Use of Natural Capital Accounting as a Forecasting & Planning Tool

GASKELL NORTH CASE STUDY

L Pantelic, B Maybee, K Meney, V Newton

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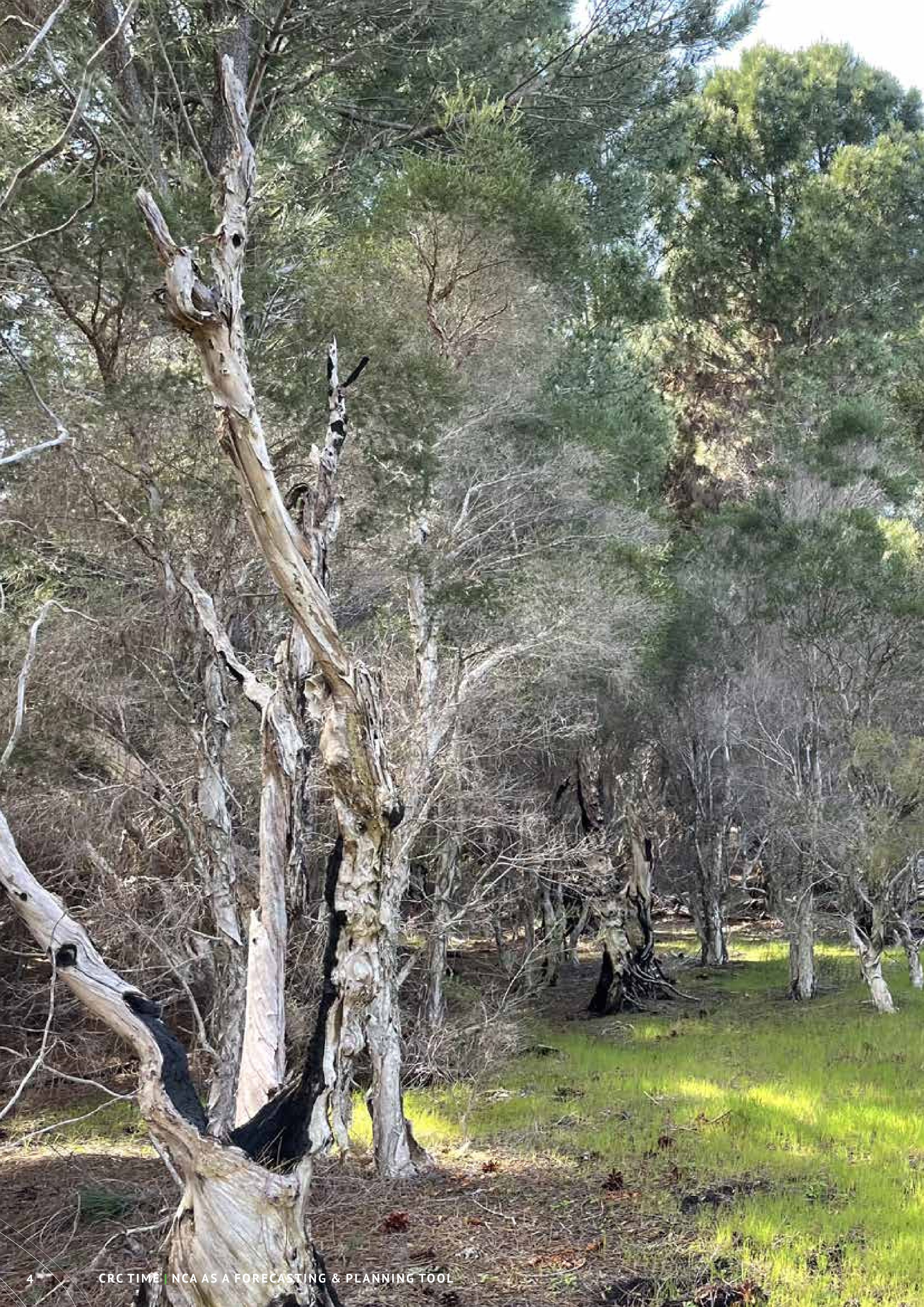

Acknowledgements

The mining sector Environmental Economic Accounting project was supported by the Australian Government's Department of Climate Change, Energy, the Environment and Water.

The project has bought together industry, research providers and engaged stakeholders to promote the adoption and streamlining of natural capital accounting and disclosure in the mining sector.

The project team thanks our partners: Alcoa, BHP, Hanson Construction Materials Pty Ltd, CSIRO, CRC TiME, Murdoch University, Curtin University, University of South Australia, Syrinx Environmental PL, Minerals Council of Australia, Digital Finance CRC and the Western Australian Biodiversity Science Institute.

Citation

Pantelic, L. [a], Maybee, B. [b], Meney, K. [a], Newton, V. [c] 2023 Use of Natural Capital Accounting as a Forecasting & Planning Tool: Gaskell North Case Study. CRC TiME, Australia.

[a] Syrinx Environmental PL
[b] CRC TiME/Curtin University
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1.0 Introduction

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1.0 Introduction

1.1 THIS STUDY

Hanson Australia Pty Ltd (Hanson) Gaskell Avenue Sand Operations is one of the four initial sites selected as case studies for testing and demonstrating applicability of Natural Capital Accounting (NCA) in the mining sector.

This current report is an extension of the initial case study work completed in May 2023 (Pantelic et al., 2023), and explores the role of NCA in forecasting, as opposed to its current use in capturing the changes in the stocks and flows of natural capital assets and ecosystem services. This is a new application of NCA that brings more of a strategic opportunity for operational mines to identify natural capital impacts, values and opportunities ahead of mining to influence better decisions and nature-positive outcomes moving forward.

This is a hypothetical exercise intended to test the process of extending NCA application in mining into the realm of forecasting. The data used, assumptions made and site-specific outcomes for this test case are not sufficient to be used for purposes beyond the experimental intent of this study.

1.2 CONTEXT AND PREVIOUS WORK

This CRC TiME project is part of a larger DCCEEW (Department of Climate Change, Energy, the Environment and Water) funded collaborative mining sector ecosystem accounting project.

It is intended to trial and demonstrate the value and the usefulness of NCA for the mining industry and build capability within the mining sector to develop natural capital accounts. The project also aims to identify and highlight existing constraints and gaps pertinent to NCA application in the mining sector, as well as possible opportunities for expanding the role and benefits of the NCA-based approach to this industry sector.

The Hanson (Gaskell Sand Quarry) NCA Case Study was initiated in October 2022 and was run in partnership between CRC TiME, Curtin University, Hanson, and Syrinx. Syrinx's role on this project was both as a technical lead for developing a set of physical accounts (stocks and ecosystem services) and as a strategic partner providing expertise and guidance for the overall project delivery.

In line with the System of Environmental-Economic Accounting - Ecosystem Accounting (SEEA-EA) approach, development of physical accounts for the Hanson NCA case study (Pantelic et al., 2023) included the following steps: i) determination of relevant spatial and temporal boundaries, ii) identification of units of assessment and development of the natural asset register, iii) mapping of ecosystem extent and development of extent account, iv) assessment of ecosystem condition and development of condition accounts, and v) ecosystem services assessment (carbon). Syrinx based this work on a comprehensive analysis of all available and relevant data pertinent to this site and the project.

The NCA assessment of the Gaskell Sand Quarry, which was focused on the Gaskell Avenue portion of the site, demonstrated the prospect for the use of NCA in the mineral sand industry and highlighted a myriad of existing barriers that may hinder wider and more rapid uptake of this approach within the industry. Many of these issues are associated with the fact that NCA assessment requires a broad and comprehensive range of datasets that are commonly not collected under the existing rehabilitation/restoration monitoring programs.

Furthermore, the study demonstrated that irrespective of rehabilitation efforts and success, for mines that are still active, the overall NCA 'picture' is primarily influenced by reductions in ecosystem extent as a result of mining operations. This means that until the area of restoration becomes greater than the area of exploitation (e.g., at the closure stage), the NCA physical accounts (combined ecosystem condition/extent, and carbon stock) will almost always show a net loss of natural capital.

Importantly though, throughout the Hanson NCA project and especially during discussions held in many project team meetings and workshops, it became evident that there is an opportunity for NCA to play another beneficial and possibly even more significant role in the mining sector, which is to inform restoration forecasting and mine planning.

1.3 NCA AS A FORECASTING & PLANNING TOOL

The primary role of NCA is to describe the change in the state of natural capital stocks and flows of ecosystem services with the defined assessment boundary from the account opening date to closing date.

It therefore provides a retrospective picture as it captures the changes resulting from all activities and events that happen during the accounting period. However, there is an opportunity to use the same structured NCA analytical approach and the underpinning datasets to gain an insight into the future, which is to forecast future changes in stocks and flows using the findings from the previous periods (past).

Using this approach, it could be possible to create informed forecasts of how successfully various project areas and ecosystems units are likely to respond (in terms of their condition) to different restoration efforts and/or other activities or events (e.g., changes in mining practices).

For example, if adequate information is available for a particular restored post-mine area that is immediately adjacent to a planned mining area, then it may be assumed that the latter will respond similarly to restoration efforts if both areas: i) belong to the same ecosystem type, ii) have similar pre-mining condition, and iii) are subjected to similar mining and rehabilitation activities.

Combined with the assumptions regarding the future mining footprint and rate of exploitation, this would enable development of hypothetical future NCA accounts under different scenarios, which could 'paint a picture' of the natural capital potential for a given site and project, and identify what could and should be done to maximise this potential.

This forecasting would then allow the industry to assess the project, not only from an operational capital return perspective, but also from an NCA outlook when making operational and strategic investment decisions. As such, the forecasting process could provide a beneficial pathway for NCA adoption in the mining sector.

1.4 PROJECT OBJECTIVES

This forecasting pilot study is a first attempt to test the NCA forecasting process and its applicability and value as a planning tool in mining. The focus was on the following tasks:

- Assessing if the existing ecological data could be used to facilitate the use of NCA as a forecasting and planning tool, with an emphasis on ecosystem condition.
- Ascertaining the limitations of such data application.
- Identifying other data or assumptions that can be used to facilitate the forecasting process.
- Produce recommendations on how the process can be used and improved.
- Test the uptake of the process by the industry.

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2.0 About the forecasting pilot site

2.1 LOCATION AND CONTEXT

The environmental and social context of Hanson's Gaskell Sand Quarry is well described in numerous publicly available reports and publications. In brief, the quarry is situated within the northern suburbs of Perth on remnants of Banksia woodland on the Swan Coastal Plain (a threatened ecological community, TEC), Bush Forever Reserves, and the Gnangara Pine Plantation.

It is located within a global biodiversity hotspot with approximately 1,000 plant species occurring in the area, and sits within the Bassendean Dune sands (Jandakot and Gavin soil units) (Figure 1).

The work undertaken for the initial NCA study (Pantelic et al., 2023) identified five broad native ecological communities and six native vegetation communities across the site, with *Banksia woodland on dune slopes and crests* and *Low-lying Banksia woodland* being the dominant ecological communities.

The environmental sensitivity of the quarry area is also influenced by its location on the Gnangara Water Mound, which is a Priority 1 drinking water source for the northern suburbs.

2.2 TENEMENTS

For the initial NCA case study, the agreed land boundary included two mine tenements: actively mined Gaskell Avenue (M70/238) to the south comprising of four pits (Gaskell Avenue, Bentley Road, Bell Road and Barlow Lane), and the future mining area Gaskell North (M70/1366) (Figure 1).

For this forecasting study, the focus was on the Gaskell North (M70/1366) tenement only given this area is considered by Hanson to be a long-term resource option for the supply of silica, concrete and building sands. Gaskell North originated from the three separate leases of P70/1298, P70/1299 and P70/1300 covering ~525 ha (Mineralisation Report for a Mining Lease Application P70/1298, P70/1299 & P70/1300, InSitu Advisory 2017).

The area is bound by Gnangara Road to the south, Drumpellier Drive to the east, and the existing M70/238 operation immediately north and north-west, and is located within the Gnangara Pine Plantation.

The Gaskell North tenement is adjacent to the Tick Road sand extraction operations (M70/776), which is held by Boral Resources (WA) Ltd and is operated historically by Hanson Australia through a joint venture agreement (Figure 1).

Mining tenement M70/776 comprises Crown Land, which like Gaskell and Gaskell North, forms part of State Forest 65 (Gnangara-Moore River State Forest). State Forest 65 is administered by the Department of Biodiversity, Conservation and Attractions (DBCA) and comprises a combination of pine plantation and native vegetation.

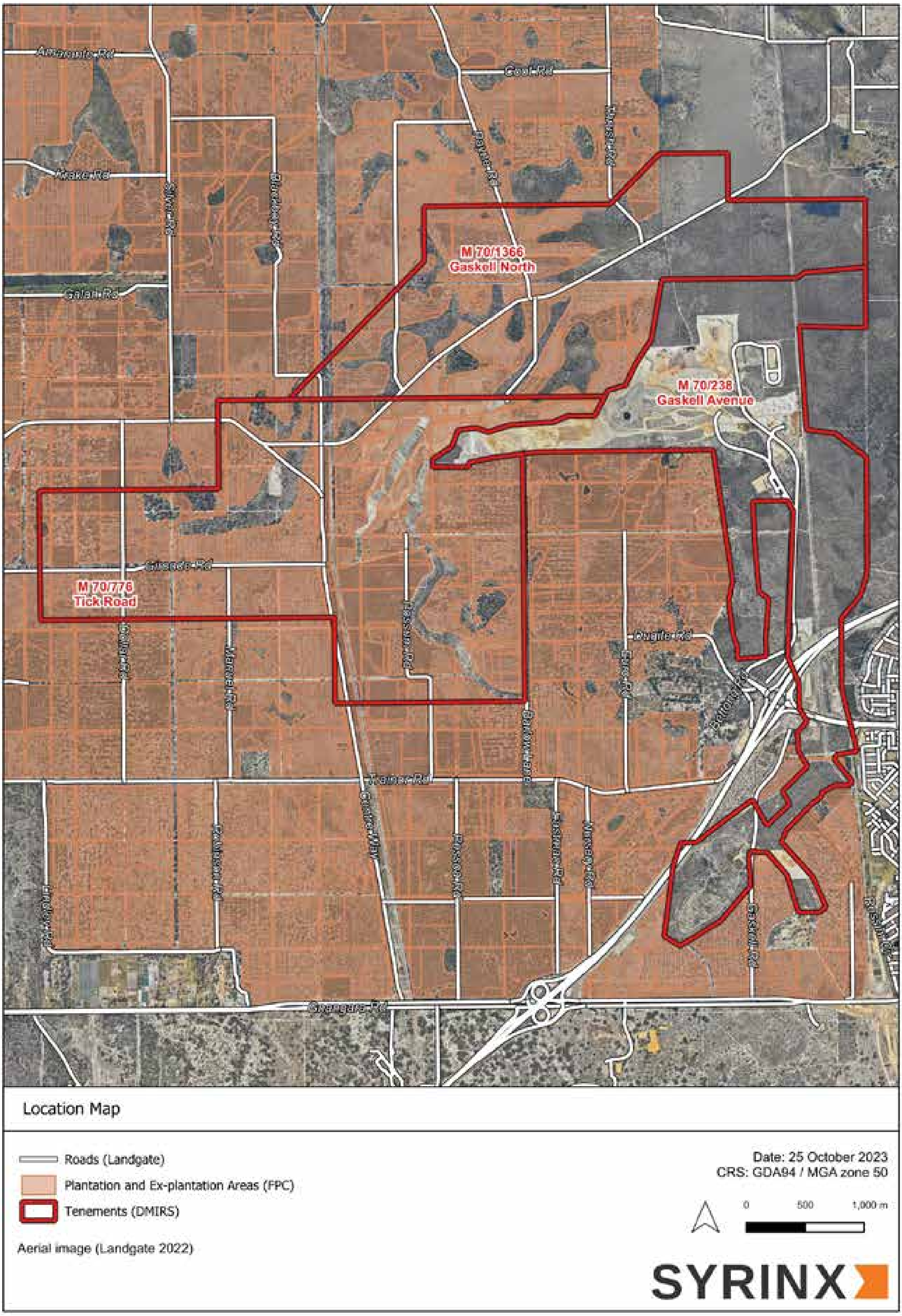

Figure 1. Hanson's mine lease tenements and forecasting study pilot project location

2.3 MINING ACTIVITIES

Information used in this section was sourced from Hanson's documents, primarily the two mine closure plans: *Mine closure plan Gaskell Avenue mining lease M70/238* (RPS 2018) and *Revised mine closure plan (1480AB) Gnangara sand excavation M70/776 (RPS 2020).*

The process of sand extraction within Hanson's Gaskell Sand Quarry, including the adjacent Tick Road (Boral) site, involves clearing the vegetation from undulating hill sites, stripping the topsoil, and removing the underlying white and/or yellow quartz sand horizons constituting 18-40 m of the sand profile. As a result, the sand profile depth is reduced by at least 20 m.

Sand extraction is undertaken by a mechanical wheeled loading shovel with the product either taken to processing plants or loaded directly to road trucks for offsite delivery.

Concrete sand is either dry-screened or washed. Silica sand is extensively processed into several different grades and either sold in bulk or further processed within the drying and screening plant located on the site (RPS, 2017; 2018).

2.4 REHABILITATION & MONITORING

Hanson has a strong commitment towards progressive rehabilitation of their post-mine areas and is continuously undertaking rehabilitation monitoring and reporting. The overall aim of progressive rehabilitation efforts is to re-establish the original Banksia woodland that existed prior to clearing and mining as closely as possible.

Rehabilitation works conducted within Hanson's post-mining areas typically include: reconstruction of soil profiles (establishment of topographic contours); handling of topsoil seedbank and application of topsoil to a depth of up to 10 cm; hand broadcasting of seed (canopy stored species and supplementary seeder species); and planting of greenstock (canopy species such as *Banksia attenuata*, *Banksia menziesii* and *Eucalyptus todtiana*).

A critical element of this process and key to the reported rehabilitation success is the collection of native seed from the surrounding local plant communities within Hanson's land; this seed is either propagated into seedlings and/or used for direct seeding back onto the rehabilitated areas.

Another important element of the overall rehabilitation approach taken by Hanson is their research collaborations with the Botanic Gardens and Parks Authority (BGPA) since 1996, and documented in Banksia Woodlands: A Restoration Guide for the Swan Coastal Plain, together with with CRC TiME as an industry member, and through ongoing rehabilitation-specific research projects with several universities.

Rehabilitation monitoring and assessment is undertaken on an annual basis across all Hanson's operation domains, including Gaskell Avenue and Tick Road areas.

The rehabilitation monitoring program, which has been ongoing for more than 20 years, involves vegetation monitoring, and erosion and landform stability assessment. Vegetation monitoring and observations typically include: i) native seedling recruitment levels, ii) native plant % cover, plant abundance and species richness, and iii) weed recruitment and persistence (% cover, richness).

Rehabilitation sites are monitored at 1, 2, 3, 5, 10 years and then in 10-year increments after restoration, to enable tracking of restoration trajectories. Sites are assessed on how well they are progressing towards achieving the completion criteria for each site domain.

These criteria are:

- A final landform compatible with the surrounding contours.
- An established, self-sustaining cover of native vegetation.
- Weed species at levels not likely to threaten native species.

Hanson reports on the rehabilitation success and areas (ha) rehabilitated each year to the DMIRS (Department of Mines, Industry Regulation and Safety) via Annual Environmental Reports.

3.0 Forecasting pilot study methodology

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3.0 Forecasting pilot study methodology

3.1 STUDY SCOPE AND STARTING ASSUMPTIONS

In delivering this NCA Forecasting pilot study, the following starting assumptions were adopted:

1) **Pilot Study Boundary**

As stated in previous sections, the forecasting study was limited to the area planned to be mined within the Gaskell North (M70/1366) tenement (Figure 2). The planned mine area (study boundary) is ~351 ha. The remaining ~174 ha of the Gaskell North tenement to the east is currently not part of Hanson's future extraction plans.

2) **Forecasting Time Scenarios**

Four future scenarios were explored in this forecasting study with 2023 being a starting point (Year 0). The future time points were set in 5-year increments, as follows:

- *Time Point 1:* 5 years from Year 0 (2028)
- *Time Point 2:* 10 years from Year 0 (2033)
- *Time Point 3:* 15 years from Year 0 (2038)
- *Time Point 4*: 20 years from Year 0 (2043).

3) **Scope of Assessment**

The forecasting study did not entail a complete NCA analysis; rather, a highly modified SEEA-EA approach was adopted.

The focus was identifying the anticipated change in certain ecosystem condition parameters and ecosystem extent only at different time points (as shown above); ecosystem services assessment was excluded.

Specifically, the emphasis was on determining likely future rehabilitation performance, with the condition assessment restricted to the key available vegetation and floristic parameters including:

A. Compositional state characteristics - describes composition and diversity of ecological communities at a given location and time:

- Native species richness
- Species similarity index
- Number of weed species
- Presence of Threatened communities (TECs)
- Number of Threatened species and Priority flora.

B. Structural state characteristics - includes attributes primarily focused on the vegetation and biomass of ecosystems:

- Vegetation cover (%)
- Weed cover (%)
- Plant density.

Important to note are the exclusions from full NCA ecosystem condition assessment, including fauna data, chemical, functional and landscape states.

These are commonly analysed as part of the ecosystem condition assessment under the SEEA-EA approach; however, could not be included in the condition assessment for this forecasting study due to lack of the required data.

3.2 DATASETS USED FOR FORECASTING

Source of Data

The historic rehabilitation data collected for the Tick Road site (Tenement M70/776 held by Boral) was used for predicting (forecasting) the likely future performance of the Gaskell North pilot site.

This was considered a suitable dataset given the following:

1) *Proximity of the two tenements* (Gaskell North and the Tick Road sites) (Figure 1, Figure 2).
2) *Similar local geology* – both tenements sit within the Bassendean Dune sands. Gaskell North is also characterised by areas of interspersed localised dark grey peaty clay.
3) *Location within a pine plantation* – as described in the original Hanson NCA report (Pantelic et al., 2023), and shown in Figure 2, Gaskell North is located within the Gnangara Pine Plantation and is characterised by a mix of pine plantation and native vegetation regrowth. Tick Road tenement has also been dominated by the pine plantation in the past. Progressive rehabilitation of post-mine pine areas within this tenement has been managed by Hanson over the last 20 years.
4) *Mining and rehabilitation approaches* – mining operation/extraction activities (depth of excavation, methods, etc.) on the Gaskell North site are likely to follow Hanson's standard operational approaches applied across all their domains. Furthermore, postmining rehabilitation methods (described in the previous section) are likely to be similar too; that is, progressive rehabilitation of areas after mining has ceased, with only limited follow-up revegetation activities such as hand broadcasting of seed and some planting to promote native vegetation cover.

Therefore, it was assumed that rehabilitation data collected from this area provides a reasonable indication of the possible rehabilitation success trajectory that could be expected in other post-pine/post-mine rehabilitation areas, such as Gaskell North.

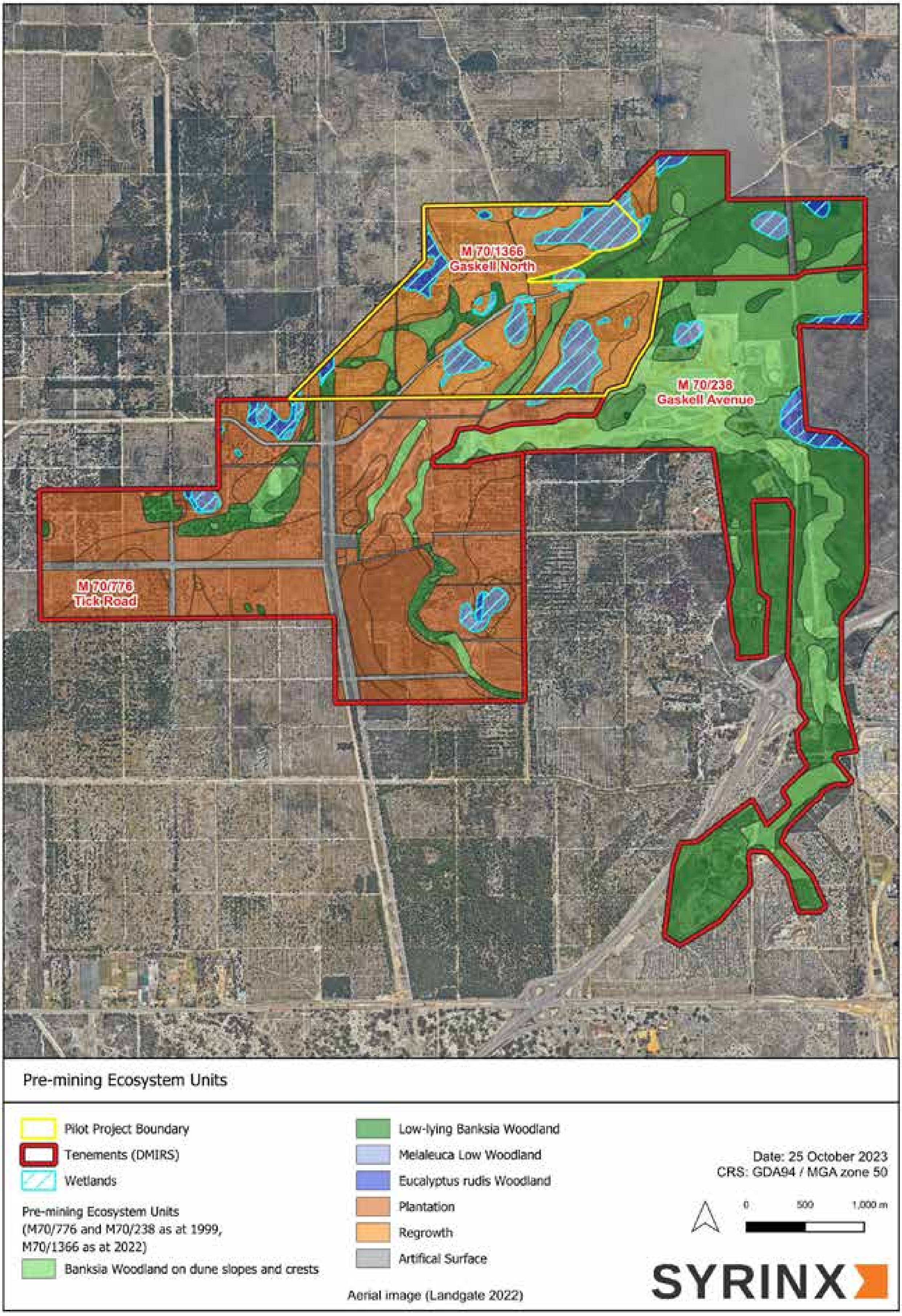

Figure 2. Forecasting pilot study boundary and existing ecosystem units

Ecosystem Units

The Gaskell North Forecasting pilot study is an extension of work undertaken for the initial Hanson NCA project (Pantelic et al., 2023). Therefore, ecosystem units originally defined for Hanson's site were adopted for this forecasting exercise.

These native ecosystem units were defined according to their geomorphic setting (*terrestrial* areas: dunes/slopes, interdunal swales, and *wetland* areas: damplands and sumplands at this site), and their ecosystem and vegetation communities. Five broad native ecological communities and six native vegetation communities were originally identified across the Gaskell Avenue and Gaskell North site (Table 1).

Swales, damplands, sumplands and their vegetation complexes are classed as groundwater dependent ecosystems, which means that they are in close proximity to groundwater and are dependent on this water source at this site (either fully or partly). Damplands and sumplands at this site are wetlands characterised by peaty clay soils and silty sands and are hydrologically defined as seasonally saturated (damplands) or seasonally inundated (sumplands).

For the forecasting study, the existing mapping of these ecosystem units (done in a geographic information system, GIS) was used as the starting point and was extended to include the Tick Road tenement (Figure 2).

Changes in Mine Footprint

Information on the likely progression of mining operations within the Gaskell North tenement for the agreed pilot study timeframe (20 years from 2023 to 2043) was sourced from Hanson. It was assumed that Hanson will undertake progressive rehabilitation of this tenement, with rehabilitation activities starting immediately after excavation and when extraction for any given area is completed.

The likely mine plan, and anticipated changes in the mine footprint and the rehabilitation extent, was done spatially using QGIS.

Rehabilitation and Reference Data

Rehabilitation data from the Tick Road tenements was used to forecast changes in the vegetation condition within the Gaskell North site at different time points post mining. For this, a seven-year set of rehabilitation data collected annually from 2016 to 2022 was used. In

Table 1. Ecosystem units within Hanson's Gaskell Sand Quarry site

UNITS OF ASSESSMENT	DUNES/SLOPES	INTERDUNAL SWALES		DAMPLANDS	
	Pale grey sands (S8 sand) on slopes and dunes >10m above water table	Pale grey sands (S8) <10m to seasonal low water table		Seasonally water saturated sands (S10, Mg) and peats (Cps) of wetlands (<3m to seasonal low water table)	
NVIS LEVEL 3 **Ecological Communities**	***Banksia woodland on dune slopes and crests.*** Banksia Woodlands of the Swan Coastal Plain (Threatened Ecological Community)	***Low-lying Banksia woodland.*** Banksia Woodlands of the Swan Coastal Plain (Threatened Ecological Community)		***Melaleuca Low Woodlands***	***Eucalyptus rudis Woodlands***
NVIS LEVEL 5/6 **Vegetation Communities**	Low Woodland of *Banksia attenuata* and *Banksia menziesii* (FCT23b)	Low Woodland of *Banksia menziesii*, *B. attenuata* and *Eucalyptus todtiana* over *Adenanthos cygnorum*, *Hibbertia hypericoides*, *Regelia* sp, *Eremaea* sp. (FCT21c)	Low Open Woodland of *Banksia attenuata*, *Banksia ilicifolia*, *Nuytsia floribunda*, *Philotheca spicata* (FCT22)	Low Open-Woodland of *Melaleuca preissiana* over *Kunzea ericifolia* and *Astartea fascicularis* shrubland	Low Open-Woodland of *Eucalyptus rudis* and *Melaleuca preissiana* over *Taxandria linearifolia* tall shrubland over low shrubland (FCTS17)

total, data from 66 rehabilitation sites was used, with some sites being monitored more than once (Figure 3). As is standard for Hanson's rehabilitation program, these monitoring sites were 20m x 20m plots with nested 1m x 1m and 5m x 5m quadrants.

For the forecasting assessment, vegetation cover data collected at a 20m x 20m scale was used, while for density, this involved data collected in 5m x 5m nested quadrats. In both instances, data for individual life forms (trees, shrubs, herbs) and weeds was extracted and used.

For density, this included counts of seedlings, saplings and mature plants. Additional elements of rehabilitation datasets were also extracted and used in the assessment, including species richness, and presence of TEC, priority and threatened species.

Rehabilitation data was compared with remnant vegetation data collected in 2019 from 14 reference sites located within Hanson-owned tenements (Figure 3). Note, data from these reference sites was only collected in 2016 and 2019. Given the rehabilitation data used for forecasting spanned from 2016 to 2022, reference data from 2019 was considered to be a reasonable mid-point for comparison.

SUMPLANDS	VARIABLE (PLANTATION)	
Seasonally inundated sands and peats (Cps)	Variable geomorphic units	
Closed-Sedgeland/ Rushland	**Plantation of Pinus pinaster**	**Regrowth**
Closed-Sedgeland dominated by *Baumea articulata* and *Juncus pallidus*.	Plantation of *Pinus pinaster*	

OTHER LAND	
Artificial Surfaces and Associated Areas	**Bare Areas (Clearing)**

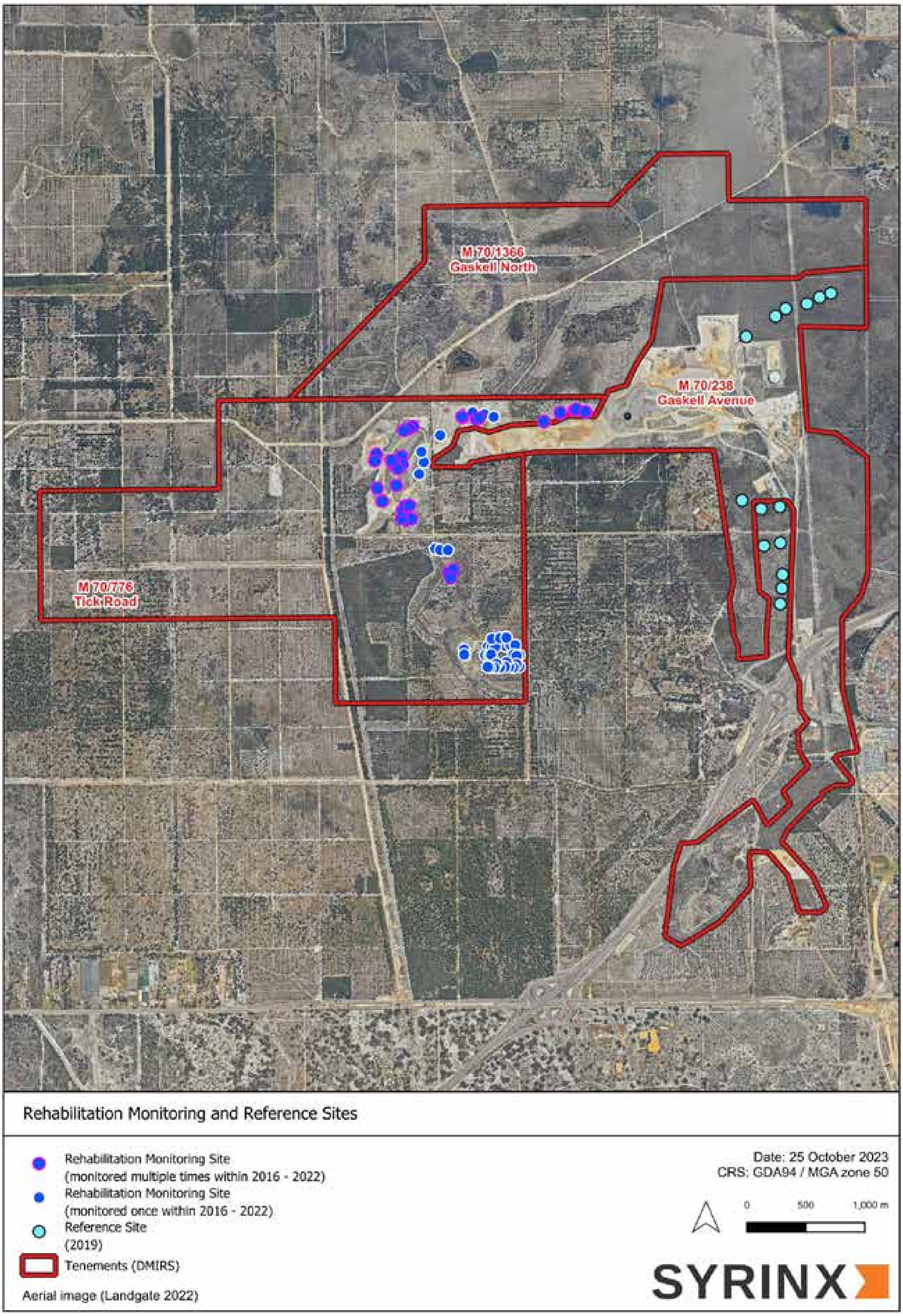

Figure 3. Reference and rehabilitation monitoring sites used in the forecasting study

3.3 APPROACH & METHODS

The overall forecasting approach is aligned with the method used in developing Hanson's NCA case study (Pantelic et al., 2023) and followed the sequence of analysis as outlined below:

1) Mapping planned temporal and spatial changes in mining and rehabilitation areas within the pilot study area (Gaskell North).
2) Assessing vegetation condition on rehabilitated areas within the Tick Road tenement using available rehabilitation and reference data and following a broad SEEA-EA approach.
3) Assessing the existing wetlands on site.
4) Applying condition values from the Tick Road area and wetland assessment to the corresponding future rehabilitation areas within the pilot site.
5) Mapping extent and condition changes across the set forecasting time periods.

Area Change Mapping

The first step in the forecasting approach was developing a timeframe of land use changes within the pilot study area in the Gaskell North tenement.

The section of the pilot site marked for future operations was divided into three areas, which are planned to be mined in succession.

The size of these areas and the anticipated mining timelines are given in Table 2 with additional visual illustrations included in Appendix 1.

Note, the planned mine area does not cover the entire pilot project area. Approximately 63 ha within the forecasting project boundary is mapped as wetlands (Table 3), and these areas are not planned to be mined given they do not hold a meaningful sand resource and are below the allowable mining depth to groundwater.

Within the planned mine area, rehabilitation is assumed to immediately follow cessation of mining activities on these individual areas.

The anticipated sequence of mining vs rehabilitation events and changes in operational vs rehabilitation areas for the adopted forecasting time points are summarised in Table 4.

Table 2. Mine plan for Gaskell North pilot study area

PLANNED MINE AREAS		SIZE (ha)	MINING PERIOD	
Area 1	1A	72.7	5 years	2023-2028
	1B	44.8		
Area 2	2A	47.9	5 years	2028-2033
	2B	39.3		
Area 3	3A	45.9	5 years	2033-2038
	3B	27.9		
TOTAL		278.5		

Table 3. Breakdown of planned mined vs non-mined areas within the forecasting study boundary

AREAS	SIZE (ha)	% OF TOTAL
Planned mine area	**278.5**	79%
Roads	**8.0**	2%
Wetlands	**64.6**	18%
TOTAL	**278.5**	

Table 4. Mining vs rehabilitation events and areas for different forecasting time points

TIME POINT	YEAR	ACTIVITIES	
Starting point (Baseline - Time 0)	2023	**All Areas**	no cleared / mined areas across the pilot site area no rehabilitated areas
Time Point 1 (5 years after Time 0)	2028	**Area 1**	cleared and mined in full 1A block - mining ceased and area is rehabilitated; average age of rehabilitation is 3 years 1B block - mining still occurring; no rehabilitation
		Areas 2 & 3	not mined; pre-mining vegetation present
Time Point 2 (10 years after Time 0)	2033	**Area 1**	1A block - fully rehabilitated; average age of rehabilitation is 8 years 1B block - fully rehabilitated; average age of rehabilitation is 3 years
		Area 2	cleared and mined in full 2A block - mining ceased and area is rehabilitated; average age of rehabilitation is 3 years 2B block - mining still occurring; no rehabilitation
		Areas 3	not mined; pre-mining vegetation present
Time Point 3 (15 years after Time 0)	2038	**Area 1**	1A block - fully rehabilitated; average age of rehabilitation is 13 years 1B block - fully rehabilitated; average age of rehabilitation is 8 years
		Area 2	2A block - fully rehabilitated; average age of rehabilitation is 8 years 1B block - fully rehabilitated; average age of rehabilitation is 3 years
		Areas 3	cleared and mined in full 3A block - mining ceased and area is rehabilitated; average age of rehabilitation is 3 years 3B block - mining still occurring; no rehabilitation
Time Point 4 (20 years after Time 0)	2043	**Area 1**	1A block - fully rehabilitated; average age of rehabilitation is 18 years 1B block - fully rehabilitated; average age of rehabilitation is 13 years
		Area 2	2A block - fully rehabilitated; average age of rehabilitation is 13 years 1B block - fully rehabilitated; average age of rehabilitation is 8 years
		Areas 3	3A block - fully rehabilitated; average age of rehabilitation is 8 years 3B block - fully rehabilitated; average age of rehabilitation is 3 years

Table 5. Rehabilitation age groups

AGE CATEGORY	REHAB AGE OF TICK ROAD MONITORING SITES USED IN THE ANALYSIS	NO. OF MONITORING SITES ANALYSED
3 years	1-4 years	55
8 years	5-9 years	33
13 years	10 -15 years	18

Vegetation Condition Assessment

As can be seen in Table 4, the average rehabilitation ages in planned mining areas falls into three main categories: 3 years, 8 years and 13 years post rehabilitation. To derive relevant values for these age groups, a mid-point approach was taken, with rehabilitation data from Tick Road tenement grouped and analysed as shown in Table 5.

The methodology taken in this forecasting pilot study for assessing vegetation condition follows the original approach taken by Syrinx in the previous NCA study developed for Hanson (Pantelic et al., 2023), and is in line with the SEEA-EA approach (UN, 2021).

In brief:

- Site-specific data for species richness, weed and native plant cover, and density for rehabilitated areas was used to develop condition variables. Monitoring data was checked for quality control, updated to reflect the currently correct nomenclature for species (checked against FloraBase), and then assigned to the appropriate age group.
- For all three key characteristics (native cover, density, richness), total native data and data for separate lifeform categories (tree, shrub and herb) were used in variable and index accounts. Note, median values were used throughout this assessment.
- For weed cover, % cover was recalculated to 100% and expressed as a rank using the following approach:

RANKING CRITERIA RANGE	
2 - 10%	**1**
10 - 30%	**2**
30 - 50%	**3**
50 - 70%	**4**
70 - 100%	**5**

- In terms of the threatened species, two species (*Schoenus griffinianus*, P4 and *Drosera paleacea,* P1) were recorded only in the 3-year age group, but not in other age groups or reference sites.
- Species similarity index was determined between the reference sites and the individual age groups (3, 8 and 13 years) using the Jaccard coefficient.
- Indicator values were calculated by comparing values for individual age groups with the relevant values for reference sites (e.g., % tree cover in 3-year group with % tree cover in reference sites).
- Index values for individual ecosystem variables were calculated by multiplying indictor values with the specific weight assigned.
    - » The two condition states used (structural and compositional) were given an equal weight of 1/2=0.5.
    - » Compositional state: The five key sub-variable groups (native richness, similarity index, weed richness, TEC, and protected species) were given an equal weight of 1/5. For richness, this was further divided to address lifeforms and total richness. For protected species, this was also further divided to reflect threatened and priority species.
    - » Structural state: The three key sub-variable groups (native cover, weed cover and native density) were given an equal weight of 1/3. For cover, this was further divided by total number of lifeforms and total cover.
- In line with the approach adopted in the Hanson NCA assessment as well as the other NCA studies (Pantelic et al., 2023; Meney et al, 2023), the stylised values (Low, Medium, High) related to the selected ranges (total index range 0-1) were used to derive the final aggregated condition values as shown below.

CONDITION/ QUALITY SCALE			
HIGH	0.75	-	1
MEDIUM	0.50	-	0.75
LOW	0	-	0.50

The SER's Recovery Wheel approach (International Standards for the Practice of Ecological Restoration, https://seraustralasia.com/wheel/) uses a 5-star scale describing a restoration site's similarity to a reference ecosystem, from very low to very high.

Comparing with this framework, the LOW condition derived in this forecasting assessment would correspond to a 1 to 2-star SER performance (very low to low), while the MEDIUM condition would correspond with 3 to 4 stars (medium to high).

SEEA		SER
LOW	0.02	**1** very low
0 - 0.5	0.2 - 0.4	**2** low
MEDIUM 0.5 - 0.75	0.4 - 0.6	**3** medium
HIGH	0.6 - 0.8	**4** high
0.75 - 1	0.8 - 1	**5** very high

Wetland Assessment

Five remnant wetlands and the southern portion of a further wetland are present within the pilot study area (Figure 4). Five of these wetlands are classed as damplands (seasonally saturated basin wetlands), and one as a sumpland (seasonally inundated basin) according to the State geomorphic mapping database (Hill et al, 1993).

All the wetlands belong to the Jandakot suite, which occur on Bassendean Dunes and were formed by groundwater at surface or near surface in depressions, and which are characterised by peat or peaty sands overlying quartz sands.

One is mapped as Conservation Category, while the others are classed as Multiple Use or Resource Enhancement (Table 6).

While wetland areas will be excluded from mining, since there is no material sand source, they form part of the natural capital assets for the site, and hence are meaningful to consider in terms of the natural capital value of the study area during and post mining.

Given no baseline data was available, a brief site visit was made in August 2023 to assess two of the dampland wetlands (8409, 8398), and these were used to infer the current and likely future condition of all wetlands within the study area.

Table 6. Wetlands within Gaskell North pilot study boundary

UFI	CLASSIFICATION	MANAGEMENT CATEGORY	UNDERLYING SOILS
8385	Dampland	Resource Enhancement	Cps - PEATY CLAY
8386	Dampland	Resource Enhancement	Cps - PEATY CLAY
8241	Dampland	Resource Enhancement	Cps - PEATY CLAY
8398	Dampland	Multiple Use	Cps - PEATY CLAY
8409	Dampland	Multiple Use	Cps - PEATY CLAY
8408	Sumpland	Conservation	Cps - PEATY CLAY

For this site assessment, the following tasks were undertaken:

1) Traverses from perimeter to wetland centre or near centre.
2) List of ecological communities, dominant species (native and weeds) and qualitative condition assessment.
3) Soil stratigraphy to 1m (dug by spade), predominantly to measure depth of peat and extent of wetness.

The location of the assessed wetlands, and areas traversed within these wetlands, is shown in Figure 5. In all cases, while wetlands within the Gaskell North site were incorporated into the pine plantation, in the main the original vegetation was not cleared, and most of the pines are regrowth, except on the wetland margins.

Importantly a more significant and extensive assessment covering all wetlands would be needed to validate these extrapolations.

In addition to the site work, a previous qualitative site assessment undertaken by PGV Environmental (April 2023) was referenced, however, again this only considered the same two of the five wetlands present within the site since the assumption was made that the other wetlands would be fully excluded from mining impacts.

For forecasting purposes, all wetlands are included due to their extent and natural capital values. The evaluation was assisted by comparing these wetlands with data and information from the published literature.

In determining future scenarios for forecasting purposes, the following assumptions were made regarding mining impacts on wetlands:

1) No changes to the hydrology of the wetlands – it is assumed any dewatering will be compensated by active recharge to maintain peat saturation.
2) Pines can be removed from the wetlands with minimal disturbance to existing soils and vegetation.
3) Perimeter weedy/cleared areas can be restored to a high standard.

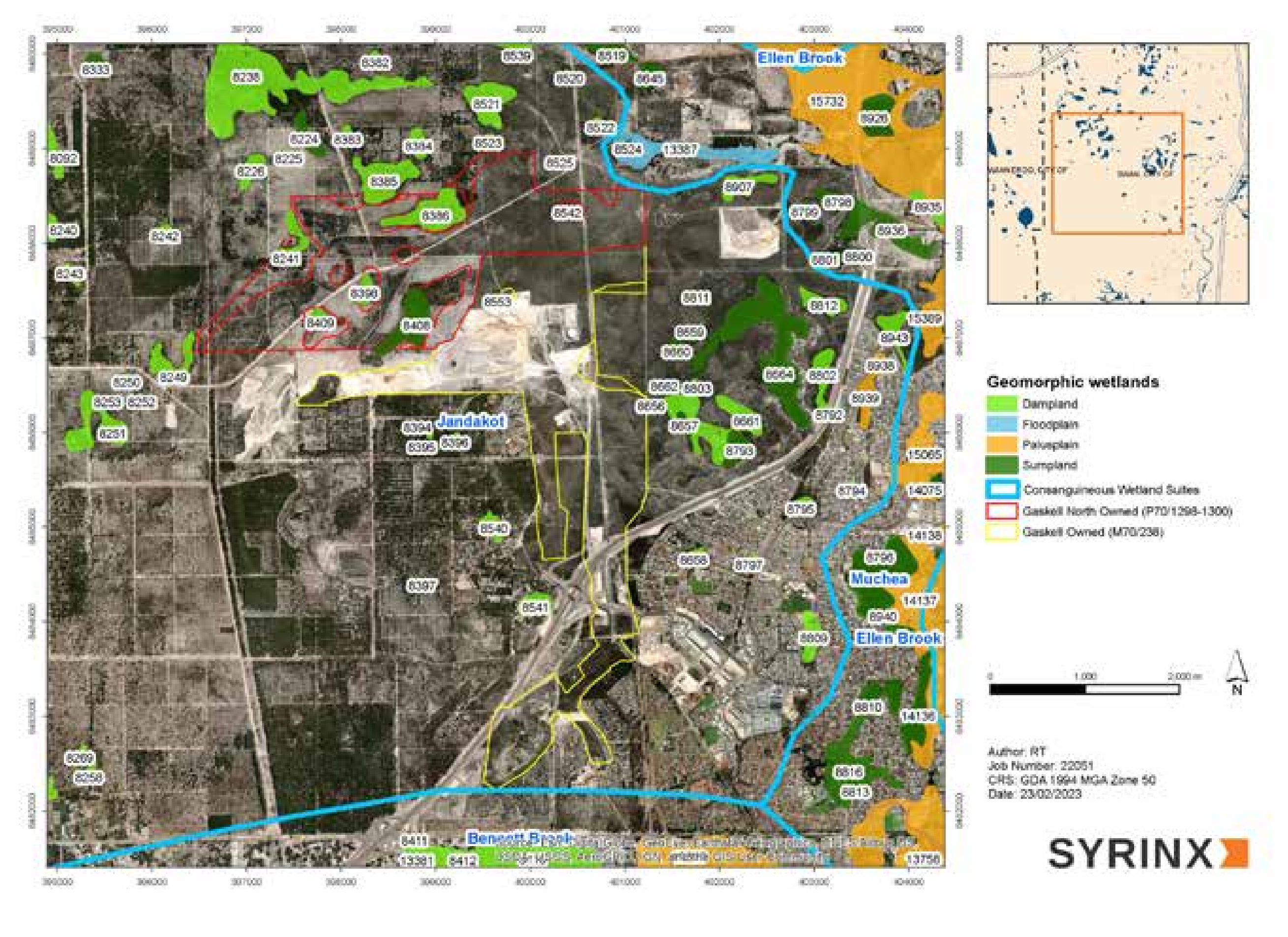

Figure 4. Wetland location and types within Gaskell North and the surrounding region

Integration of Extent/Condition Accounts on Pilot Area

The last step in the forecasting process was development of integrated extent/condition accounts for the four set forecasting time periods. This involved the following steps and assumptions:

- Allocation of appropriate qualitative condition values (LOW, MEDIUM or HIGH) for different ecosystem types present within the study boundary (remnant vegetation, rehabilitated areas, plantation areas and wetlands) and for different time periods. For rehabilitation areas, condition values were derived from results of Tick Road data analysis. For plantation and remnant areas for which there was no site-specific data, information from published studies and other available literature was used. For wetlands, findings from the field assessment were used to develop appropriate condition values.
- Mapping, comparison and analysis of extent changes for different condition categories within the Gaskell North pilot study using time and area sequence, as detailed in Table 5.

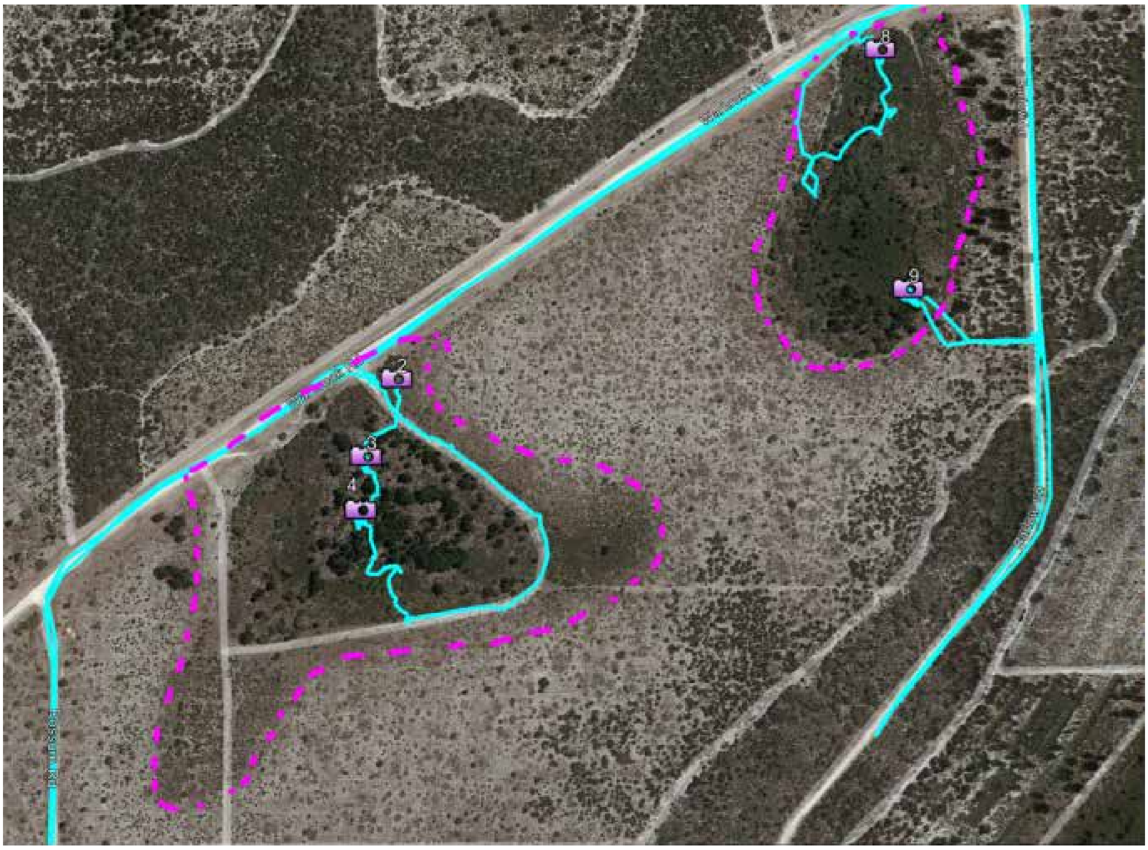

Figure 5. Wetlands assessed on site, blue lines indicate traverses

4.0 Forecasting pilot study findings and outcomes

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4.0 Forecasting pilot study findings and outcomes

4.1 FORECASTING EXTENT ACCOUNTS

The ecosystem extent accounting is intrinsically linked with the land use accounts, as ecosystems are the key adopted analytical unit in the SEEA-EA NCA approach that was adopted in this forecasting project.

Changes in the extent of the key ecosystem units (Table 1) across the defined time period are presented in Figure 6 and Table 7.

At present (Year 0), the pilot project area is characterised by pine plantation and dominant native regrowth. Areas of remnant vegetation and wetlands, while not dominant, are also present within the project boundary. As this tenement is not currently mined, artificial surfaces are limited to roads only (~8 ha) (Table 7).

During the forecasting period, it is anticipated that changes in the extent will be primarily driven by two parallel activities: clearing as part of mining operations and restoration of post-mined areas. It is also assumed that all areas will be mined on average for three years, at which time post-mined areas will immediately transition to the rehabilitation phase.

In developing the forecasting extent account, it was assumed that cleared remnant areas of Banksia woodland on dune slopes and crests and Low-lying Banksia woodland, would return to the same ecological communities post rehabilitation.

This would have to be reassessed in the future, when actual groundwater and topographic contours are known (post mining and post rehab), and should be done so it aligns with the methodology developed for the original mapping of ecological communities within Hanson's tenements (Pantelic et al., 2023). Rehabilitated plantation areas were included in a new general Banksia community unit – Rehabilitated Banksia Woodland unit (Table 7), utilising the methodology outlined in Banksia Woodlands: A Restoration Guide for the Swan Coastal Plain.

Given restoration is expected to be progressive, the mining/artificial surfaces will never exceed 15% of the total area. Note, this assumes restoring 15-20 ha each year. Planned mining activities are expected to result in the clearing of 36.7 ha of remnant vegetation by the end of Time Point 4 (2042), and 242 ha of plantation.

This will be balanced by progressive rehabilitation works that are expected to result in the rehabilitation of ~279 ha within by 2043 (Table 7, Figure 6). Accordingly, while areas of remnant vegetation will be reduced during the forecasting period, the total area of native vegetation will progressively increase, and by 2043 is forecast to be 70% greater compared to the starting time point.

Table 7. Forecasted changes in the extent of the key ecosystem units within the pilot site

		AREA (ha)				
		Starting Point 2023	Time Point 1 2023/28	Time Point 2 2028/33	Time Point 3 2033/38	Time Point 4 2038/2043
DUNES/SLOPES	Banksia woodland on dune slopes and crests	21.9	18.0	16.7	21.9	21.9
INTERDUNAL SWALES	Low-lying Banksia woodland	14.8	14.8	9.0	14.8	14.8
REHABILITATION	Rehabilitated Banksia woodland	0.0	65.7	139.6	214.0	241.8
DAMPLANDS	Melaleuca Low Woodlands	53.5	53.5	53.5	53.5	53.5
	Eucalyptus rudis Woodlands	11.1	11.1	11.1	11.1	11.1
PLANTATION	Plantation & regrowth	241.8	135.3	73.8	0.0	0.0
OTHER LAND	Bare areas/artificial surfaces	8.0	52.8	47.4	35.9	8.0
TOTAL AREA		351	351	351	351	351
TOTAL NATIVE ECOSYSTEMS		101	163	230	315	343
TOTAL PLANTATION		242	135	74	0	0
TOTAL ARTIFICIAL SURFACES		8	53	47	36	8
TOTAL REMNANT VEGETATION		101	90	65	65	65
TOTAL REHABILITATION		0	73	165	251	279

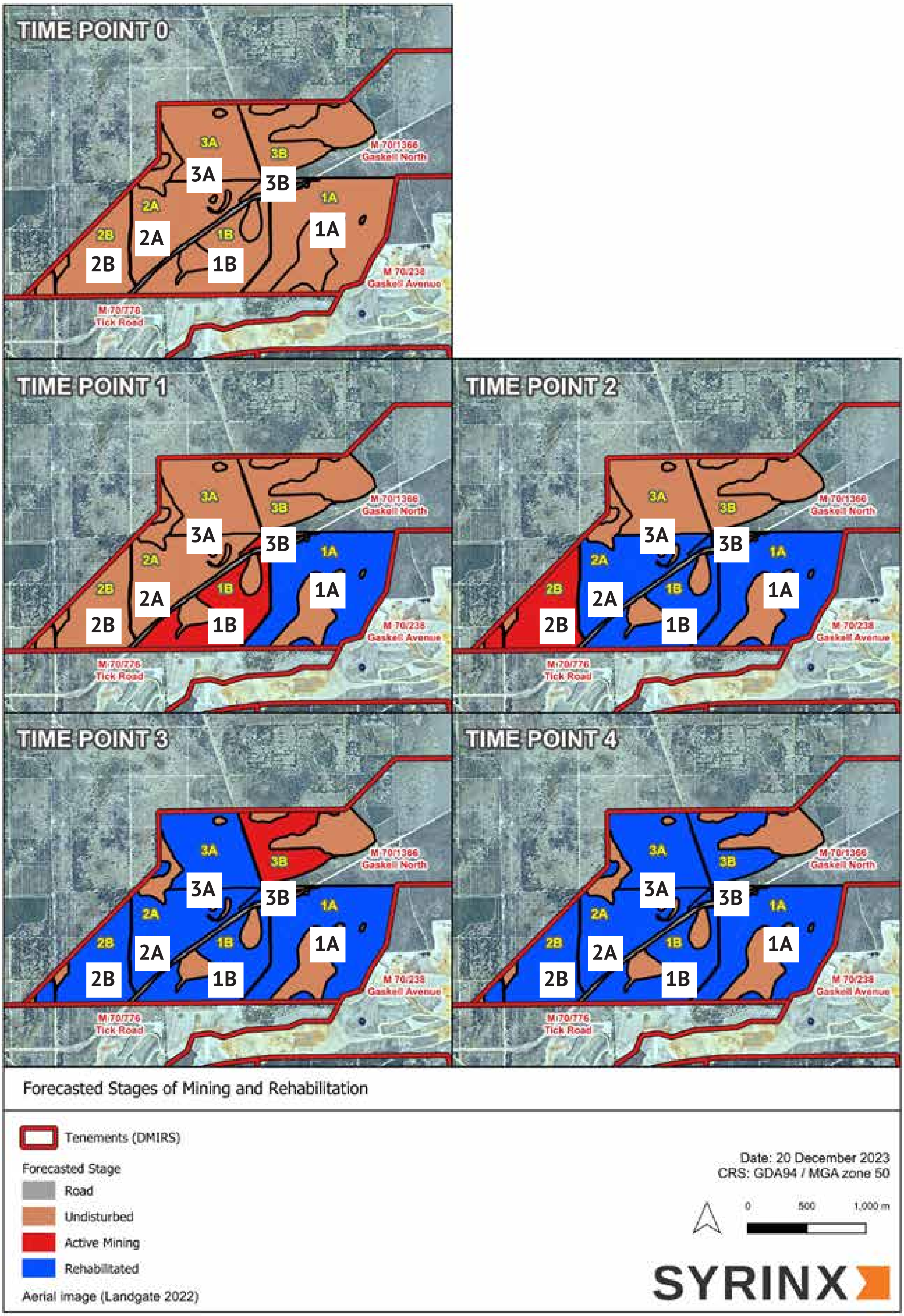

Figure 6. Extent changes at different time points

4.2 FORECASTING CONDITION ACCOUNTS

4.2.1 REHABILITATED AREAS

Condition assessment of post-pine and post-mine rehabilitated areas within the Hanson-operated Tick Road mining tenement was undertaken for the set time periods following the methodology described in Section 3.0. For all three set age groups (3, 8 and 13 years post rehabilitation), the condition was found to be MEDIUM (Table 8).

In terms of structural characteristics, while native cover was high and on par with reference sites, the overall index value was medium primarily due to the lower overall native plant density and weeds (higher weed density and % weed cover). For compositional state characteristics, medium values were influenced by the high number of weed species reported at rehabilitated sites (richness) (Table 9).

It should be noted that rehabilitation sites performed equally well as reference sites in terms of the presence of TEC, and scored above reference sites in this assessment due to the presence of priority flora species (recorded only within rehabilitation sites). This may reflect differences in survey methods and levels of accuracy in different years.

On the other hand, tree cover and tree density were found to be low at all time points and significantly lower compared to reference sites, indicating that rehabilitation sites are still on the trajectory of reaching the required level of naturalness.

No major differences were observed between rehabilitation areas of different ages for either compositional or structural characteristics. While % cover for all life forms showed a progressive increase with rehabilitation age, hence contributing positively to the structural state index value, native plant density showed a somewhat reducing trend with age (older rehabilitation sites have lower density compared with early rehab) (Table 9).

Further contributing to the performance of the young sites for the compositional state is the fact that 2 priority species were recorded in this age group.

Hypothetical Assessment of Topsoil Application on Condition Performance

Rehabilitation of post-mine areas within the Tick Road tenement typically includes application of topsoil to a depth of 5 to 10 cm (as described in Section 2.0). Rehabilitation results from these areas were used for the main forecasting exercise; that is, it is assumed that rehabilitation across the pilot study area will also include topsoil application.

As requested by Hanson (Vern Newton, pers. comm), a comparative condition assessment was also undertaken for a hypothetical situation where topsoil is not applied on rehabilitated areas within the pilot study area. The objective of the 'no topsoil' hypothetical assessment was to test a scenario where topsoil is not readily available and hence is not used in rehabilitation.

Table 8. Condition index values for rehabilitated sites at Tick Road (with topsoil)

	REHABILITATED SITES (index value)		
INDEX VALUES	YEAR 3 post rehab	YEAR 8 post rehab	YEAR 13 post rehab
COMPOSITIONAL STATE	0.36	0.37	0.30
STRUCTURAL STATE	0.25	0.23	0.30
OVERALL	0.61	0.60	0.60

CONDITION/ QUALITY SCALE			
HIGH	0.75	-	1
MEDIUM	0.50	-	0.75
LOW	0	-	0.50

Table 9. Performance of Tick Road rehabilitated areas of different ages for vegetation cover, density and richness

% COVER	Years post rehabilitation			
	YEAR 3	YEAR 8	YEAR 13	REFERENCE SITE
Herb cover (%)	1.5%	1.3%	1.5%	1.2%
Shrub cover (%)	4.0%	12.6%	20.1%	22.5%
Tree cover (%)	0.01%	0.01%	0.05%	0.12%
Total native cover (%)	6.5%	14.5%	23.5%	23.8%
Weed cover (%)	20%	14%	10%	0%
DENSITY (no of plants/m2)	Years post rehabilitation			
	YEAR 3	YEAR 8	YEAR 13	REFERENCE SITE
Herb	0.08	0.04	0.06	0.54
Shrub	1.48	0.28	0.78	1.84
Tree	0.00	0.00	0.00	0.12
Total native	1.24	0.28	0.82	2.50
Weed	0.00	0.40	0.40	0.00%
RICHNESS (no of species)	Years post rehabilitation			
	YEAR 3	YEAR 8	YEAR 13	REFERENCE SITE
Herb	81	70	49	50
Shrub	65	54	43	50
Tree	4	4	3	4
Total native	150	128	95	104
Weed	47	42	41	12

The aim was to highlight the value that topsoil plays in the rehabilitation process, as shown in previous site studies in nearby sites (Brown, 2022).

To undertake this assessment, and as suggested by Hanson, a broad level assumption was adopted whereby the overall condition performance of Tick Road rehabilitation sites was reduced by 25% (note, the Brown 2022 study showed a ~30% reduction in species richness, and 25% for diversity).

For the illustrative purpose of this study, an overall 25% reduction across structural and compositional condition states was applied (see comparison with Table 8).

Results of this hypothetical assessment show that without topsoil, the overall vegetation condition of rehabilitated areas (as assessed in this particular study) would likely be reduced from medium to LOW across all three analysed age groups (Table 10). Importantly though, this outcome is still better than the regrowth pine plantation which currently exists.

Table 10. Condition index values assuming no topsoil

INDEX VALUES	CONDITION INDEX OF REHABILITATED (index value) NO TOPSOIL SCENARIO		
	YEAR 3 post rehab	YEAR 8 post rehab	YEAR 13 post rehab
COMPOSITIONAL STATE	0.27	0.28	0.22
STRUCTURAL STATE	0.19	0.17	0.22
OVERALL	0.46	0.45	0.44

CONDITION/ QUALITY SCALE			
HIGH	0.75	-	1
MEDIUM	0.50	-	0.75
LOW	0	-	0.50

4.2.2 REMNANT VEGETATION AND PLANTATION AREAS

The condition of the pine plantation and pine regrowth areas within the pilot area were assigned a LOW ecosystem condition quality, based on visual interrogation of aerial photography and data extracted from a regional linkage study (Brown et al, 2009), given no site-specific data was available. This is in line with assumptions and approach taken in Hanson's NCA study (Pantelic et al., 2023).

The native vegetation areas were assigned a HIGH ecosystem condition value. This was based on the assumption that these remnants were relatively undisturbed in the absence of any data; this is in line with the approach taken for Hanson's NCA study.

4.2.3 WETLAND AREAS

Based on the findings from the field study undertaken in August 2023, the following observations were made:

- Both wetlands, while mapped currently as damplands, would historically have been sumplands. Surface soils were still saturated at the time of survey in spring, and lack of seedlings within the core of the wetland indicate inundation still occurs in the deepest parts of each of the basins. This indicates the drying cycle associated with the pine plantation and drying climate has not impacted on the peats and vegetation integrity or species composition significantly.
- The dominant vegetation association is Low Open-Woodland of *Melaleuca preissiana* over K*unzea ericifolia* and *Astartea scoparia* shrubland; however, there are pockets of *Melaleuca rhaphiophylla* (indicative of sumplands). Condition was very good to excellent in ~75% of each wetland area. Pines and perimeter weeds are the dominant disturbance factors.
- Vegetation condition was generally only degraded (poor) around the margins of both wetlands, and progressively improved further into the wetland core (very good to excellent condition). Very large paperbarks (*Melaleuca preissiana*) dominated both wetlands, over dense and extensive wetland shrubland. Pines penetrated well into the first wetland (8409), however largely were absent from the core because conditions were generally saturated at surface. Pines were much more peripheral in the second wetland (8398). Species indicative of persistent and stable wetland conditions included *Regelia ciliata*, P*ultenaea reticulata*, *Hypocalymma angustifolium*, *Eutaxia virgata*. Images from each wetland are attached in Appendix 2.
- Soils are dominated by saturated peats and peaty sands.
- Both wetlands had intact fibrous peats and peaty sands to around 0.6 m deep; these may be deeper in other locations. These depths are deeper than recorded in most other wetlands within the Jandakot suite. The persistence of the peats within the former pine plantation is significant and indicates these wetlands have not been irreversibly impacted by the altered hydrology and hydrochemistry associated with the pine plantation. Further, these peat wetlands are considered of high conservation value since they provide habitat for a range of aquatic invertebrates that appear to be uncommon or absent in other types of wetlands on the Swan Coastal Plain (Pinder, 2005).

In determining the likely trajectory of condition of these wetlands, the following observations/evidence lines were applied:

1) Presence and condition of remnant vegetation – this was found to vary from low on the outer perimeter of the wetlands impacted by pines and roads, and medium to high through the wetlands, impacted predominantly by pine regrowth.
2) Presence of recruitment of native species from a range of strata and species – seedling recruitment of most keystone taxa (*Melaleuca*, *Astartea*, *Hypocalymma*, *Regelia*) was high in both wetlands and evidenced variable aged plants from seedlings to juveniles. This indicates excellent recovery potential.
3) Presence and condition of peats, peaty sands (as a proxy for hydrological stability) – peats and peaty sands indicated a stable wetting cycle and the absence of permanent drying impacts (note, this assumes no dewater impacts from mining).
4) Relative ease of restoration activities – these wetlands met this criterion since the key actions would involve pine removal, weed control, and minor assisted revegetation efforts.
5) Conservation significance of these wetlands in their Swan Coastal Plain context – although wetlands within the Jandakot suite are not considered rare, wetlands in this suite retaining peats and indicating resilience to groundwater level impacts from climate change are considered of high conservation value and would readily be viewed as capable of being upgraded to Conservation Category wetlands (Vic Semeniuk pers. comm 2023, Semeniuk & Semeniuk 2005).

The above approach resulted in a nominal ecosystem condition assessment of MODERATE for the wetlands currently, and HIGH immediately after remedial works have been undertaken (i.e., the removal of pines and other minor weeds are seen as sufficient to trigger removal of the disturbance threat and enable reclassification of the wetlands). It is assumed that these works will be done within the first forecasting time period, resulting in wetlands condition change (improvement) from MEDIUM to HIGH from Y0 to Y5.

In reality, there is a high probability that these wetlands could be reassigned to Conservation Category wetlands, and this would bring significant value gains to the Gaskell North site, given the area of these wetlands is reasonably significant (~65 ha or 18% of the total study area). Although not undertaken in this forecasting study, the value of stored carbon and the sequestered carbon value, along with the obvious biodiversity values of these wetlands, could form a substantial part of Hansons nature-positive story moving forward.

4.3 EXTENT AND CONDITION INTEGRATED ACCOUNTS

Table 12 summarises the outputs of this assessment, and the integration of the assessment results with the extent accounts, with final ecosystem condition maps shown spatially in Figure 7.

As can be seen in the summary table and graphs, there is a progressive improvement in the overall condition of the pilot site area with time; that is, the Gaskell North area is expected to be characterised by a larger overall area with improved condition at all the future forecasting time points when compared to the starting point (Y0). This is primarily due to the following:

- **Progressive rehabilitation of post-mined areas** – if, as assumed in this study, rehabilitation works start immediately after cessation of excavation, then the overall mine-impacted areas would never be above ~50 ha or 15% of the total pilot study area. This means that bare areas would always be significantly lower compared to vegetated (remnant and rehabilitated) areas throughout the forecasting period (Table 11).
- **Given the planned mining areas** are reduced with time (Area 1 greatest, Area 3 smallest, Table 2), the % bare (artificial) areas is the highest in the first 5 years of planned excavation works, after which it progressively declines in time (Table 11). By Time Point 4 (20 years after starting year), mining is expected to be finished within the pilot study site (note, all artificial surfaces by that stage will be associated with roads), and all post-mine areas fully rehabilitated with a minimum 3 years in rehabilitation age.
- **Rehabilitation of pine plantation areas** – the pilot study is dominated by pine plantation and regrowth areas that have LOW overall condition. Hence, restoration of these areas after mining will result in an improved overall condition, given data from the Tick Road restoration site indicates that MEDIUM condition can be achieved even at sites that are 3 years of post-rehab age. Again, as % restoration areas increase with time (Table 11), so does the overall performance of the pilot study area.
- **Progressive improvement in wetlands condition and status** – implementation of early remedial works on the existing wetland areas (removal of pines, weed management) is expected to result in the improvement in condition of ~65 ha of wetlands within the first 5 years (from MEDIUM to HIGH) (Table 12). As previously mentioned, wetlands present within the project study area provide a range of significant ecosystem services including carbon storage and sequestration, water storage, and services associated with their high biodiversity value. Therefore, their protection/conservation together with the condition enhancement has a major potential to increase the overall natural capital value of the Hanson site and facilitate their nature-positive efforts.
- **Topsoil plays a significant role in achieving positive future impacts** – under scenarios where topsoil is unavailable to be applied on future rehabilitation areas and using a broad reduction factor of 25% in the condition assessment (as explained in Section 4.2), the overall performance for all forecasted time points was found to be likely markedly reduced, though better than regrowth pine plantation. As can be seen in Table 13 and Figure 8, under this hypothetical case, mining will result in clearing of high condition remnant areas. Post mining, progressive rehabilitation will result in the overall increase of native vegetation on site; however, the majority of vegetation in rehabilitated areas will be of low condition, with wetlands being the only areas of high condition.

Table 11. Forecast changes in mined and rehabilitated areas within the pilot study site

	Starting Point	Time Point 1	Time Point 2	Time Point 3	Time Point 4
% artificial areas	2%	15%	13%	10%	2%
% rehabiliated areas	0%	21%	47%	71%	79%
% native areas	29%	46%	87%	90%	98%

Table 12. Hanson forecasting pilot study – integrated condition and extent account (with topsoil)

LAND CLASSIFICATION						
	FAO *Level 3*	**IUCN** *Level 1: Realm*	*Level 2: Biome*	**ALUM V8** *Primary Land Use Class*	**GEOMORPHIC HIC UNITS**	**Ecological Communities**
NATURAL	A12. Natural and Semi-Natural Vegetation	**TERRESTRIAL**	T2 Temperate-Boreal Forests and Woodlands	*1. Conservation and Natural environments*	DUNES/SLOPES	***Banksia woodland on dune slopes and crests***
					INTERDUNAL SWALES	***Low-lying Banksia woodland***
					REHABILITATION	***Rehabilitated Banksia woodland***
	A24. Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation	**FRESHWATER/ TERRESTRIAL**	TF1 Palustrine Wetlands	*6. Water*	DAMPLANDS	***Melaleuca Low Woodlands***
						Eucalyptus rudis Woodlands
MODIFIED / SEMI-NATURAL	A12. Natural & Semi-Natural Vegetation	**TERRESTRIAL** T7 Intensive land use systems	T7 Intensive land use systems	*3. Production from Dryland Agriculture & Plantations*	PLANTATION	***Plantation of Pinus pinaster / Regrowth***
ARTIFICIAL	B15. Artificial Surfaces and Associated Areas	**TERRESTRIAL**		*5. Intensive Uses*	Artificial Surfaces and Associated Areas (Mine)	

HIGH
MEDIUM
LOW

HANSON FORECASTING PILOT STUDY ECOSYSTEM EXTENT & CONDITION									
Starting Point 2023		Time Point 1 2023/28		Time Point 2 2028/33		Time Point 3 2033/38		Time Point 4 2039/43	
Extent (ha)	**Condition**	**Extent (ha)**	**Condition**	**Extent (ha)**	**Condition**	**Extent (ha)**	**Condition**	**Extent (ha)**	**Condition**
21.9	HIGH	11.5	HIGH	-	HIGH	-	HIGH	-	HIGH
-	MEDIUM	6.6	MEDIUM	16.7	MEDIUM	21.9	MEDIUM	21.9	MEDIUM
-	LOW	-	LOW	-	LOW	-	LOW	-	LOW
14.8	HIGH	14.3	HIGH	-	HIGH	-	HIGH	-	HIGH
-	MEDIUM	0.5	MEDIUM	9.0	MEDIUM	14.8	MEDIUM	14.8	MEDIUM
-	LOW	-	LOW	-	LOW	-	LOW	-	LOW
-	HIGH	-	HIGH	-	HIGH	-	HIGH	-	HIGH
-	MEDIUM	65.7	MEDIUM	139.6	MEDIUM	214.0	MEDIUM	241.8	MEDIUM
-	LOW	-	LOW	-	LOW	-	LOW	-	LOW
-	HIGH	53.5	HIGH	53.5	HIGH	53.5	HIGH	53.5	HIGH
53.5	MEDIUM	-	MEDIUM	-	MEDIUM	-	MEDIUM	-	MEDIUM
-	LOW	-	LOW	-	LOW	-	LOW	-	LOW
-	HIGH	11.1	HIGH	11.1	HIGH	11.1	HIGH	11.1	HIGH
11.1	MEDIUM	-	MEDIUM	-	MEDIUM	-	MEDIUM	-	MEDIUM
-	LOW	-	LOW	-	LOW	-	LOW	-	LOW
241.8	LOW	135.3	LOW	73.8	LOW	0.0	LOW	0.0	LOW
8.03	-	52.78	-	47.35	-	35.90	-	8.03	-

36.7	90.4	64.6	64.6	64.6
64.6	72.7	165.4	250.7	278.5
241.8	135.3	73.8	0.0	0.0

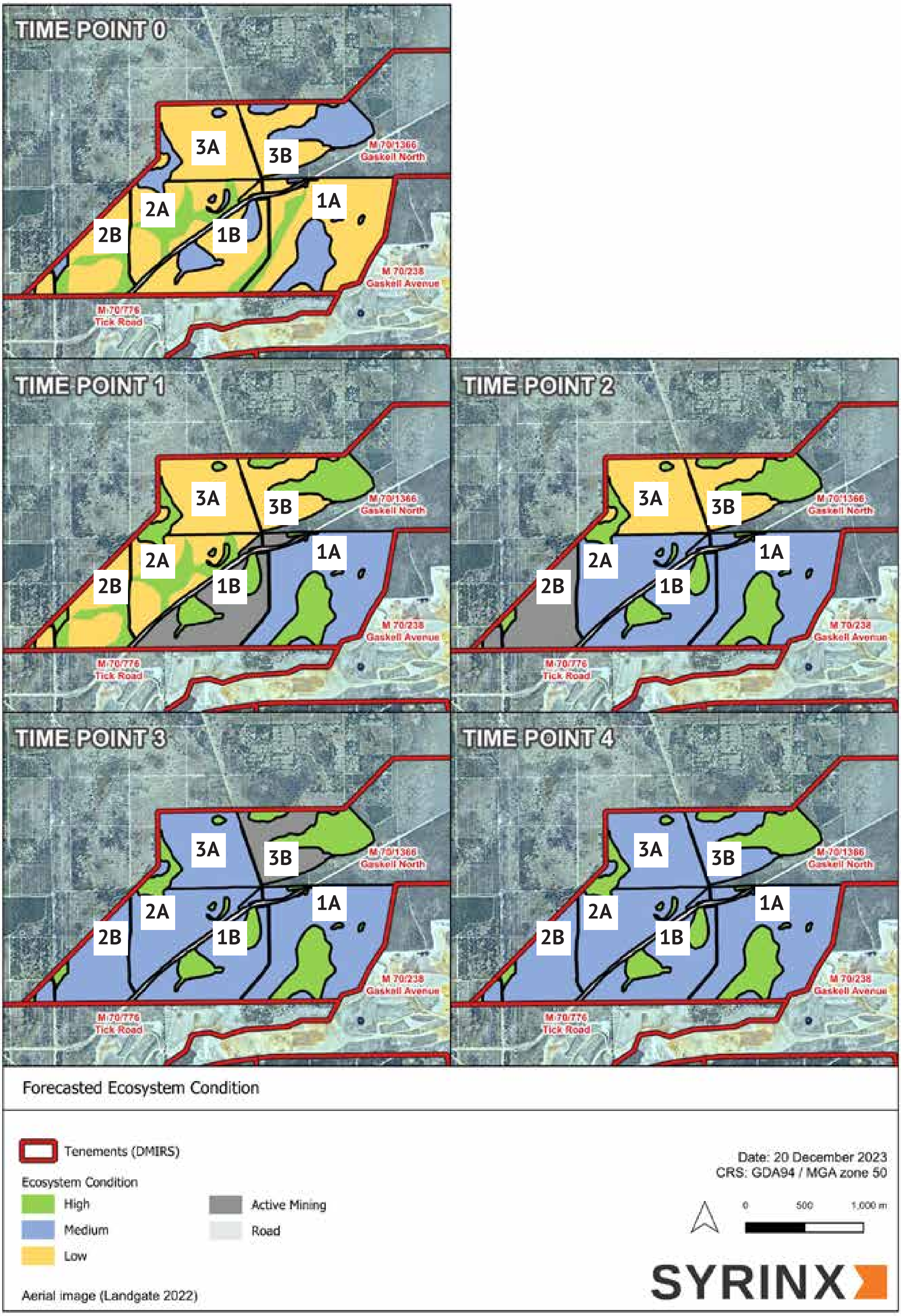

Figure 7. Hanson forecasting pilot project – changes in ecosystem condition account (with topsoil)

Table 13. Integrated condition and extent account – No Topsoil Scenario

LAND CLASSIFICATION						
	FAO *Level 3*	**IUCN** *Level 1: Realm*	*Level 2: Biome*	**ALUM V8** *Primary Land Use Class*	**GEOMORPHIC UNITS**	**Ecological Communities**
NATURAL	A12. Natural and Semi-Natural Vegetation	**TERRESTRIAL**	T2 Temperate-Boreal Forests and Woodlands	*1. Conservation and Natural environments*	DUNES/SLOPES	***Banksia woodland on dune slopes and crests***
					INTERDUNAL SWALES	***Low-lying Banksia woodland***
					REHABILITATION	***Rehabilitated Banksia woodland***
	A24. Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation	**FRESHWATER/ TERRESTRIAL**	TF1 Palustrine Wetlands	*6. Water*	DAMPLANDS	***Melaleuca Low Woodlands***
						Eucalyptus rudis Woodlands
MODIFIED / SEMI-NATURAL	A12. Natural & Semi-Natural Vegetation	**TERRESTRIAL** T7 Intensive land use systems	T7 Intensive land use systems	*3. Production from Dryland Agriculture & Plantations*	PLANTATION	***Plantation of Pinus pinaster / Regrowth***
ARTIFICIAL	B15. Artificial Surfaces and Associated Areas	**TERRESTRIAL**		*5. Intensive Uses*	Artificial Surfaces and Associated Areas (Mine)	

HIGH
MEDIUM
LOW

HANSON FORECASTING PILOT STUDY ECOSYSTEM EXTENT & CONDITION									
Starting Point 2023		Time Point 1 2023/28		Time Point 2 2028/33		Time Point 3 2033/38		Time Point 4 2039/43	
Extent (ha)	Condition	Extent (ha)	Condition	Extent (ha)	Condition	Extent (ha)	Condition	Extent (ha)	Condition
21.86	HIGH	11.45	HIGH	-	HIGH	-	HIGH	-	HIGH
-	MEDIUM	-	MEDIUM	-	MEDIUM	-	MEDIUM	-	MEDIUM
-	LOW	6.55	LOW	16.74	LOW	21.86	LOW	21.86	LOW
14.84	HIGH	14.34	HIGH	-	HIGH	-	HIGH	-	HIGH
-	MEDIUM	-	MEDIUM	-	MEDIUM	-	MEDIUM	-	MEDIUM
-	LOW	0.50	LOW	9.04	LOW	14.84	LOW	14.84	LOW
-	HIGH	-	HIGH	-	HIGH	-	HIGH	-	HIGH
-	MEDIUM	-	MEDIUM	-	MEDIUM	-	MEDIUM	-	MEDIUM
-	LOW	65.67	LOW	139.64	LOW	213.96	LOW	241.83	LOW
-	HIGH	53.46	HIGH	53.46	HIGH	53.46	HIGH	53.46	HIGH
53.46	MEDIUM	-	MEDIUM	-	MEDIUM	-	MEDIUM	-	MEDIUM
-	LOW	-	LOW	-	LOW	-	LOW	-	LOW
-	HIGH	11.10	HIGH	11.10	HIGH	11.10	HIGH	11.10	HIGH
11.10	MEDIUM	-	MEDIUM	-	MEDIUM	-	MEDIUM	-	MEDIUM
-	LOW	-	LOW	-	LOW	-	LOW	-	LOW
241.8	LOW	135.3	LOW	73.8	LOW	0.0	LOW	0.0	LOW
8.03	-	52.78	-	47.35	-	35.90	-	8.03	-

36.7	90.4	64.6	64.6	64.6
64.6	0.0	0.00	0.0	0.0
241.8	208.0	239.2	250.7	278.5

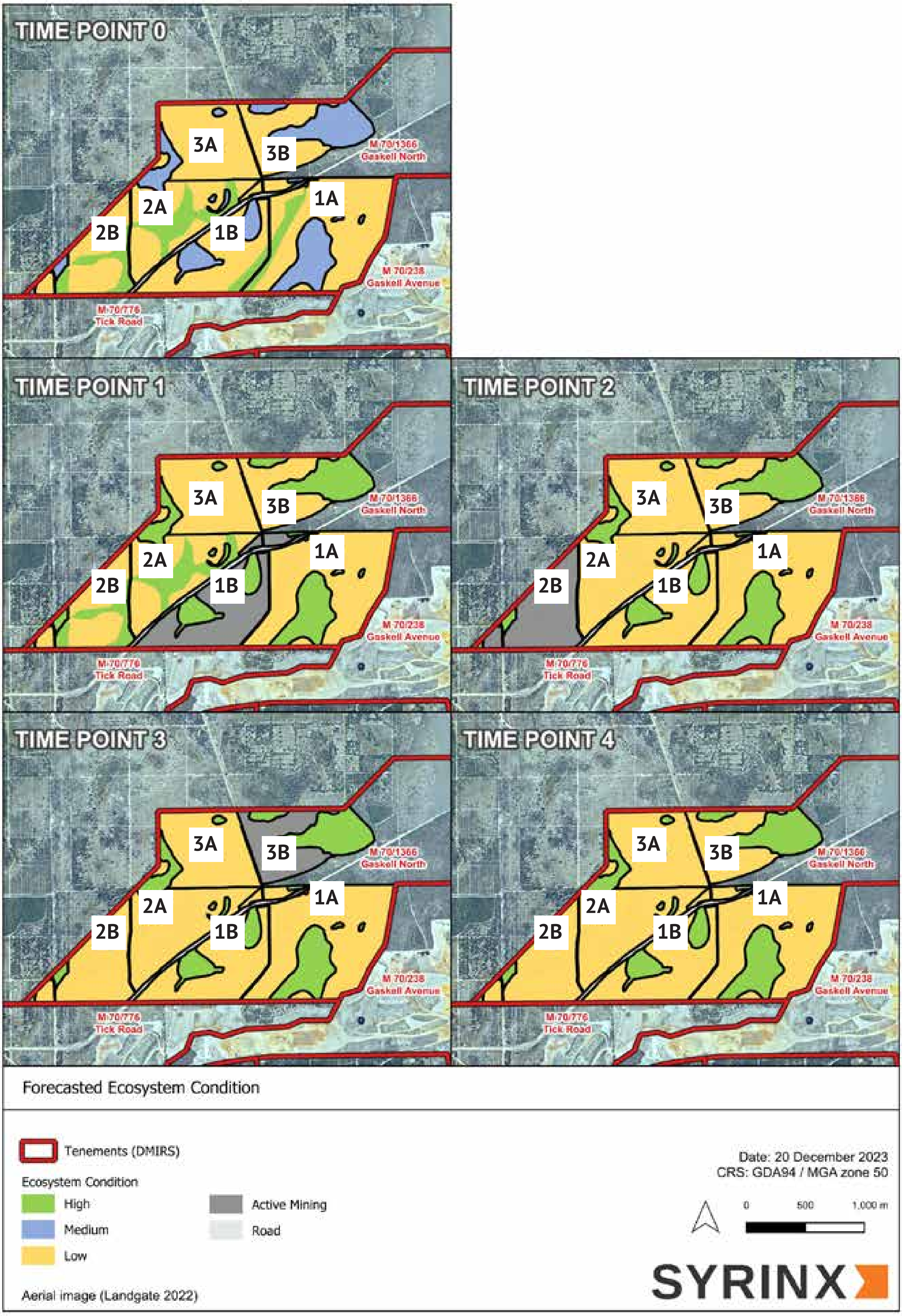

Figure 8. Changes in ecosystem condition account - No Topsoil Scenario

5.0 Summary and key findings

5.0 Summary and key findings

The forecasting exercise applied on Hanson's Gaskell North area showed that for this particular case study, a positive future outcome can be achieved if progressive rehabilitation and wetland remedial works are implemented at the onset of future mining activities.

While this study focused on Hanson's project area, it was intended to more broadly examine the NCA forecasting approach, and is the first attempt to test if the SEEA framework could efficiently be used for strategic planning within the mining sector (rather than merely the current compliance-driven NCA reporting).

Specifically, the study examined the applicability of the SEEA NCA analytical process for acquiring insights into the likely changes in natural stocks and flows on areas set for future mining, using relevant historic data.

This is seen as being a powerful tool for ensuring that planning and investments into future mining activities are founded on the understanding of the dependencies and impacts those activities have on nature, thereby helping balance *nature-positive* outcomes with commercial and corporate goals.

This study also outlines limitations and some key challenges associated with the creation of hypothetical future NCA accounts and scenarios, which would need to be further addressed if this NCA-based forecasting process is to be adopted more broadly within the industry.

The summary of key findings from this pilot study is as follows:

- **The forecasting process requires an in-depth understanding of the ecological context within the project area.**

  This includes, as a minimum, delineation of the ecosystem units and ecological communities present within the project area at the start of the forecasting period, and their condition. For Hanson's pilot study, this information was compiled during the original NCA assessment and included ecological and hydrological spatial mapping (GIS).

  Hanson's forecasting pilot study was limited to assessment of vegetation condition only. If other datasets (e.g., fauna) or other NCA aspects (e.g., ecosystem services) are to be included in the forecasting process, the starting context would require even more comprehensive site data.

  For example, forecasting of carbon stocks and flows would involve development of biocarbon and soil carbon accounts, which would then need to be tracked over the forecasting period(s).

- **The forecasting exercise requires development of a mine plan that includes set forecasting time periods and clear definition of activities planned to be undertaken during these periods.**

  A time investment in thorough thinking and spatial planning of future activities and their progressive succession is critical.

  This should include delineation of areas that will or will not be impacted by mining (clearing, dewatering, excavation etc.), and those that may be impacted by associated activities within the study area, such as roads or other infrastructure works. Details on the planned rehabilitation activities in terms of the areas, timing and specific rehabilitation methodology, are also critical.

  For Hanson's pilot study, four forecasting periods were identified and finely defined in terms of clearing and rehabilitation extent changes (spatial). However, these are entirely hypothetical, as often occurs when assessing a project's feasibility. Wetlands were identified as areas that will not be cleared, or impacted by mine dewatering; as discussed previously, wetlands had a major impact on the overall performance and outcomes.

- **Historical vegetation and other ecological data can be used to forecast future condition performance and develop forecasted condition accounts.**

  For the Hanson study, historical Post Pine Plantation Banksia Woodland Restoration rehabilitation data from the Tick Road tenement was used to derive forecasted condition of areas that are to be rehabilitated within the Gaskell North areas post mining.

  This approach can be adopted only if:

  » ***areas from where the historical data is collected belong to the same Ecological Community as the future forecasted areas;***

  for the Hanson pilot study, this included using historical rehabilitation data for Banksia communities collected from monitoring sites located within the adjacent Tick Road tenement.

  » ***historic data is collected over a period of time that is appropriate for the selected forecasting time periods;***

  for the Hanson pilot study, historical rehabilitation data collected over 20 years of monitoring enabled assessment of 4 future time periods (5, 10, 15 and 20 years post rehab).

- *planned activities within forecasted areas match those on areas used as the source of data;*

  for the Hanson pilot study this includes the same mine process impacts and the same specific rehabilitation approaches and activities.

  Note, while this pilot study was focused on forecasting ecosystem condition based on the analysis of vegetation data only, a similar approach can be adopted if other relevant ecological datasets are available, including fauna or landscape connectivity data.

- **Relevant dataset and ecological expertise in data collection, processing and application is key to the validity of the forecasting process and hence is the key to its wider adoption within the mining industr**y.

  As is the case with the NCA assessment, and as illustrated by the previous summary point, the forecasting process is based on the integration and in-depth scientific analysis of comprehensive and varied datasets (environmental, ecological, spatial). Therefore, adoption of the forecasting approach necessitates a purposeful investment in data gathering and management. Given ecological understanding underpins the forecasting process, ensuring involvement of ecological expertise in forecasting studies is another key factor.

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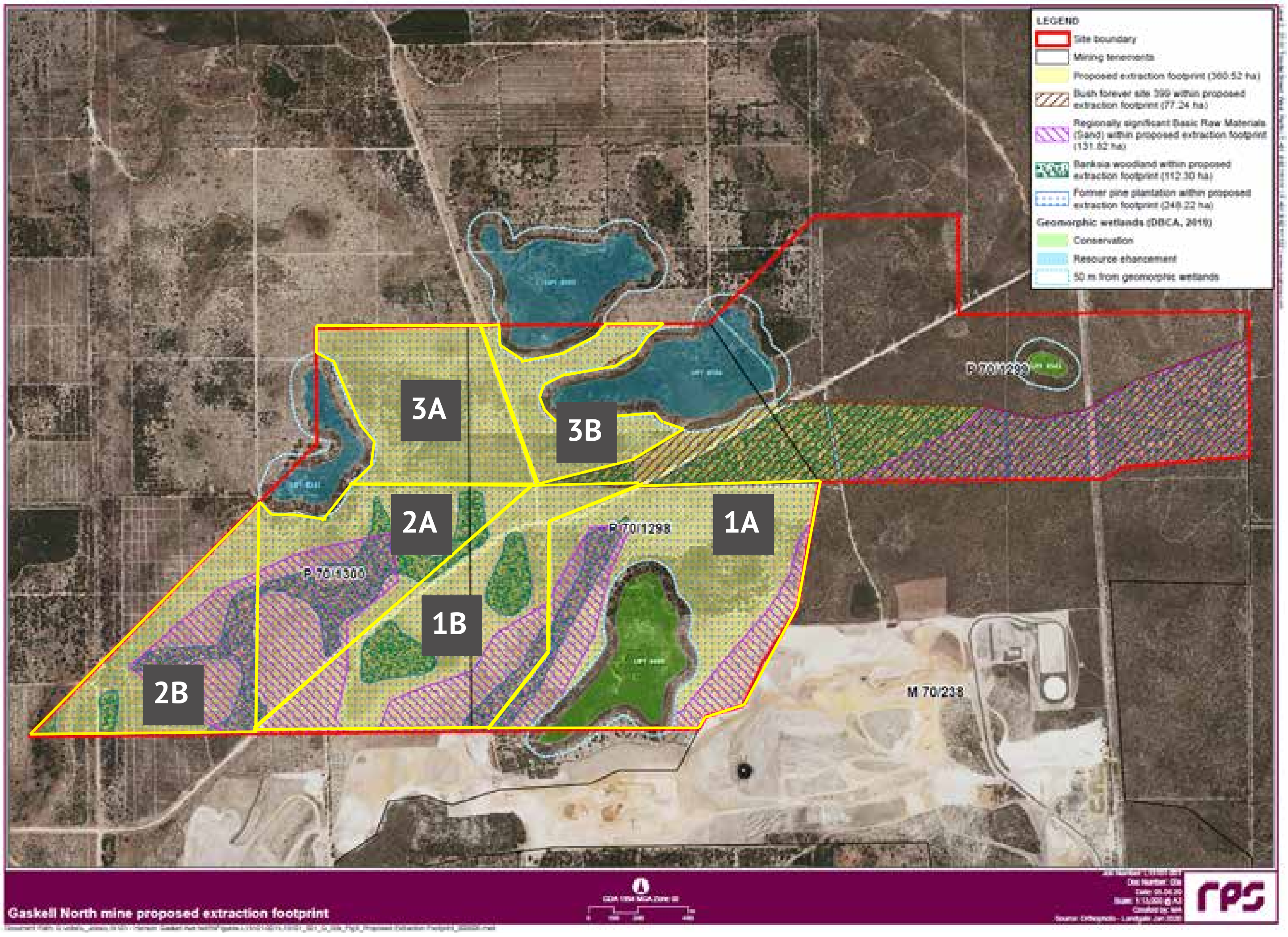
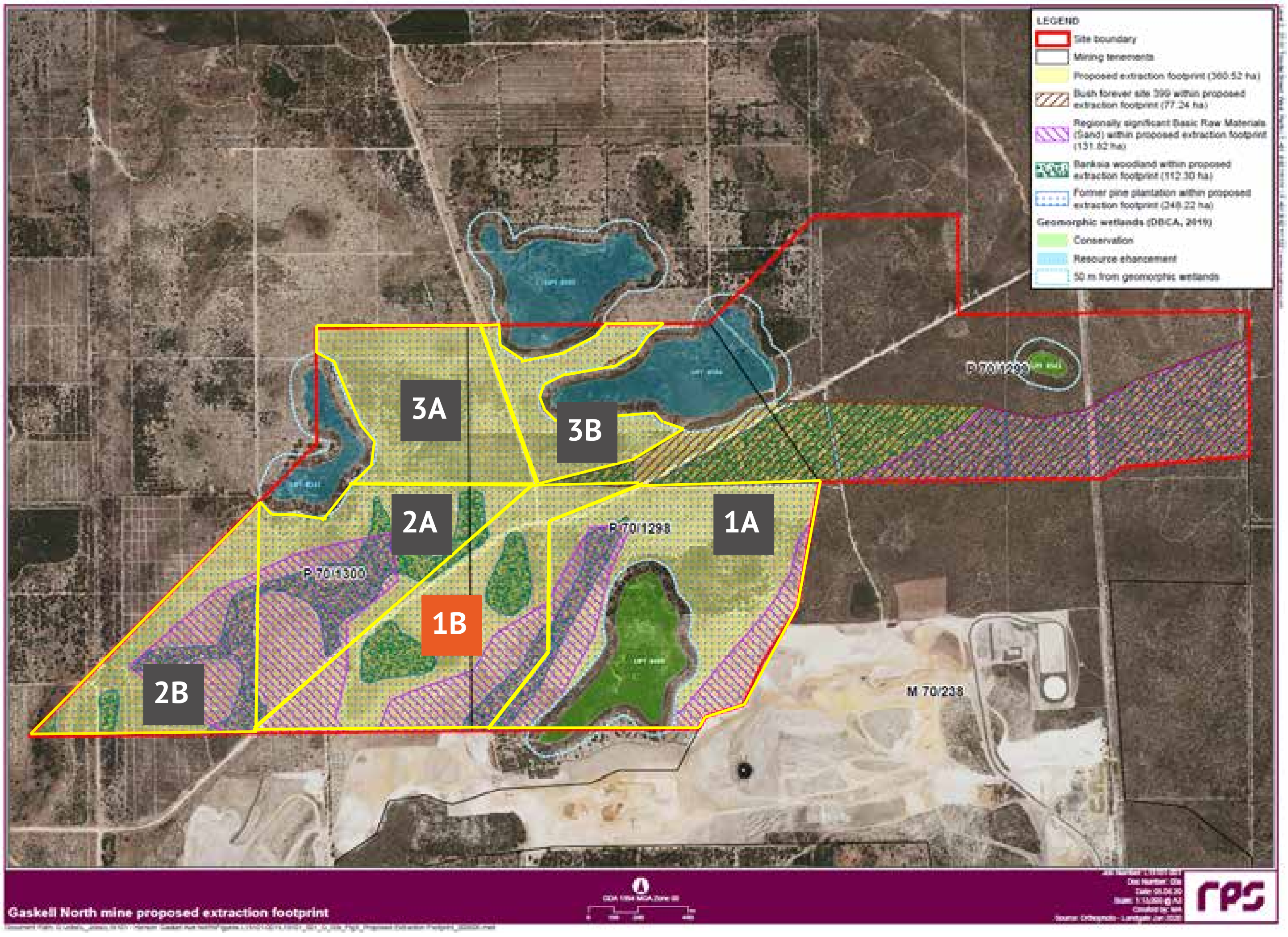
Appendix 1:
Mine Plan used in Forecasting Pilot Study



TIME 0

- Mining Blocks are divided by thick yellow lines
- Label shows state

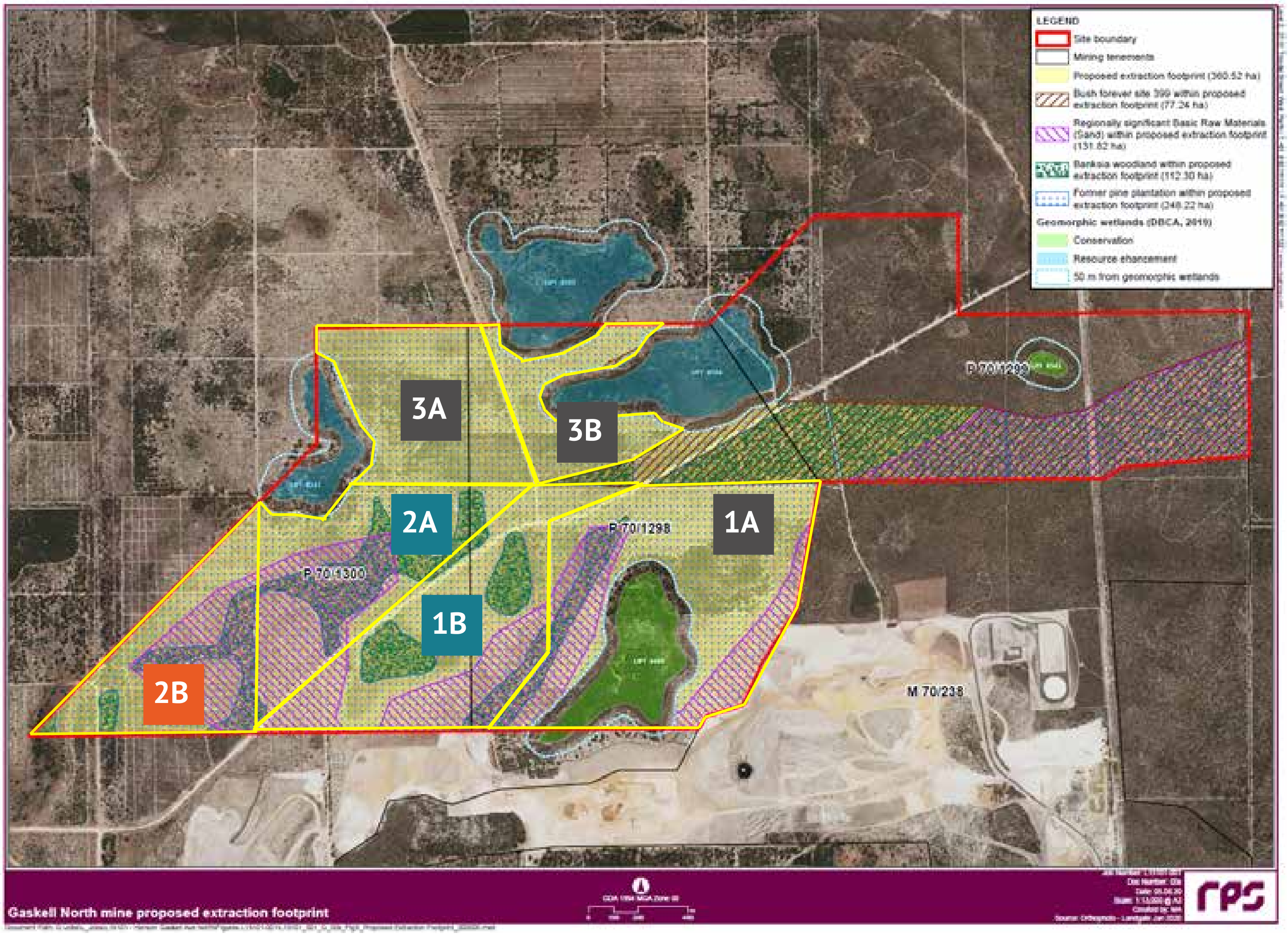
- Undisturbed
- Cleared & Mined
- Rehab – 3yr
- Rehab – 8yr
- Rehab – 13yr
- Rehab – 18yr



TIME 1

- Mining Blocks are divided by thick yellow lines
- Label shows state

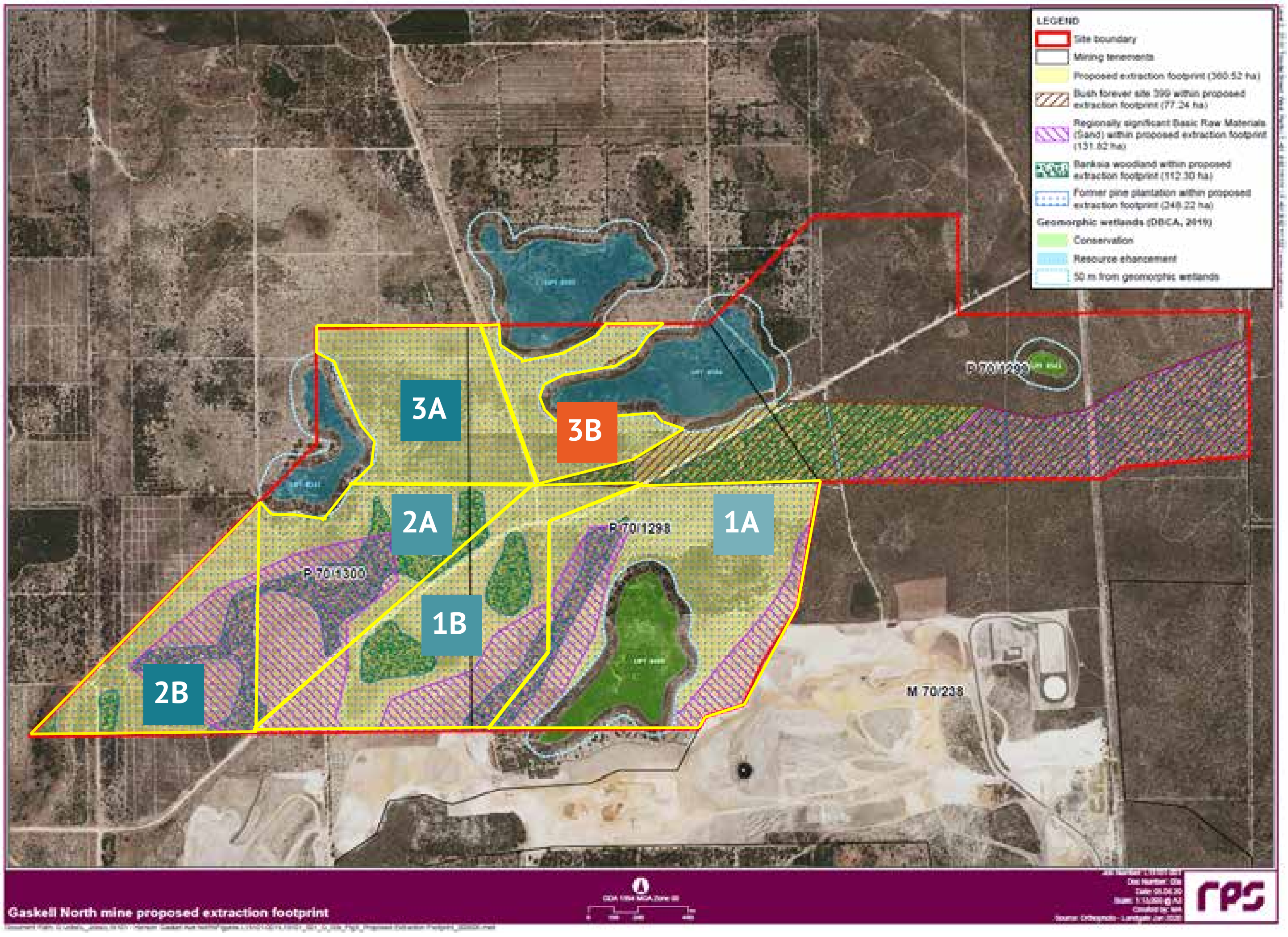
■	Undisturbed
■	Cleared & Mined
■	Rehab – 3yr
■	Rehab – 8yr
■	Rehab – 13yr
■	Rehab – 18yr



TIME 2

- Mining Blocks are divided by thick yellow lines
- Label shows state

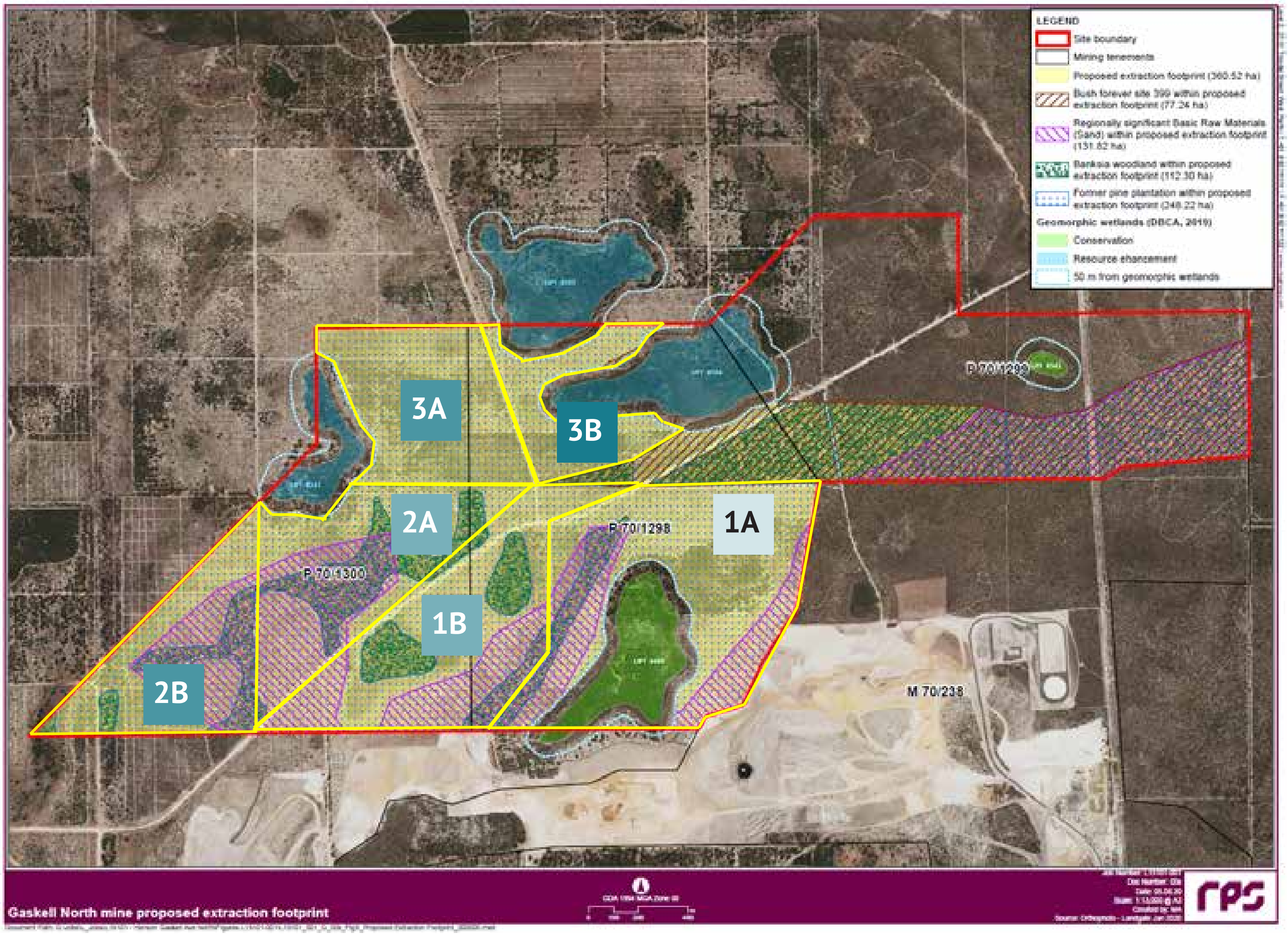
- Undisturbed
- Cleared & Mined
- Rehab – 3yr
- Rehab – 8yr
- Rehab – 13yr
- Rehab – 18yr



TIME 3

- Mining Blocks are divided by thick yellow lines
- Label shows state

- Undisturbed
- Cleared & Mined
- Rehab – 3yr
- Rehab – 8yr
- Rehab – 13yr
- Rehab – 18yr

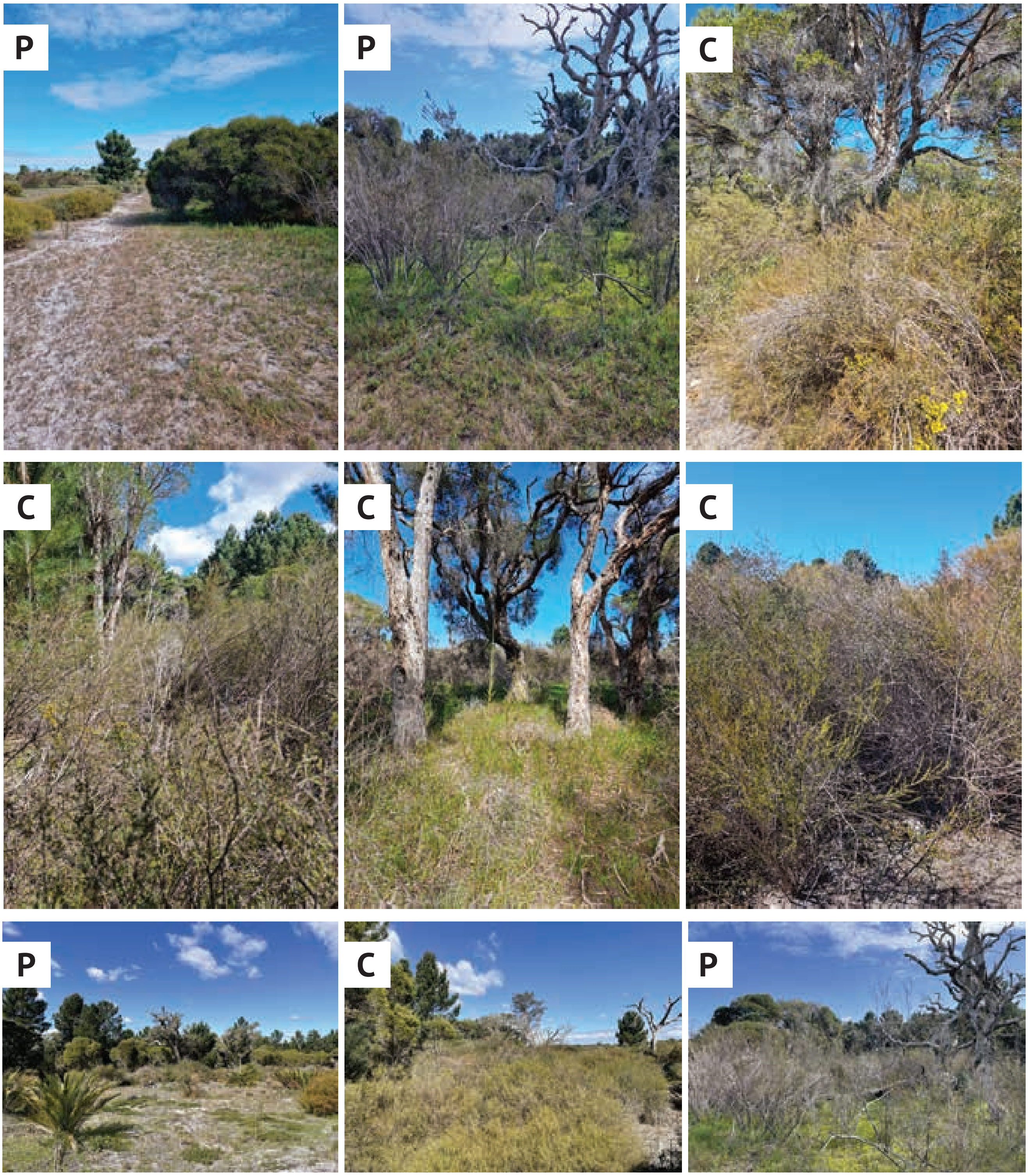


TIME 4

- Mining Blocks are divided by thick yellow lines
- Label shows state

- Undisturbed
- Cleared & Mined
- Rehab – 3yr
- Rehab – 8yr
- Rehab – 13yr
- Rehab – 18yr

Appendix 2:
Photo Record of Wetland Field Study August 2023



SITE VISIT AUGUST 2023

Wetland photos showing:

P - wetland outer perimeter showing weed impacts.

C - towards wetland centre showing healthy remnant vegetation with some emergent pines.








SITE VISIT AUGUST 2023

Wetland photos in central saturated zones showing intact peats and peaty sands show.

Appendix 3:
Photo Record of Restoration Progress (YEAR 1, YEAR 3, YEAR 5, YEAR 10, YEAR 20)

Photo Record depicting the reference sites used to represent the expected condition of restoration activities for each time step in the forecasting study.

YEAR 1

YEAR 3

YEAR 5

YEAR 10

YEAR 20

CRC TiME

Transformations in Mining Economies

E hello@crctime.com.au

T +61 (08) 9263 9805

W www.crctime.com.au

Part of the Australian Government's flagship CRC Program, the Cooperative Research Centre for Transformations in Mining Economies (CRC TiME), brings together diverse stakeholders to help re-imagine and transform mine closure and transitions for the better. It is the world's only dedicated research focused on what happens after mining ends.

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