
Data quality	Aggregate of data sets used for the layer and a function of both: • data accuracy (scale, reliability) • data age (where relevant)	• Confidence of data used for the mapping of protected areas is moderate • Data sets for the priority areas have an overall high confidence[17] • Assuming a strategic approach (focussing on priority areas), score has been set as high	2	3	3
Permanence	Resilience of the benefits of the offset activity	• Ecological thinning has been shown to be temporary and needs to be repeated as coppice vigorously return (Wardell-Johnson et al., 2024). However, greater success may be achieved if thinned areas are revegetated with understory species	1	1	2
Measurable	• Proportion of the outcome that can be measured • Quality of the baseline	• There are many factors that contribute to the water balances in the NJF, therefore the benefits attributable to thinning can be difficult to measure	1	1	1
Additional	• Requirement for management • Level of management	• Suggested areas for thinning include areas with increasing woody vegetation outside of urban areas, that are additional to both the conservation estate and areas currently planned to be thinned	3	3	3
Effective	Level of risk from other processes	• Thinning has been shown to improve water balances, however, other processes that extract water and the effects of climate change may mitigate its benefits	2	2	2

17. Analysis of data quality is available as supplementary information to this report.



Criteria	Measure	Score			
		Comment	Thinning opportunities	Priority areas for thinning	Strategic approaches
ACCURACY/CONFIDENCE					
Efficient	• Cost of implementation/ regulation • Likelihood of achieving offset benefit	• The offset may be costly to implement but can facilitate adaptive management	2	2	2
Strategic	Scale across landscape: • contribution to ecological linkages • Contribution to co-benefits	• Thinning can contribute to co-benefits but are unlikely to provide a long-lasting contribution to ecological linkages	2	2	2
		Total accuracy / confidence score	**1.9**	**2.0**	**2.1**
ACCEPTABILITY					
No concerns raised and support from six stakeholders across five sectors. In addition, five stakeholders from four sectors also identified water management and hydrology as a priority for the NJF			3		
		OVERALL RISK	Low-medium	Low-medium	Low-medium



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