ST IVES GOLD MINE -
THE BEYOND 2018 PROJECT

ENVIRONMENTAL REVIEW DOCUMENT

ASSESSMENT NO. 2113

SEPTEMBER 2018

DOCUMENT INFORMATION

Document Name	St Ives Gold Mine - The Beyond 2018 Project		
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DISTRIBUTION LIST

Names	Positions	Organisations
Nyomi Bowers	Assessment Officer	Environmental Protection Authority Services

Proposal name:	The Beyond 2018 Project (Revised Proposal)
Proponent:	St Ives Gold Mining Company Pty Ltd
Assessment number:	2113
Location:	Approximately 20 km southeast of Kambalda
Local Government Area:	Shire of Coolgardie
Public Review Period:	Environmental Review Document - 6 weeks

INVITATION TO MAKE A SUBMISSION

The Environmental Protection Authority (EPA) invites people to make a submission on the environmental review for this proposal.

In order to ensure the continuation of operations for up to 10 years beyond 2018, St Ives Gold Mining Company Pty Ltd proposes to expand its existing mining operations located near Kambalda, Western Australia, by increasing its land and lake based mining activity on Lake Lefroy and on adjacent land. The primary objective of the Beyond 2018 Project (B2018 Project) is to ensure the continuation of the St Ives Gold Mine beyond 2018. The total additional disturbance proposed under the proposal will be up to 5,000 ha over a ten year period and is comprised of up to 2,000 ha of lake-based disturbance and up to 3,000 ha of terrestrial disturbance. The Environmental Review Document (ERD) has been prepared in accordance with the EPA's ***Procedures Manual (Part IV Divisions 1 and 2).*** The ERD is the report by the proponent on their environmental review which describes this proposal and its likely effects on the environment.

The ERD is available for a public review period of 6 weeks from **3 October 2018**, closing on **14 November 2018**.

Information on the proposal from the public may assist the EPA to prepare an assessment report in which it will make recommendations on the proposal to the Minister for Environment.

Why write a submission?

The EPA seeks information that will inform the EPA's consideration of the likely effect of the proposal, if implemented, on the environment. This may include relevant new information that is not in the Environmental Review Document, such as alternative courses of action or approaches.

In preparing its assessment report for the Minister for Environment, the EPA will consider the information in submissions, the proponent's responses and other relevant information.

Submissions will be treated as public documents unless provided and received in confidence, subject to the requirements of the *Freedom of Information Act 1992*.

Why not join a group?

It may be worthwhile joining a group or other groups interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group. If you form a small group (up to 10 people) please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

Developing a submission

You may agree or disagree with, or comment on information in the Environmental Review Document.

When making comments on specific elements in the ER document:

- Clearly state your point of view and give reasons for your conclusions.
- Reference the source of your information, where applicable.
- Suggest alternatives to improve the outcomes on the environment.

What to include in your submission

Include the following in your submission to make it easier for the EPA to consider your submission:

- Your contact details – name and address.
- Date of your submission
- Whether you want your contact details to be confidential.
- Summary of your submission, if your submission is long.
- List points so that issues raised are clear, preferably by environmental factor.
- Refer each point to the page, section and if possible, paragraph of the ERD.
- Attach any reference material, if applicable. Make sure your information is accurate.

The closing date for public submissions is: **14 November 2018.**

The EPA prefers submissions to be made electronically via the EPA's Consultation Hub at **https://consultation.epa.wa.gov.au.**

Alternatively submissions can be:

- posted to: Chairman, Environmental Protection Authority, Locked Bag 10, EAST PERTH WA 6892, or

- delivered to: the Environmental Protection Authority, Level 8, The Atrium, 168 St Georges Terrace, Perth 6000.

If you have any questions on how to make a submission, please contact the Office of the Environmental Protection Authority on 6145 0800.

SCOPING CHECKLIST

This table outlines where in this document the requirements of the Environmental Scoping Document have been met.

Task No.	Required Work	Section and Page No.
EPA Key Environmental Factor - Flora and Vegetation		
1.	Identify and characterise flora and vegetation in the proposal area in accordance with the requirements of EPA Guidance. The survey needs to include all areas that are likely to be directly or indirectly impacted (including by changes to groundwater) as a result of the proposal.	Section 4.2 (Flora and Vegetation) (p 4-6), Appendices C-F.
2.	Provide an analysis of the vegetation and significant flora species present and likely to be present within the Development Envelope.	Section 4.2 (Flora and Vegetation) (p 4-6), Appendices C-F.
3.	Identify any areas in the Development Envelope where flora and vegetation surveys have not previously been undertaken, and undertake field surveys in these areas in accordance with EPA guidance.	Section 4.2 (Flora and Vegetation) (p 4-6), Appendices C-F.
4.	Survey effort needs to be greater for Chenopodiaceae (saltbush) family within areas influenced by Lake Lefroy. The vegetation surveys must be a 3m by 3m or equivalent area, succession of quadrats from playa edge to terrestrial vegetation assemblages (transect), recording species zonation and collecting voucher specimens following a methodology that allows recollection of the same individual at a later date.	Section 4.2 (Flora and Vegetation) (p 4-6), Appendices C, E and F.
5.	A large number of *Tecticornia* species have been identified in the proposal survey area and surrounds. To optimise the identification of *Tecticornia* taxa, two sampling events are required for each quadrat in the lake edge survey: the first sampling event to occur between August and October when winter-flowering taxa are in fruit and spring flowering taxa are in late flower, and a second in December or January if voucher specimens are unable to be identified from the first sampling and/or if it is recommended by relevant experts at the WA Herbarium, when spring-flowering taxa are in fruit. All *Tecticornia* specimens are to be identified by relevant experts at the WA Herbarium.	Section 4.2 (Flora and Vegetation) (p 4-6), Appendices C, E and F.
6.	Provide a weed species list, and maps showing weed species occurrence in the proposal area, with a focus on areas likely to be directly or indirectly impacted by the proposal.	Section 4.2 (Flora and Vegetation) (p 4-6), Appendix D.

Task No.	Required Work	Section and Page No.
7.	Provide figures of the proposed clearing and predicted indirect impact to vegetation and significant flora species including threatened/priority ecological communities, threatened/priority flora, and significant flora and significant vegetation as defined by EPA guidance.	Section 4.2 (Flora and Vegetation) (p 4-6). Note that: • No specific footprint is available for the B2018 Project. • No TECs or PECs located within the Development Envelope.
8.	Discuss, and determine significance of, potential direct and indirect impacts to significant flora and vegetation as a result of the proposal at a local and regional level.	Section 4.2 (Flora and Vegetation) (p 4-6).
9.	Discuss cumulative impacts and demonstrate that all practicable measures have been taken to reduce both the area of the proposed disturbance footprint and the Development Envelope based on proposal design and understanding of the environmental impacts.	Section 4.2 (Flora and Vegetation) (p 4-6).
10.	Demonstrate that the proposal has been designed to avoid and minimise impacts including the placement of any access roads and infrastructure within vegetated areas, and that placement has had regard to utilising existing areas of disturbance.	Section 4.2 (Flora and Vegetation) (p 4-6).
11.	Discuss proposed management, monitoring and mitigation methods to be implemented demonstrating that the proposal has addressed the mitigation hierarchy, and ensure residual impacts (direct and indirect) are not greater than predicted.	Section 4.2 (Flora and Vegetation) (p 4-6).
12.	Discuss the residual impacts, if any, including as appropriate, monitoring programmes to measure residual impacts, and management programmes to further mitigate these residual impacts and to deal with circumstances where outcomes fall short of intended objectives.	Section 4.2 (Flora and Vegetation) (p 4-6).
13.	Describe the proposed rehabilitation methodology, including but not limited to: • physical and chemical characteristics of soil and soil profile; • topsoil management; • retention or reuse of vegetative material; • return of species and communities (where feasible) consistent with the pre-existing composition of the affected area; and • timeframes for rehabilitation, including sequencing of excavation and progressive rehabilitation.	Section 4.2 (Flora and Vegetation) (p 4-6), Appendix H.

Task No.	Required Work	Section and Page No.
14.	Prepare a Rehabilitation and Closure Plan consistent with the DMP and EPA (2015) Guidelines for Preparing Mine Closure Plans. The Plan should include but not be limited to: • closure objectives and completion criteria (quantitative or qualitative) addressing post mining landforms and soil profile reconstruction, native vegetation and habitat for conservation significant flora and fauna; and • establish and where possible measure, vegetation and fauna reference and analogue sites, to inform completion criteria.	Appendix H.
15.	Demonstrate and document in the PER how the EPA's objective for this factor can be met.	Section 4.2 (Flora and Vegetation) (p 4-6).
EPA Key Environmental Factor - Terrestrial Fauna EPA Key Environmental Factor - Subterranean Fauna		
16.	Conduct a desktop study, including a literature review, in accordance with EPA guidance. The desktop study needs to address terrestrial vertebrate fauna, short range endemic (SRE) invertebrate fauna and aquatic invertebrate fauna in the Development Envelope.	Sections 4.3 (Terrestrial Fauna) (p 4-55) and 4.4 (Subterranean Fauna) (p 4-87); Appendices H and J.
17.	Using the desktop study, identify any areas in the Development Envelope which have not previously been subject to fauna surveys that meet the requirements of EPA guidance, and undertake the required field surveys in these areas in accordance with EPA guidance. Ensure that the historical and new survey data will collectively be sufficient to place the impacts of the proposal, into local and regional contexts.	Sections 4.3 (Terrestrial Fauna) (p 4-55) and 4.4 (Subterranean Fauna) (p 4-87); Appendices H and J.
18.	Ensure that in addition to the other survey requirements prescribed by EPA guidance, the field surveys address fauna and fauna assemblages that are known to, or are likely to occupy, restricted habitats: including SRE invertebrates, aquatic invertebrates and reptiles in samphire habitats. The surveys need to be completed at an appropriate time of year by zoologists who have experience with these habitats, and familiarity with species that might look morphologically similar. The WA Museum should be consulted prior to field surveys to identify any requirements for specimen collection.	Sections 4.3 (Terrestrial Fauna) (p 4-55) and 4.4 (Subterranean Fauna) (p 4-89); Section 4.6 (Inland Waters Environmental Quality) (p 4-125). The latter contains information about aquatic biota. See also Appendices H, J and N.
19.	Conduct a targeted Malleefowl survey in accordance with EPA and Commonwealth guidance.	Sections 4.3 (Terrestrial Fauna) (p 4-55), Section 7.3 (p7-2), Appendix I.

Task No.	Required Work	Section and Page No.
20.	Conduct a targeted Night Parrot habitat survey in consultation with, and on advice of, the Department of Biodiversity, Conservation and Attractions (DBCA) and as per current guidelines. Provide a detailed evaluation of the need for any follow-up targeted Night Parrot survey, based on the results of the habitat survey and in consultation with, and on the advice of, the Department of Water and Environmental Regulation (DWER) and DBCA.	Sections 4.3 (Terrestrial Fauna) (p 4-55), Appendix J.
21.	If the evaluation of the results of the Night Parrot habitat survey determine that a targeted Night Parrot survey is warranted, conduct a targeted Night Parrot survey in consultation with, and on the advice of, the DWER and DBCA and as per current guidelines.	Sections 4.3 (Terrestrial Fauna) (p 4-55), Appendix J.
22.	Based on the outcomes of the desktop study and field surveys, list and evaluate the likelihood of occurrence of all other significant vertebrates and SRE invertebrates potentially occurring in the Development Envelope and conduct additional targeted significant species surveys as warranted. Map the occurrence of significant species within the Development Envelope and the surrounding area.	Sections 4.3 (Terrestrial Fauna) (p 4-55) and 4.4 (Subterranean Fauna) (p 4-89), Appendices H and J.
23.	Provide justification that the completed desktop study and field surveys have addressed all baseline knowledge gaps, are representative of the current conditions in the Development Envelope, provide suitably current information on populations and locations of significant fauna, and have been carried out using methods consistent with EPA guidance.	Sections 4.3 (Terrestrial Fauna) (p 4-55) and 4.4 (Subterranean Fauna) (p 4-89), Appendices H and J.
24.	Map and discuss the cumulative impacts of past, current and approved exploration and mining activities on Lake Lefroy and the surrounding area, with respect to salt lake habitats, other significant habitats, significant fauna and fauna that are known or likely to occupy restricted habitats (including SRE invertebrates and reptiles in samphire habitats). This should be based on quantitative data from relevant local and regional surveys.	Sections 4.3 (Terrestrial Fauna) (p 4-55) and 4.4 (Subterranean Fauna) (p 4-89), Appendices H and J.
25.	Assess direct and indirect impacts on fauna, significant fauna and fauna habitats. Provide figures showing the likely extent of loss of habitat types and the extent of habitat areas expected to recover from both direct and indirect impacts.	Sections 4.3 (Terrestrial Fauna) (p 4-55) and 4.4 (Subterranean Fauna) (p 4-89).
26.	Assess the likelihoods of the habitats supporting SRE invertebrate species. Provide figures clearly showing impacts to SREs.	Sections 4.3 (Terrestrial Fauna) (p 4-55).

Task No.	Required Work	Section and Page No.
27.	If disturbance associated with the proposal will intersect areas of prospective troglofauna habitat, including but not limited to quaternary alluvial deposits in the south-east of the Development Envelope and islands within Lake Lefroy, conduct a troglofauna desktop assessment and pilot field survey to characterise the troglofauna values of the area.	Section 4.4 (Subterranean Fauna) (p 4-89). Note that potential troglofauna habitat (Quaternary alluvial deposits) is widespread outside of the Development Envelope.
28.	In consultation with and on the advice of the DWER, conduct a comprehensive troglofauna survey if the results of the desktop study and pilot field survey indicate that range-restricted troglofauna would potentially be impacted by the proposal.	Not applicable.
29.	Demonstrate that the proposal has been designed to avoid and minimise impacts including the placement of any access roads and infrastructure within fauna habitat areas and that placement has had regard to utilising existing areas of disturbance.	Sections 4.3 (Terrestrial Fauna) (p 4-55) and 4.4 (Subterranean Fauna) (p 4-89).
30.	Discuss proposed management, monitoring and mitigation methods to be implemented demonstrating that the proposal has addressed the mitigation hierarchy, and ensure residual impacts (direct and indirect) are not greater than predicted.	Sections 4.3 (Terrestrial Fauna) (p 4-55) and 4.4 (Subterranean Fauna) (p 4-89).
31.	Demonstrate and document in the PER how the EPA's objective for these factors can be met.	Sections 4.3 (Terrestrial Fauna) (p 4-55) and 4.4 (Subterranean Fauna) (p 4-89).
EPA Key Environmental Factor - Hydrological Processes		
32.	Provide a detailed description of the design and location of the parts of the proposal with the potential to impact surface water or groundwater, including new bores.	Section 4.5 (Hydrological Processes) (p 4-99). Note that the precise location of project infrastructure is yet to be determined. The impact assessment is based on areas within a Development Envelope.
33.	Develop a conceptual model of the hydrogeological system including recharge and discharge mechanisms, water chemistry and aquifer connectivity (surface/ground water interaction), and the potential for winter rainfall storage at Lake Lefroy.	Section 4.5 (Hydrological Processes) (p 4-99), Appendix M.
34.	Characterise baseline surface, hydrological and hydrogeological regimes, flood risks and water quality - including description of surveys undertaken, baseline and monitoring data collected, and environmental values identified.	Section 4.5 (Hydrological Processes) (p 4-99), Appendices L and M.
35.	Undertake a H3 assessment - detailed hydrogeological assessment including drilling, pump testing and a groundwater model.	Appendix M.

Task No.	Required Work	Section and Page No.
36.	Characterise the lake's hydroperiod, and estimate the extent including depth of the salt crust.	Section 4.5 (Hydrological Processes) (p 4-99), Appendix L.
37.	Characterise lake inundation extent in dry and flooded conditions as a result of dewatering discharge and 1:20 average recurrent interval (ARI) rainfall with the 1:100 ARI rainfall to be considered as an upper limit sensitivity scenario.	Section 4.5 (Hydrological Processes) (p 4-99), Appendix L.
38.	Identify, analyse and discuss surface water and groundwater impacts. The analysis must include: • changes in groundwater levels and changes to surface water flows associated with the proposal (abstraction and dewatering); • the nature, extent and duration of the impacts; and • changes in water quality (including modelling plumes where relevant) associated with the proposal.	Section 4.5 (Hydrological Processes) (p 4-99), Appendices K and L.
39.	Identify any mine wastewater discharges in the site water balance and identify potential impacts on the environment.	Section 4.5 (Hydrological Processes) (p 4-99), Appendix N.
40.	Model the impact of different flooding scenarios during operations and post-closure in mining areas, infrastructure and final landforms.	Section 4.5 (Hydrological Processes) (p 4-99), Appendix L.
41.	Discuss the proposed management, monitoring and mitigation to minimise groundwater and surface water impacts as a result of implementing the proposal.	Section 4.5 (Hydrological Processes) (p 4-99).
42.	Outline the outcomes/objectives, management, monitoring, trigger and contingency actions, within environmental management plans, to ensure impacts (direct and indirect) are not greater than predicted.	Section 4.5 (Hydrological Processes) (p 4-99).
43.	Demonstrate how the mitigation hierarchy of avoid, minimise, mitigate has been applied during the mine planning and design stages of the Beyond 2018 Project.	Section 4.5 (Hydrological Processes) (p 4-99).
44.	Demonstrate and document in the PER how the EPA's objective for this factor can be met.	Section 4.5 (Hydrological Processes) (p 4-99).
EPA Key Environmental Factor - Inland Waters Environmental Quality		
45.	Characterise the lake environment and surrounding wetlands (chemical, physical and biological processes) within the Development Envelope, in a local and regional context.	Section 4.6 (Inland Waters Environmental Quality) (p 4-125), Appendix O.
46.	Characterise the surface water and groundwater quality in a local and regional context.	Section 4.5 (Hydrological Processes) (p 4-99), Appendices L and M.

Task No.	Required Work	Section and Page No.
47.	Describe surveys undertaken to establish water and sediment quality, the biological data collected, and the environmental values identified.	Section 4.6 (Inland Waters Environmental Quality) (p 4-125), Appendix O.
48.	Undertake ecological surveys of the lake (and peripheral wetlands), and identify and describe the impacts from this proposal to ecological values, including both direct and indirect impacts.	Section 4.6 (Inland Waters Environmental Quality) (p 4-125), Appendix O.
49.	Describe the impacts from this proposal on the associated inland water and sediment quality and groundwater quality, including direct and indirect impacts.	Section 4.6 (Inland Waters Environmental Quality) (p 4-125).
50.	Assess the nature, extent and duration of potential impacts of groundwater abstraction and dewatering, including potential impacts on surrounding wetlands.	Section 4.6 (Inland Waters Environmental Quality) (p 4-125).
51.	Undertake waste characterisation studies of waste rock and other materials, and carry out an acid and metalliferous drainage risk assessment for the proposed development within the Development Envelope, both on land and on the lake surface.	Section 4.6 (Inland Waters Environmental Quality) (p 4-125), Appendix P.
52.	Discuss the proposed management, monitoring and mitigation to ensure impacts on inland water quality and ecological values are not greater than predicted as a result of implementing the proposal.	Section 4.6 (Inland Waters Environmental Quality) (p 4-125).
53.	Demonstrate how the mitigation hierarchy of avoid, minimise, mitigate has been applied during the mine planning and design stages of the Beyond 2018 Project.	Section 4.6 (Inland Waters Environmental Quality) (p 4-125).
54.	Demonstrate and document in the PER how the EPA's objective for this factor can be met.	Section 4.6 (Inland Waters Environmental Quality) (p 4-125).

EXECUTIVE SUMMARY

Introduction

The subject of this Environmental Review Document (ERD) is the proposal by St Ives Gold Mining Company Pty Ltd (**SIGMC**), to continue the existing open-cut and underground gold mining developments at Lake Lefroy, approximately 20 kilometres south east of Kambalda in the Goldfields region of Western Australia (WA). The project is referred to as the **Beyond 2018 Project** (or **B2018 Project**).

SIGMC is part of the Gold Fields Australia (GFA) group of companies, the ultimate parent company of which is Gold Fields Limited (GFL).

Background and context

Gold was first discovered at Red Hill within the location of SIGMC's current tenure in 1897. Mining was intermittent over these years with full scale gold mining operations commencing in 1980. Gold Fields Ltd purchased the gold operations in 2001 and remains the current operator of the site. A long history of operations has resulted in significant historical disturbance which spans over the SIGMC tenure.

In relation to the *Environmental Protection Act 1986* (EP Act), the lake-based mining operations that commenced between 2000 and 2010 were originally regulated under Ministerial Statement No. 548 (MS548). A proposal to continue operations (the Beyond 2010 Project) was originally considered by the Environmental Protection Authority (EPA) in 2010 pursuant to Part IV of the EP Act. The Minister for the Environment published Ministerial Statement No. 879 (MS879) in November 2011 formally approving the Beyond 2010 Project subject to a number of binding conditions. MS879 provides sufficient mining capacity until the end of 2018 after which further operational areas are required to maintain the operational continuity of St Ives Gold Mine.

SIGMC submitted a Referral to the EPA under section 38 of the EP Act on 15 December 2016 regarding the B2018 Project. Subsequent to the Referral, the EPA set the level of assessment to 'Environmental Review – 6 week public review' pursuant to section 39(1) of the EP Act on 15 February 2017. The ESD for the Project was prepared by the EPA and, following a number of revisions, finally approved on 6 October 2017. The final ESD for the Project outlines the range of studies expected to be completed by the EPA to demonstrate the significance (or lack thereof) of the project on a range of key Environmental Factors. This ERD responds to the framework set out within the ESD and reflects the detail within the ESD as well as considering the discussions held between the proponent and various stakeholders (including State Government and the local community).

Overview of the proposal

The primary objective of the B2018 Project is to ensure the continuation of the St Ives Gold Mine beyond 2018. The B2018 Project will require an expansion outside of the existing MS879 approved disturbance footprint with the aim to provide sufficient ore reserves to facilitate mining for a ten year period (i.e. to 2028). This continuation of operations is unlikely to require a change to the current mining or processing methods.

Given the difficulties in defining ore reserves over such a period of time, the proposal put forward by SIGMC is not based on a defined project footprint but rather an approach that includes both terrestrial and lake-based tenure within a set disturbance limit based on location. This approach maximises operational flexibility over the 10-year operational timeframe for the proposal and minimises the need to revert back to the EPA as new resources and operational areas are defined. Such an approach also aligns with SIGMC's long-term approach to mine closure and rehabilitation and maximises the opportunity to take a strategic approach to approvals, operations and long-term plans for closure. The approach also provides some level

of certainty for the stakeholders who benefit from the continuation of the operations (including the town of Kambalda).

The maximum proposed disturbance is up to 5,000 ha which consists of:

- Lake based disturbance of approximately 200 ha per year over a ten year period with a total maximum disturbance of up to 2,000 ha; and
- Land based disturbance of approximately 300 ha per year over a ten year period with a total maximum disturbance of up to 3,000 ha.

Together with the approved disturbance that has or will take place, the proposed disturbance results in up to 9,146 ha of total disturbance consisting of 4,061 ha of lake disturbance and 5,085 ha of land disturbance within the Development Envelope.

The annual dewatering volumes are predicted to increase slightly as a result of expansion to operations and processing facilities and be well below the currently approved 30 GL. Despite this, the new maximum annual dewatering volume SIGMC is seeking an approval for is 40 GL, a 10GL increase from the current approved value of 30 GL per annum. This volume provides a sufficient reserve for dewatering discharge volumes should changes in the mining schedule occur.

The key characteristics/elements of the B2018 Project are:

- New open cut pits;
- New underground operations;
- Expansions to existing open cut pits and underground operations;
- Construction of new waste rock landforms;
- Construction of new tailings facilities;
- Construction of mining and ancillary infrastructure (workshops, offices, laydown areas etc.);
- Construction of new dewatering discharge structures; and
- Increase in dewatering discharge volume.

Throughput in the Lefroy Mill may increase but will remain within the existing design capacity and licence limits currently applied under Part V of the EP Act.

The key characteristics of the proposal are set out in Table ES 1 and Table ES 2. The key proposal characteristics may change as a result of the findings of studies and investigations conducted and the application of the mitigation hierarchy by the proponent.

Table ES 1: Summary of the Proposal

Proposal title	The Beyond 2018 Project
Proponent name	St Ives Gold Mining Company Pty Ltd
Short description	The Beyond 2018 Project comprises expansion of the existing open-cut and underground gold mining developments at Lake Lefroy, approximately 20 kilometres (km) south east of Kambalda. The total additional disturbance proposed is up to 5,000 hectares (ha) over a ten year period, with a maximum of 2,000 ha of lake-based disturbance and 3,000 ha of terrestrial disturbance. The maximum annual dewatering volume is estimated to be 40 GL.

Table ES 2: Location and Proposed Extent of Physical and Operational Elements

Element	Existing Approval (MS879)	Other Approval	Proposed Change	Total Proposed Extent
Physical Elements				
Lake-based operations	2,061 ha	N/A	2,000 ha	4,061 ha
Land-based operations	N/A	2,085 ha (under *Mining Act 1978*)	3,000 ha	5,085 ha
Operational Elements				
Mine dewatering and discharge	N/A	30 GL per annum (regulated under Part V of the *Environmental Protection Act 1986*).	Additional dewatering of up to 10 GL annually.	Up to 40 GL annually (regulated under Part V of the *Environmental Protection Act 1986*).
Area of direct riparian zone disturbance	Up to 90 ha	N/A	Additional 20 ha	Up to 110 ha
Waste rock disposal	A minimum of 95 million tonnes.	Approximately 118 million tonnes (regulated under *Mining Act 1978*).	Approximately 450 million tonnes.	Approximately 663 million tonnes.
Height of waste rock dumps	Up to 40 m	Up to 40 m (regulated under *Mining Act 1978*)	No change.	Up to 40 m.
Ore processing	NA – regulated under Part V of the *Environmental Protection Act 1986* and *Mining Act 1978.*	DWER licensed operational throughput up to 9 Mtpa.	No change.	DWER licensed operational throughput up to 9 Mtpa.
Tailings disposal	N/A	Four above ground TSFs and five in-pit TSFs (regulated under Part V of the *Environmental Protection Act 1986* and *Mining Act 1978*).	Additional above ground or in-pit tailings storage capacity.	Above ground and in-pit TSFs (regulated under Part V of the *Environmental Protection Act 1986* and *Mining Act 1978*)

Summary of potential impacts, proposed mitigation and outcomes

During the assessment of the proposal the following key environmental factors were identified by the EPA to be relevant for the B2018 Project:

- Flora and Vegetation;
- Terrestrial Fauna;
- Subterranean Fauna;
- Hydrological Processes; and
- Inland Waters Environmental Quality.

EPA also often identifies other environmental factors or matters as relevant to a proposal. These factors are not significant enough to warrant full assessment by the EPA or can be regulated through other regulatory processes and agencies to meet the EPA's objectives. For B2018 Project the other environmental factors or matters identified include:

- Social Surroundings (Heritage);
- Social Surroundings (Amenity); and
- Air Quality (Greenhouse Gas (GHG) Emissions).

SIGMC considers that the information and assessment presented in this ERD adequately identifies and addresses environmental impacts relevant to the proposal, meets the requirements set in the ESD and is suitable to enable the EPA to undertake its assessment of the B2018 Project under the Section 38 of the EP Act.

The key environmental factors along with the potential impacts, proposed management measures, commitments and predicated outcomes are summarised in Table ES 3.

Table ES 3: Summary of Potential Impacts, Proposed Management Measures, Commitments and Predicted Outcomes

Flora and Vegetation	
EPA objective	*To protect flora and vegetation so that biological diversity and ecological integrity are maintained*
Potential Impacts	**Clearing of native vegetation** Clearing of native vegetation, significant vegetation types and Priority Flora in areas proposed for mine development is up to 3,000 ha on land for the duration of B2018 Project (10 years). Five species of conservation significance and eleven vegetation types of local conservation significance occur within the Development Envelope. Away from the existing mine operations, vegetation is typically in very good condition. **Introduction or spread of weed species** A number of weed species have been recorded within the Development Envelope but there are no known significant populations. Weeds can be spread during earthmoving or transport operations. **Other impacts** Other potential impacts include dust deposition on vegetation resulting from nearby mining or transport operations and a range of other potential indirect impacts. Fires initiated by the mine's operations are also a risk to vegetation.
Management Measures	**Avoid:** SIGMC will implement five exclusion zones inside the Development Envelope. No mine-related activity will occur within these exclusion zones. The location and size of the zones has been selected offer a significant level of protection to the conservation values identified during surveys. SIGMC will use procedures to minimise the risk of accidental fires. Local drainage will be considered when constructing new haul roads and access tracks and maintaining existing road infrastructure. **Avoid/Minimise:** The total clearing of native vegetation is limited to 3,000 ha on land for the duration of the B2018 Project. Ground disturbing activities at SIGMC are managed through the implementation of a Surface Disturbance Permit Procedure (SIG-ENV-PR049). These procedures are intended to prevent accidental disturbance of areas not scheduled for clearing and to advise field personnel on methodology for topsoil recovery and stockpiling, and related matters. **Minimise:** Further targeted surveys will be conducted outside the Development Envelope during the B2018 Project to build on the understanding of conservation significant vegetation types and flora. Weed control will be carried out to control weeds in accordance with the SIGMC Weed Management Plan (SIG-ENV-PL047), Weed Monitoring procedure (SIG-ENV-PR041) and Weed Control procedure (SIG-ENV-PR042).

	Dust associated with the operations will be managed in accordance with the SIGMC Dust Management Procedure (SIG-ENV-PR029).
	Rehabilitation: SIGMC will undertake progressive rehabilitation in areas where mining operations have been completed. For land-based operations this will involve rehabilitation of disturbed areas and constructed landforms such as WRLs and TSFs. The rehabilitation will be undertaken in accordance with the RMCP (Appendix H) and site-wide MCP. The MCP will be updated every three years to reflect changes in operations and environmental baseline data. The overall aim of the rehabilitation and closure is that all disturbed areas are rehabilitated in accordance with the closure priorities of safe, non-polluting and stable at all locations, with self-sustaining ecological communities where possible.
Commitments	**Commitment 1: To protect flora and vegetation, establish five exclusion zones – Exploration 1, Oyster and Coral Islands, Pistol Club West, Pilbailey and Implacable - within the Development Envelope within which no mine-related activities may occur.** **Commitment 2: The total clearing of native vegetation is limited to 3,000 ha on land for the duration of the B2018 Project.** **Commitment 3: Further targeted surveys will be conducted outside the Development Envelope during the B2018 Project to build on the understanding of conservation significant vegetation types and flora.**
Outcomes	In consideration of the outcomes of the EIA and proposed management measures, SIGMC considers that EPA's objective for Flora and Vegetation to 'protect flora and vegetation so that biological diversity and ecological integrity are maintained' can be achieved. The following outcomes are predicted: • No loss of any Threatened Ecological Community or Priority Ecological Community. • All vegetation types in which clearing will potentially occur are listed as Least Concern and have around 90% or more of their Pre-European extent intact. • No loss of any regionally significant vegetation types. • No loss of groundwater dependent ecosystems. • Some potential loss in area of locally significant vegetation types, all of which are also known from outside the Development Envelope. • No loss of any Threatened species. • Some potential loss of one P1 flora species although most of the known numbers (78%) within the Development Envelope are protected within Exclusion Zones. Two other P1 flora species also occur within the Development Envelope but are fully (100%) protected within Exclusion Zones. All three species also occur outside of the Development Envelope. • No significant risk of an increase in weeds. By implementing management measures detailed above and through the implementation of the Exclusion Zones, the residual impact is not significant and no offsets are considered to be required.

Terrestrial Fauna	
EPA objective	*To protect terrestrial fauna so that biological diversity and ecological integrity are maintained.*
Potential Impacts	**Loss and fragmentation of fauna habitats** Clearing of fauna habitats in areas proposed for mine development of up to 3,000 ha is proposed for the duration of B2018 Project (10 years). Five broad fauna habitats have been identified within the Development Envelope. The two habitats likely to be the most affected are the sale lake playa and open woodland on plain. Loss and fragmentation of vegetation will reduce fauna habitat in the local area. A number of species of conservation significance occur in the area but their habitats are broadly represented at the regional scale and these fauna should not be significantly affected. Surveys failed to record any sightings or signs of the Night Parrot. **Mortality during land clearing** The land clearing may cause mortality to individual animals, potentially including malleefowl. **Other potential impacts** Dust generated during construction and from operational areas can potentially degrade surrounding vegetation and essential habitat resources including feeding areas and shelter sites. Degradation of these areas through introduction of weeds or feral animals may potentially render the habitat unsuitable for fauna. Habitat may also be negatively impacted by introduced flora species, noise and vibration and changes in fire regimes.
Mitigation	**Avoid:** Three of the five exclusion zones identified to protect flora and vegetation will also serve to protect fauna, primarily SRE and potential SRE fauna. No mine-related activity will occur within these exclusion zones. The location and size of the zones has been selected to offer a significant level of protection to the conservation values identified during surveys. **Avoid/Minimise:** Further SRE survey work will be undertaken prior to ground disturbing works to clarify the status of fauna only known from the Development Envelope. Ground disturbing activities at SIGMC are managed through the implementation of a Surface Disturbance Permit Procedure (SIG-ENV-PR049). These procedures are intended to prevent accidental disturbance of areas not scheduled for clearing and to advise field personnel on methodology for topsoil recovery and stockpiling, and related matters. Incorporate checks for malleefowl mounds into the Surface Disturbance Permit Procedure. **Minimise/Avoid:** Maintain existing routine controls for dust, weeds and feral animals. Apply vehicle speed limits and restrictions on offroad driving. Minimise the risk of accidental fires.

	Rehabilitation: Where practicable, SIGMC will undertake progressive rehabilitation in areas where mining operations have been completed with the aim to provide self-sustaining ecosystems and habitat for fauna in areas disturbed by mining operations. The rehabilitation will be undertaken in accordance with the RMCP and site-wide MCP which is required to be updated every three years to reflect changes in operations and environmental baseline.
Commitments	**Commitment 4: To protect terrestrial fauna, establish three exclusion zones – Exploration 1, Pilbailey and Implacable - within the Development Envelope within which no mine-related activities may occur.** **Commitment 5: Undertake further SRE survey work prior to ground disturbing works to clarify the status of fauna only known from the Development Envelope.**
Outcomes	In consideration of the outcomes of the EIA and proposed management measures, SIGMC considers that EPA's objective for Terrestrial Fauna to '*protect terrestrial fauna so that biological diversity and ecological integrity are maintained*' can be achieved. The following outcomes are predicted: • No loss of any Threatened Ecological Community or Priority Ecological Community. • No loss of important populations of conservation significant fauna. • Loss of fauna habitat is negligible at the regional scale. • Retention of riparian habitat for SREs both outside of the Development Envelope and within Exclusion Zones within the Development Envelope.

Subterranean Fauna	
EPA objective	*To protect subterranean fauna so that biological diversity and ecological integrity are maintained.*
Potential Impacts	The Development Envelope does not support stygofauna species as the groundwater is too saline. Troglofauna may occur in the Quaternary alluvial deposits that reach into the south-east of the Development Envelope, and continue to a much larger extend beyond. Disturbance of these sections may therefore result in loss of habitat. Given the relatively small portion of Quaternary alluvial deposits in the Development Envelope when compared to the region, the predicted impacts to troglofauna from the Project are considered negligible.
Mitigation	No mitigation measures are proposed for subterranean fauna.
Commitments	No commitments.
Outcomes	SIGMC considers that EPA's objective for Subterranean Fauna to '*protect subterranean fauna so that biological diversity and ecological integrity are maintained.*' can be readily achieved. The following outcomes are predicted: • No known populations of stygofauna within the Development Envelope and no known potential habitat. • No known populations of troglofauna within the Development Envelope. Very limited occurrence of one potential troglofauna habitat within the Development Envelope but the habitat is widespread outside the Development Envelope.

Hydrological Processes	
EPA objective	*To maintain the hydrological regimes of groundwater and surface water so that environmental values are protected*
Potential Impacts	**Dewatering discharge to Lake Lefroy – hydrology and water balance** Surface water modelling was undertaken to examine the potential effect of dewatering on the lake when it occurs in conjunction with major rainfall events. The potential for prolonged inundation, and potential degradation, of riparian vegetation was considered Modelling considered the extent to which 'vegetation points' around the lake were inundated under a range of rainfall and discharge scenarios. It was concluded that the dewatering discharge will have little impact on the extent of inundation of Lake Lefroy which is largely an effect of rainfall events. **Dewatering discharge to Lake Lefroy – salt load and salt crust formation** Operations to date have increased the salt load and salt crust formation on the surface of Lake Lefroy and this process will continue under the B2018 Project. High level show that the salt crust may increase by less than 20 mm for the larger lake segments, increasing to approximately 160 mm for segments that receive the majority of the dewater discharge and are not readily connected to other parts of the lake. The bathymetry of the lake surface means that an accumulation of a salt crust at or close to the more sensitive lake shoreline is unlikely, provided the discharge point is located away from these areas. **Groundwater drawdown or mounding** The operations have the potential to produce localised and temporary decline in groundwater levels around the dewatered voids and underground workings. While vegetation will not utilise the groundwater due to its high salinity, a reduction on groundwater levels may reduce availability to other users. Studies found the regional extent of drawdown is relatively limited with the 1 m drawdown contour not extending far beyond the SIGMC tenement boundary. Deeper drawdowns in terms of tens of metres are limited to the immediate vicinity of the mining operations operated at the particular point in time. Consequently, other groundwater users in adjoining tenements are unlikely to be experience any significant change in groundwater levels. Conversely, some of the current operations (e.g. TSF4, heap leach) have resulted in groundwater mounding originating from seepage from these facilities. Groundwater mounding has the potential to enter the root zone of vegetation where it is likely to cause a decline in vegetation condition although there is no evidence that this has occurred.
Mitigation	**Minimise:** Prior to the commencement of the B2018 Project, SIGMC will produce a detailed dewatering discharge plan that considers different dewatering discharge strategies, water management controls (including culvert location) and location of dewatering discharge points with the aim of minimising the impacts to Lake Lefroy. **Avoid/Minimise:** SIGMC will also commence routine monitoring of salt crust formation around lake discharge points.

	Construction of tailings storage facilities will be informed by detailed hydrogeological and hydrological assessments and designed to minimise seepage. Groundwater monitoring with trigger levels to indicate if further action is required will be ongoing. Existing monitoring programs for groundwater and surface water will be maintained and extended as the project develops. **Rehabilitate** SIGMC will consider closure options for dewatering discharge points and their associated salt crust formations. The options will consider how significant salt crusts can be removed, encapsulated or otherwise prevented from dispersal or partial dispersal across the lake surface following mine closure.
Commitments	**Commitment 6: A dewatering discharge strategy will be developed for each new open pit operation on the lake, prior to its commencement. The strategy will consider:** • **Existing dewatering practices elsewhere and impacts, if any;** • **Likely discharge volumes;** • **Potential for localised flooding;** • **Likely extent and location of salt crust formation; and** • **Potential for impact to the riparian zone and, where necessary, measures for protection of the riparian zone.** **Commitment 7: SIGMC will commence routine monitoring of salt crust formation around lake discharge points.**
Outcomes	SIGMC considers that EPA's objective for Hydrological Processes to '*maintain the hydrological regimes of groundwater and surface water so that environmental values are protected*' can be achieved. The following outcomes are predicted: • Dewatering discharge onto the surface of Lake Lefroy will not significantly alter the extent or duration of flooding occurring after significant rainfall events. • Dewatering discharge onto the surface of Lake Lefroy will not result in a significant change in the water quality regime i.e. dissolution of naturally-occurring surface salts after a rainfall event already results in a hypersaline water body on the lake. • Groundwater drawdown due to pit dewatering is very unlikely to adversely impact water availability to other groundwater users.

Inland Waters Environmental Quality	
EPA objective	*To maintain the quality of the groundwater and surface water so that environmental values are protected*
Potential Impacts	**Direct disturbance to Lake Lefroy and peripheral wetlands** With the disturbance proposed under the B2018 Project, a total of up to 46 km^2 (8.3%) of the lake surface will be directly disturbed, up to approximately 10% of the lake surface if the area potentially affected by dewatering discharge is considered. The remaining 90% should be enough sufficient area of lake surface for basic ecological processes to be maintained, provided key areas such as those adjacent to the riparian zone, are not disproportionately affected. With regard to the peripheral wetlands, SIGMC has mapped a total extent of 2103.2 ha within a buffer zone of approximately 2 km around the main body of Lake Lefroy. Some wetlands will have been lost during the early stages of mine development at St Ives but it is believed the great majority remain. Of the remaining wetlands, a total of 1002.0 ha (47.6 %) occurs within the B2018 Project Development Envelope. As the wetlands within the Development Envelope have a broad distribution around the lake, it is unlikely that most or all would be impacted under the B2018 Project. However, given their restricted occurrence, some measures are required to reduce potential impacts on peripheral wetlands as much as possible. Other than direct impacts, there is some risk posed by indirect impacts. For example, each wetland appears to function within a small sub-catchment. Changes to drainage patterns have the potential to significantly alter the runoff received by individual wetlands. **Discharge of potential contaminants to Lake Lefroy** There is little evidence that the discharge of dewatering discharge to Lake Lefroy has resulted in any significant change to water quality on Lake Lefroy, with the exception of salinity. Current water monitoring and practice of discharge to a turkey nest on the surface of the lake should continue. Some risks remain – hydrocarbon spillage and AMD within pits that are actively being dewatered has the potential for poor quality water to be discharged to the lake if not appropriately monitored. **Indirect disturbance to peripheral wetlands** No dewatering discharge occurs into peripheral wetlands and none is proposed in the Beyond 2018 Project. However, the ecology of the peripheral wetlands may also be subject to indirect impacts such as changes to the surface hydrology and or the hydrogeological regime. There is also a risk of potential contaminants entering the peripheral wetlands via unmanaged runoff or seepage. These indirect impacts may for example alter drainage patterns, or the quality or quantity of runoff received by the peripheral wetlands.
	Management of potentially acid-forming materials The majority of waste rock at SIGMC is not acid-forming. However, two lithologies, Kapai Slate and Cave Rocks Sediments, are known to be acid-

	forming and several others have some potential to oxidise and produce acid drainage. An AMD Optimisation Study concluded that "current management practices and procedures in place at SIGM are considered to be at a standard that is consistent with current industry practice and appropriate for the management of AMD risk at the site". The same study also recommended further work to refine the AMD risk assessment, including ongoing testwork to understand longer lag-time AMD characteristics.
Mitigation	**Avoid:** SIGMC proposes that the exclusion zones developed for protection of biodiversity can also be used to protect peripheral wetlands. While almost half of the peripheral wetlands around Lake Lefroy fall within the Development Envelope, the potential for direct impacts reduces to 18.3 % when exclusion zones are applied. This should be adequate to ensure the function and representation within peripheral wetlands is maintained under the B2018 Project. **Avoid/Minimise:** SIGMC proposes to continue .to refine datasets to progress the understanding the ecological values of the peripheral wetlands and the lake within a regional context. Other management measures include: • Incorporation of an assessment of potential subcatchment drainage impacts into the Surface Disturbance Permit Procedure and develop appropriate management measures. • Maintain a monitoring program for all dewatering discharge to the surface of Lake Lefroy. • Maintain implementation of existing management practices whereby risk materials are identified and placed within open pit voids or in core areas of WRLs, and • Undertake further work to refine the AMD risk assessment, including ongoing testwork to understand longer lag-time AMD characteristics.
Commitments	**Commitment 8: To protect peripheral wetlands, establish three exclusion zones – Exploration 1, Pistol Club West and Implacable - within the Development Envelope within which no mine-related activities may occur.** **Commitment 9: Continue to refine datasets to progress the understanding the ecological values of the peripheral wetlands and the lake within a regional context.**
Outcomes	SIGMC considers that EPA's objective for Inland Waters Environmental Quality to '*maintain the quality of the groundwater and surface water so that environmental values are protected*' can be achieved. The following outcomes are predicted: • No impact to any wetlands which are Ramsar-listed, Conservation Category, or listed in the Directory of Important Wetlands in Australia;

	• While peripheral wetlands around the main playa of Lake Lefroy are significantly more biodiverse than the lake itself, the function and representation of these wetlands is common within the Goldfields, Wheatbelt, Pilbara and more widely. These values will be maintained as over 80% occur either outside the Development Envelope or in exclusion zones within the Development Envelope; • No expected impact to new described aquatic biota as none is limited to the Development Envelope; and • There is some potential for acid production as waste rock oxidises but the proportion of waste rock with acid-forming potential is small and readily managed.

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1 INTRODUCTION

1.1 *Purpose and Scope*

The subject of this Environmental Review Document (ERD) is the proposal by St Ives Gold Mining Company Pty Ltd (SIGMC) to further develop open-cut and underground gold mining at Lake Lefroy, Western Australia – the Beyond 2018 Project (B2018 Project). The operations are approximately 20 kilometres south east of Kambalda in the Goldfields region of Western Australia (Figure 1-1).

Gold mining operations at a substantial scale have been undertaken on and around Lake Lefroy by SIGMC or previous entities since the 1980s. The purpose of this ERD is to assess the potential environmental impacts associated with a major expansion of both lake-based and land-based gold mining operations.

The scope of the assessment relates to potential environmental impacts arising from activities occurring within a Development Envelope (see Section 2) within which particular activities are proposed. Although SIGMC tenure extends well beyond the Development Envelope, potential environmental impacts associated with mining or mining-related activities outside of the Development Envelope have been, or will be, assessed by other means.

The scope of the ERD also focusses on preliminary key environmental factors identified by the Environmental Protection Authority (EPA) based on preliminary information (EPA 2017) although other environmental factors are also considered. The ERD will outline the potential environmental impacts and describe how SIGMC can avoid, mitigate or manage these impacts.

The ERD will be the basis on which submissions on the Proposal from stakeholders can be made. The ERD, submissions and SIGMC's responses to the submissions will then form the basis for the EPA's assessment.

1.2 *Proponent*

The proponent for the proposal is St Ives Gold Mining Company Pty Ltd (SIGMC), part of the Gold Fields Australia (GFA) group of companies, the ultimate parent company of which is Gold Fields Limited (GFL). The details of the proponent are as follows:

St Ives Gold Mining Company Pty Ltd (SIGMC) (ACN 105 124 034)
St Ives Gold Mine
PO Box 359
Kambalda West WA 6442

Proponent contact details:

Mr Jarrad Donald
Superintendent: Environment
St Ives Gold Mine, Durkin Road, Kambalda WA 6442
(08) 9088 1823
jarrad.donald@goldfields.com.au

Consultant contact details:

Mr Andrew Mack
Talis Consultants Pty Ltd
Level 1 660 Newcastle Street, Leederville WA 6007
(08) 6557 5213
andrew.mack@talisconsultants.com.au

Figure 1-1
Regional Location of B2018 Project

GOLD FIELDS
ST IVES GOLD MINE

Kalgoorlie
Coolgardie
Kambalda
Widgiemooltha

LEGEND

Development Envelope

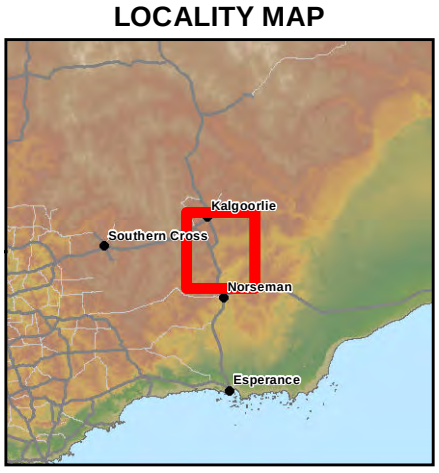
0 10 20 30 40
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	24/11/2017

LOCALITY MAP



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1.3 *Environmental Impact Assessment Process*

1.3.1 Part IV of the EP Act

Under Part IV of the EP Act, a proposal (as defined under Section 3 of the EP Act) may be referred to the EPA for environmental impact assessment (EIA). Section 38 of the EP Act makes provision for the referral to the EPA of proposals by a proponent, a decision-making authority, or any other person. The referral is the trigger for the commencement of an EIA process by the EPA. The consideration from an EIA perspective is of a 'significant' proposal which is defined within Section 37B(1) as "…a proposal likely, if implemented, to have a significant effect on the environment".

Whilst the EPA provides a range of guidance in relation to what should determine the significance or otherwise of a proposal, it is clear that the EP Act only contemplates an environmental impact assessment process being undertaken on those projects which are significant. The guidance for how this EIA process is undertaken is provided within the EPA's Environmental Impact Assessment (Part IV Divisions 1 and 2) Administrative Procedures 2016, as well as the EPA's Environmental Impact Assessment (Part IV Divisions 1 and 2) Procedures Manual 2016.

Where the EPA determines that a proposal is or may be significant, it can require a proponent to undertake an environmental review pursuant to Section 40(2)(b) of the EP Act. This environmental review process can be made public.

Once the EPA has made a decision to assess a proposal, there is a process in place whereby appropriate information should be provided to the EPA relating to the impact (or potential impact) of the proposal on the environment. As with the referral process, the EPA can require whatever information it determines necessary to undertake that assessment. This is stipulated through Section 40 of the EP Act. The assessment undertaken by the EPA must be completed against one or more key environmental factors. The EPA has provided guidelines for each factor that details the EPA's expectations in terms of investigation and data assessment.

The resultant ERD can be made publicly available through the provisions of Section 40(4). Further to this, Section 40(4) also allows that any information provided as part of the assessment process can be made available for public review and Section 40(6) requires that the proponent provides copies at their own expense and respond to any submissions received.

Once the EPA's consideration of a proposal has been completed, it prepares an assessment report containing its findings, recommendations and, in the event that the proposal were to be approved, its recommended implementation conditions. The assessment report is also made publicly available under the provisions of Section 44 (3) of the EP Act.

The final stage of the process is for the Minister to consider the EPA's recommendations and to seek input from other Ministers and Decision Making Authorities (DMAs) on the implementation of the proposal and relevant conditions (Section 45(1) of the EP Act). Once that process is complete, the Minister releases a statement pursuant to Section 45(5) of the EP Act.

1.3.2 EPBC Act

Under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), there are a number of environmental considerations which are afforded protection by the Commonwealth and are referred to as Matters of National Environmental Significance (MNES).

Under the EPBC Act, actions that have, or are likely to have a significant impact on a matter of national environmental significance require approval from the Australian Government Minister

for the Environment (the Minister). Such projects warrant referral to the Department of the Environment and Energy (DEE). The DEE will then consider the proposal and determine whether it is a 'controlled action' and where a formal conditional approval can be granted.

The ESD considers one MNES – nationally threatened species and ecological communities. No other MNES is relevant to the Proposal.

The ESD provides a list of species that are listed under the EPBC Act and have previously been recorded at Lake Lefroy and its surrounds. These species have the potential to occur within the proposal area:

- Granite Poison - *Gastrolobium graniticum* (Endangered);
- Bead Glasswort - *Tecticornia flabelliformis* (Vulnerable); and
- Malleefowl - *Leipoa ocellata* (Malleefowl) (Vulnerable).

The Development Envelope also lies within the 'medium priority area for survey' for the Night Parrot (*Pezoporus occidentalis*), as defined in May 2017 by the Department of Parks and Wildlife (now the Department of Biodiversity, Conservation and Attractions (DBCA)). This species is listed as Endangered under the EPBC Act. Three of the above mentioned four species are also protected under the Western Australian *Wildlife Conservation Act (1950)* while the remaining species, *T. flabelliformis*, is listed by DBCA as a Priority One species. All four species are discussed in sections 4.2 and 4.3.

Based on the work undertaken in relation to the Project, SIGMC is of the opinion that there is no likelihood of a significant impact occurring to any of the listed MNES. As a result, a referral to the DEE is not required. Further detail is provided in relation to this matter in Section 7 of this ERD.

1.4 *Other Approvals and Regulation*

1.4.1 Mining Act 1978 (WA)

In Western Australia, various forms of mine tenure may be obtained under the *Mining Act 1978* (Mining Act). SIGMC holds a substantial number of tenements south of the town of Kambalda in the Goldfields region, spanning approximately 60 km north to south. The tenements currently held by SIGMC or by other parties and proposed to be utilised for the B2018 Project are detailed in Appendix A and shown in Figure 1-2.

The Development Envelope incorporates an area covering 243 tenements. Of those, 219 are directly held by SIGMC, one is jointly held and 23 are held by other parties. Where a tenement is not held by SIGMC, legal access to the tenement to facilitate mining will be required prior to any disturbance. Access will be achieved via tenement acquisition, a joint venture (JV) arrangement or access agreements as required under Section 118A of the Mining Act. SIGMC already holds access agreements for gold exploration over many of the tenements not directly held and future access for mining is reasonably foreseeable. In the event that access to mine cannot be legally obtained for any given tenement, no mining will be undertaken on that tenement.

A consolidated summary of all SIGMC and other tenure occurring within the Development Envelope is shown in Table 1-1. The extent of SIGMC's tenement holdings outside of the Development Envelope is also shown.

Under the Mining Act, environmental impacts associated with significant activities must be addressed in a Mining Proposal. The Mining Proposal must be approved before mining can proceed. To date, Mining Proposals have been submitted by SIGMC to the DMIRS pursuant to Section 82 of the Mining Act for all existing mining operations. All current operations are approved under the Mining Act.

Figure 1-2
Beyond 2018 Project Tenements

GOLD FIELDS
ST IVES GOLD MINE

365000 370000 375000 380000 385000 390000 395000

6550000 6545000 6540000 6535000 6530000 6525000 6520000 6515000

M 15/1761 M 15/1519 M 15/883
M 15/1762 M 15/1520
M 15/1763 M 15/1521
M 15/1515 M 15/1522 M 15/1709
M 15/1530 M 15/1523 M 15/1708
M 15/1500 M 15/1501 M 15/1507 M 15/1529 M 15/1531 M 15/1524
M 15/1502 M 15/1508 M 15/1512 M 15/1516 M 15/1525 M 15/1598
M 15/1503 M 15/1509 M 15/1513 M 15/1517 M 15/1526 M 15/1600 M 15/1599
M 15/1504 M 15/1510 M 15/1514 M 15/1518 M 15/1527 M 15/1601 M 15/1602
M 15/1705 M 15/1704 M 15/1703 M 15/1702 M 15/1628 M 15/1604 M 15/1603
M 15/1700 M 15/1701 M 15/1629 M 15/1605 M 15/1606 M 15/1663
M 15/1698 M 15/1226 M 15/1696 M 15/1695 M 15/1608 M 15/1607 M 15/1662
M 15/1693 M 15/1691 M 15/1609 M 15/1610 M 15/1661
M 15/1690 M 15/1689 M 15/1688 M 15/1612 M 15/1664 M 15/1656
M 15/1687 M 15/1686 M 15/1685 M 15/1613 M 15/1614 M 15/1655
P 15/5886 M 15/1684 M 15/1683 M 15/1616 M 15/1615 M 15/1658
E 15/1605 E 15/975 M 15/1227 M 15/1681 M 15/1617 M 15/1618 M 15/1581
M 15/1679 M 15/1678 M 15/1620 M 15/1619 M 15/1579 M 15/1580
M 15/1677 M 15/1676 M 15/1621 M 15/1622 M 15/1578 M 15/1634
M 15/1625 M 15/1624 M 15/1623 M 15/1540
M 15/29 M 15/1627 M 15/1566
E 15/978 M 15/1675 L 15/242
M 15/1674 M 15/1567 M 15/1565
M 15/28 M 15/1568 M 15/1570 M 15/1572
M 15/1569 M 15/1571 M 15/1573
M 15/1574 M 15/1575 M 15/1549 M 15/1550 M 15/1551
M 15/1670 M 15/1553 M 15/1576 M 15/1577
M 15/1669 M 15/1555 M 15/1590 M 15/1556 M 15/1557
M 15/1558 M 15/1591 M 15/1559
M 15/1635 M 15/1593 M 15/1594 M 15/1595
M 15/1560 M 15/1561 M 15/1596
M 15/432 M 15/1802
M 15/1639 M 15/1638 M 15/1637
M 15/476 M 15/1640
M 15/1641 M 15/1642
M 15/1643
M 15/884 M 15/475
M 15/495 M 15/366 M 15/1644
M 15/1645
M 15/474 M 15/1647
L 15/239
L 15/145 M 15/452 M 15/1711 M 15/1712 M 15/1713 M 15/1649
E 15/1642 M 15/1714 M 15/1715 M 15/1716 M 15/1650
L 15/178 M 15/1651
M 15/453 ML 15/482 ML 15/375 ML 15/378
M 15/49 E 15/980 M 15/367
M 15/63 ML 15/376 ML 15/377
E 15/1641 M 15/206
ML 15/522
ML 15/521

M 15/1546 M 15/1548 M 15/1588 M 15/1587 M 15/1586 M 15/1585 M 15/1584 M 15/1583 M 15/1582 M 15/1581 M 15/1580 M 15/1579 M 15/1578 M 15/1577 M 15/1576 M 15/1575 M 15/1574 M 15/1573 M 15/1572 M 15/1571 M 15/1570 M 15/1569 M 15/1568 M 15/1567 M 15/1566 M 15/1565 M 15/1564 M 15/1563 M 15/1562 M 15/1561 M 15/1560 M 15/1559 M 15/1558 M 15/1557 M 15/1556 M 15/1555 M 15/1554 M 15/1553 M 15/1552 M 15/1551 M 15/1550 M 15/1549 M 15/1548 M 15/1547 M 15/1546 M 15/1545 M 15/1544 M 15/1543 M 15/1542 M 15/1541 M 15/1540 M 15/1539 M 15/1538 M 15/1537 M 15/1536 M 15/1535 M 15/1534 M 15/1533 M 15/1532 M 15/1531 M 15/1530 M 15/1529 M 15/1528 M 15/1527 M 15/1526 M 15/1525 M 15/1524 M 15/1523 M 15/1522 M 15/1521 M 15/1520 M 15/1519 M 15/1518 M 15/1517 M 15/1516 M 15/1515 M 15/1514 M 15/1513 M 15/1512 M 15/1511 M 15/1510 M 15/1509 M 15/1508 M 15/1507 M 15/1506 M 15/1505 M 15/1504 M 15/1503 M 15/1502 M 15/1501 M 15/1500 M 15/1499 M 15/1498 M 15/1497 M 15/1496 M 15/1495 M 15/1494 M 15/1493 M 15/1492 M 15/1491 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LEGEND

- Development Envelope
- St Ives Tenure - Live
- St Ives Tenure - Pending
- Non-St Ives Tenure - Live
- Non-St Ives Tenure - Pending

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Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	B
Date:	25/07/2018

LOCALITY MAP

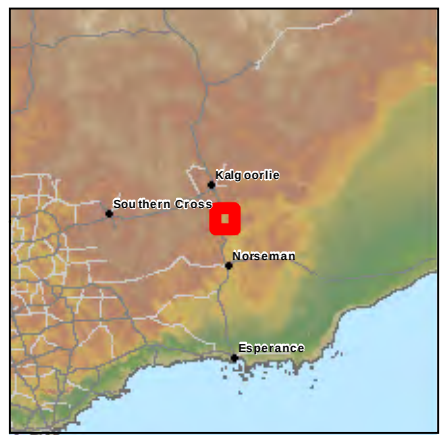

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Table 1-1: SIGMC Tenement Summary

Tenement Type	No. of Tenements (inside Development Envelope)		No. of Tenements (outside Development Envelope)
	SIGMC-held	Held by other parties	
Exploration (E)	6	5[1]	22
Mining (M)	207	5	73
Miscellaneous (L)	3	4	14
Prospecting (P)	2	2	2
Mineral Lease (ML)	0	8	3
General Purpose (G)	1	0	0
Total	**219**	**24**	**114**

SIGMC has prepared and submitted a site-wide Mine Closure Plan for its operations to DMIRS in December 2016. The 2016 MCP was prepared in accordance with the requirements of EPA Ministerial Statement (MS) 879 and the *Guidelines for Preparing Mine Closure Plans* (DMP and EPA 2015). The 2016 MCP is currently being assessed by the DMIRS and is expected to be approved by the first quarter of 2018.

The MCP guidelines and the 2010 amendments to the Mining Act, stipulate an approved MCP must be reviewed, updated and submitted to the DMIRS three years after the initial MCP approval. The next version of the MCP is expected to be submitted for approval in 2019.

In accordance with the requirements set in the ESD (EPA 2017), a separate Rehabilitation and Mine Closure Plan (RMCP) has been prepared for the B2018 Project. The latest version of the site-wide MCP has been used in preparation of this RMCP to ensure that the closure framework is consistent with existing operations and those proposed as part of the B2018 Project. Approval of the RMCP under the Mining Act is not sought. The document has been prepared to meet the requirements of the ESD and to provide a conceptual outline of how SIGMC will approach rehabilitation and closure for the B2018 Project.

1.4.2 Environmental Protection Act 1986 Part IV

1.4.2.1 Original Approval

In relation to the EP Act, the lake-based mining operations that commenced between 2000 and 2010 were originally regulated under Ministerial Statement No. 548 (MS548). MS548 addressed mining at open cut pit and underground operations, construction of waste rock dumps, access infrastructure and mining support facilities on the lake. All land-based operations to date have been managed under the Part V of the EP Act and the Mining Act.

1.4.2.2 The Beyond 2010 Project

A proposal to continue operations (the Beyond 2010 Project) was originally considered by the EPA in 2010 pursuant to Part IV of the EP Act. The Beyond 2010 Project was referred to the EPA in August 2009 that advised a PER process was required in order to appropriately assess the proposal pursuant to the provisions of the EP Act. SIGMC submitted the PER in late 2010 and received authorisation to implement the proposal in November 2011 pursuant to the conditions stipulated in MS879.

[1] One tenement jointly held with SIGMC.

The Beyond 2010 Project proposal was submitted to expand the existing open-cut and underground gold mining development within a defined area on the surface of Lake Lefroy and included the continued discharge of dewater to the lake's surface and the ongoing construction of associated mining infrastructure (including open pits and waste rock landforms). The approved Beyond 2010 Project included the following aspects:

- Existing lake-based mining operations that commenced between 2000 and 2010 (approved under the then MS548) and was increased to a final disturbance footprint of 1,713 hectares (ha);
- New open cut and underground mining developments on Lake Lefroy (within the boundaries of the original disturbance footprint of 1,713ha);
- Continuation of use of existing dewatering discharge points on Lake Lefroy (including the construction of the Santa Ana discharge point, permitted under Department of Water and Environmental Regulation (DWER) (formerly Department of Environment Regulation (DER)) Works Approval WA5077/2011); and
- An increase in mine dewatering discharge volume from 20 gigalitres (GL) per annum to a maximum of 30 GL per annum.

Since the approval of the Beyond 2010 Project in 2011 there have been a number of approved changes to the original proposal to facilitate ongoing site operations and associated expansions. The Invincible Project was included in MS879 in January 2014 via Section 45C of EP Act which increased the approved disturbance footprint by 248 ha up to 2,061 ha.

The Beyond 2016 Project Change to Proposal application was approved by the EPA Services (EPAS, formerly Office of EPA (OEPA)) in December 2016. The Beyond 2016 Project was required to realign the approved operational mine areas in order to extend the life of the SIGMC operations. The Beyond 2016 Project Change to Proposal application included the following aspects:

- Four new mining operations;
- Two existing mine pit expansions;
- One expansion to a previously approved operation;
- Two existing Part IV boundary amendments;
- Four new mine dewatering discharge locations;
- One tip head establishment;
- The mining of up to 44 million tonnes of ore;
- The disposal of up to 239 million tonnes of waste rock; and
- The dewatering and discharge of up to 30 GL of water per annum.

The Beyond 2016 Project proposed a number of new mining operations but the total approved area of disturbance remained within the 2,061 ha approved under MS879.

1.4.3 Environmental Protection Act 1986 Part V

1.4.3.1 Clearing of Native Vegetation

Clearing of native vegetation across the SIGMC tenure has been undertaken in compliance with the *Environmental Protection* (Clearing of Native Vegetation*) Regulations 2004* regulated by the DWER and DMIRS. SIGMC holds a number of permits issued under these provisions.

Where an approval under Part IV of the EP Act has been granted, there is an exemption available from the requirement to obtain a clearing permit. Consequently, SIGMC will not be required to obtain a permit or permits for the B2018 Project if approval under Part IV of the EP Act is received.

1.4.3.2 Operating Licence

St Ives is classified as a Prescribed Premises according to Schedule 1 of the *Environmental Protection Regulations 1987* (EP Regulations). Prescribed activities at St Ives as listed on Operating Licence L8485/2010/2 issued by the DWER are shown in Table 1-2 below.

Table 1-2: SIGMC's DWER Prescribed Activities

Category Number	Category Description	Category Production or Design Capacity	Premises Production or Design Capacity
5	Processing or beneficiation of metallic or non-metallic ore	50,000 tonnes or more per year	9,000,000 tonnes per year
6	Mine dewatering	50,000 tonnes or more per year	30 GL per annum
7	Vat or in-situ leaching of ore	5,000 tonnes or more per year	3,000,000 tonnes per year
54	Sewage facility	100 cubic metres or more per day	Premises production, approximately 220 cubic metres per day
64	Class ll putrescibles landfill site	20 tonnes or more per year	1,000 tonnes per year

Operations at St Ives are approved under Licence L8485/2010/2. Dewatering and discharge of up to 30 GL per annum of this water is permitted under this Licence and SIGMC is required to undertake a range of monitoring and management activities pursuant to the conditions of this licence.

1.4.4 Rights in Water and Irrigation Act 1914

SIGMC currently holds a DWER Groundwater Licence (GWL) under the RIWI Act for pit dewatering. Licence number GWL62505(9) allows abstraction of groundwater from the Goldfields Combined Fractured Rock West and Fractured Rock aquifers to a total of 30 GL per annum. This licence entitles abstraction for the purposes of mineral ore processing and other mining purposes, dewatering for mining purposes, dust suppression for mining purposes and product processing wash-down purposes between 21st February 2014 and 20th February 2024. The tenements on which the proposed dewatering locations will be situated are covered by this Groundwater Licence.

As discussed elsewhere in this document, SIGMC proposes to increase the discharge limit to Lake Lefroy to 40 GL per annum as part of the B2018 Project. Where this increase is required due to the operational requirements and results in an exceedance of the currently approved 30 GL under the RIWI Act, a new approval will be sought from the DWER.

Licence number GWL171060(2) allocates groundwater from the Mt Morgan Borefield for a total of 4.015GL per annum. This Licence entitles abstraction for the purposes of mineral ore processing and other mining purposes between 2 February 2016 and 1 February 2026. Proposed volume to be extracted to ensure continuation of operations falls within the allocated abstraction volume.

1.4.5 Native Title Act 1993

The Ngadju group are the determined native title holders over the majority of the SIGMC operational areas (Tribunal file number: WCD2014/004) as determined under the *Native Title Act 1993* (Commonwealth). SIGMC liaises with the Ngadju group in relation to heritage matters.

1.4.6 Aboriginal Heritage Act 1972

Almost all Aboriginal heritage issues in WA are managed under the *Aboriginal Heritage Act 1972* (AH Act). Any disturbance to an Aboriginal Heritage Site as defined by Section 5 of the AH Act will require a permission from the Minister for Aboriginal Affairs under Section 18 of the AH Act.

A number of Aboriginal heritage surveys have been undertaken over the B2018 Development Envelope. These surveys have identified a limited number of recorded sites. The recorded sites are protected during ground disturbance using SIGMC's internal management procedures.

Should any of the recorded sites that are considered significant be disturbed, appropriate consultation with Ngadju people in regards to the documentation, evaluation and management of these sites will be undertaken. All relevant statutory requirements and approvals will also be sought in the event that disturbance to a site is unavoidable.

1.4.7 Summary of Other Approvals and Regulation

Table 1-3 below provides a summary of approvals and regulation applicable to B2018 Project.

Table 1-3: Summary of Approvals and Regulation

Proposal activities	Land tenure/access	Type of approval	Legislation regulating the activity	Regulatory Body
Gold Mine Developments on Lake Lefroy	Mining, exploration, miscellaneous tenure Pastoral land	Ministerial Statement (MS879)	*Environmental Protection Act 1986*	DWER EPA Services
Gold Mine Developments on SIGMC tenure	Mining, exploration, miscellaneous tenure Pastoral land	Mining Proposal	*Mining Act 1978*	DMIRS
Processing or beneficiation of metallic ore	Mining tenure	Environmental Licence (L8485/2010/2)	*Environmental Protection Act 1986*	DWER
Mine dewatering	Mining, exploration, miscellaneous tenure Pastoral land	Environmental Licence (L8485/2010/2)	*Environmental Protection Act 1986*	DWER
Vat or in situ leaching of metal	Mining tenure	Environmental Licence (L8485/2010/2)	*Environmental Protection Act 1986*	DWER
Sewage facility	Mining, exploration, miscellaneous tenure Pastoral land	Environmental Licence (L8485/2010/2)	*Environmental Protection Act 1986*	DWER
Class II or III putrescible landfill facility	Mining tenure	Environmental Licence (L8485/2010/2)	*Environmental Protection Act 1986*	DWER
Groundwater Abstraction	Mining, exploration, miscellaneous tenure Pastoral land	Licences to take water (Section 5C): GWL62505 and GWL171060	*Rights in Water and Irrigation Act 1914*	DWER
Disturbance of Aboriginal heritage sites	Mining, exploration, miscellaneous tenure Pastoral land	Ministerial Consent under Section 18 to disturb heritage sites (if required)	*Aboriginal Heritage Act 1972*	Department of Planning, Lands and Heritage (DPLH)
Disturbance of Aboriginal heritage sites	Mining, exploration, miscellaneous tenure Pastoral land	Native Title Agreement	*Native Title Act 1993*	Land, Approvals and Native Title Unit

2 THE PROPOSAL

2.1 *Background*

Gold was first discovered at Red Hill within the location of SIGMC's current tenure in 1897. Mining was intermittent over these years with full scale gold mining operations commencing in 1980. Gold Fields Ltd purchased the gold operations in 2001 and remains the current operator of the site. A long history of operations has resulted in significant historical disturbance which pans over the SIGMC tenure.

The potential environmental impacts associated with gold mining and processing at the SIGMC operations are regulated through a number of statutory instruments. These are primarily Parts IV and V of the *Environmental Protection Act 1986* (EP Act) and the *Mining Act 1978* (Mining Act). In relation to the EP Act, the lake-based mining operations that commenced between 2000 and 2010 were originally regulated under Ministerial Statement No. 548 (MS548). MS548 covered mining at open cut pits and underground operations, construction of waste rock dumps, access infrastructure and mining support facilities on the lake. All land-based operations to date have been managed under the Part V of the EP Act and the Mining Act.

A proposal to continue operations (the Beyond 2010 Project) was originally considered by the Environmental Protection Authority (EPA) in 2010 pursuant to Part IV of the EP Act. This assessment was undertaken via a Public Environmental Review (PER) and resulted in the publication of EPA Report No. 1809 which recommended approval of the Beyond 2010 Project subject to a number of conditions. The Minister for the Environment published Ministerial Statement No. 879 (MS879) in November 2011 formally approving the Beyond 2010 Project subject to a number of binding conditions. Under MS879, lake-based mining, exploration and dewatering activities are permitted within delineated footprints. MS879 provides sufficient mining capacity until the end of 2018 after which further operational areas are required to maintain the operational continuity.

2.2 *The Current Proposal*

The objective of the B2018 Project is to ensure the continuation of gold mining and processing operation at St Ives beyond 2018. The B2018 Project will require an expansion outside of the existing disturbance footprint approved within MS879 with the aim to provide sufficient ore reserves to facilitate mining for a further ten years (i.e. to 2028).

A continuation of mining and processing methods currently in use is proposed. Notwithstanding this, alternative methods for cost-effective and safe mining are always under consideration and, in the event that a substantive change is desired that would alter the impacts of the B2018 Project, SIGMC understands that further consultation, and potentially assessment, may be required at that time.

SIGMC submitted a Referral to the EPA under section 38 of the EP Act on 15 December 2016 regarding the Beyond 2018 Project (Revised Proposal)[2]. Subsequent to the Referral, the EPA set the level of assessment to 'Environmental Review – 6 week public review' pursuant to section 39(1) of the EP Act on 15 February 2017. The Environmental Scoping Document (ESD) for the Project was prepared by the EPA and, following a number of revisions, was approved on 6 October 2017 (EPA 2017) (Appendix B).

The ESD outlines the range of studies required to enable assessment of the significance (or lack thereof) of the project on a range of preliminary key environmental factors. This ERD

[2] Because some of the operations included in the Proposal were previously approved under MS879 it is deemed a 'revised proposal'.

responds to the framework set out within the ESD and reflects the detail within the ESD as well as considering the discussions held between the proponent and various stakeholders (including State Government and the local community).

The Referral to the EPA was based on some initial recommendations from EPAS to better define the project and show “Indicative Disturbance Areas” and their interconnectivity. This approach did not align with SIGMC’s expectations in terms of the project and its intent but was pursued on the basis of the discussions held between EPAS and SIGMC. Subsequent discussions held after the Referral resulted in EPAS agreeing that the definition provided as part of the Referral potentially resulted in unwanted project constraints. These discussions culminated in a Change to Proposal under section 43A of the EP Act being submitted by SIGMC on 8 May 2017 to reflect the changes to the proposed Development Envelope and the dewatering discharge volumes.

As a result of this request from EPAS, SIGMC opted to revert back to their original intent to create one Development Envelope within which the overall disturbance associated with B2018 could take place. Subsequent to this, technical studies undertaken have also provided greater clarity on the B2018 Project design and potential environmental impacts and have also provided some further clarification around the expected maximum dewatering discharge volume which was increased from 30 GL to 40 GL, as reflected in the Key Characteristics Table.

2.3 *Justification*

This section details the rationale and benefits of the proposal and summarises the alternative options considered by the SIGMC and how the final B2018 Project design has been optimised to minimise environmental impacts from the proposal.

2.3.1 Project Rationale and Benefits

Gold mining is the second largest employer in the mining sector, providing jobs (directly and related) for more than 55,000 Australians. As Australia's third largest export industry, the gold industry generates annual exports in excess of $16 billion (Rush 2016). In 2016, 280 tonnes of gold was produced making Australia the second largest gold producer after China.

St Ives has produced in excess of 10.5 million ounces of gold, with the first major gold mining commencing in the mid-1980s. The continued exploration success and drilling of the mine’s extensive greenfields project pipeline has consistently led to further discoveries and new mines. In 2016, St Ives was ranked the 7th largest gold producer in the state with the production of almost 400,000 ounces of gold. It currently supports over 800 staff and contractors. The site operates mainly on a residential basis with 96% of the employees and 93% of the contractors living locally either in Kalgoorlie, Kambalda or other regional towns resulting in significant benefits to the local community. The St Ives operation has produced a significant revenue stream for both the Commonwealth and Western Australian governments in the form of taxes and royalties.

Further to the benefits of direct local employment, SIGMC has contributed heavily to the local community and economy. SIGMC and its personnel continue to be an important part of the local Kambalda community and its local activities. Through both the Gold Fields Australia Foundation and St Ives’ Community Endeavour Team (CET) sponsorships, numerous community facilities, groups and events near St Ives have benefitted from GFA’s support. These contributions have included assisting in the construction of the Kambalda Community Recreation Facility, establishment of a child-care centre, helping to re-establish a doctor’s service at the local Nursing Post and sponsoring land sailing championships, an international tennis tournament, swimming pennants and a local basketball team (Gold Fields Limited 2013).

The SIGMC budget for community support is currently managed to include education, training, arts & culture, sport and charity. Specific support is provided to:

- Shire of Coolgardie Basket Ball;
- Goldfields Children's Charity Fund;
- Kambalda Jnr football club;
- Kambalda High School football umpires;
- Kambalda Primary School camp;
- RSL Anzac Day;
- Hockey Association;
- Kambalda Swimming Club;
- Golden Open Squash;
- Police & Citizens Club;
- Boulder Rotary;
- Gemia Careers;
- Kambalda School Camp (juniors);
- Goldfields Golf Club – Ladies Charity Event;
- Kart Club;
- Triathlon Club;
- Full circle therapies;
- Tee ball Association;
- Kambalda Men's Shed; and
- Kambalda Xmas tree.

These benefits and others will continue to be realised through the continuation of the St Ives operations in to the future.

The B2018 Project ensures the continuation of the St Ives beyond 2018. The B2018 Project will require an expansion outside of the existing MS879 approved disturbance footprint (2,061 ha) to facilitate mining for a ten year period (i.e. to 2028).

It is important to recognise that the Project does not consider an intensification of activities or an increase in the rate of mining. In actual fact, the proposed maximum areas of disturbance are based on the previous years' activities and represent a business-as-usual approach, both in terms of rate of mining as well as the approach to operational and environmental management.

In securing the approvals for B2018 as proposed, SIGMC aims to avoid piece-meal and fragmented approvals approach and instead implement a strategic and holistic approvals pathway in to the future. The approach allows SIGMC to plan longer in to the future and plan for considered and long-term operations, closure and rehabilitation, thus resulting in a better environmental outcome over this duration as compared to an approach involving multiple approvals.

Implementation of the B2018 Project will also reduce regulatory ambiguity between relevant decision making authorities and subsequently reduce the regulatory burden on both the regulator and SIGMC. This will also be achieved through the benefit of longer-term operational surety and an ability to strategically plan across all statutory processes.

The B2018 Project will see the continuation of the current investment in exploration of approximately $38 million per annum. It is estimated that through this investment, St Ives will continue to maintain a production profile of approximately 350-400,000 ounces per annum.

Approval of the project will also result in further regional and local economic and community benefits which can be provisioned for further into the future, including but not limited to:

- Contribute to royalty and taxation payments;
- Contribute to value of exports;
- Continue providing direct and indirect employment and contracting opportunities within the Goldfields region; and

- Contribute to local social and economic development projects.

This provides more certainty to the recipients and greater surety regarding the future of the various entities who receive the benefit.

In considering the impacts of the project, it is important to recognise that whilst a 'traditional' focus of an EIA would reflect the negative aspects of the project, the positive benefits that may result from the project should also be considered. Generally speaking and certainly in relation to the B2018 project, such benefits are largely social in nature.

The EP Act (1986) defines the environment to mean "living things, their physical, biological and social surroundings, and interactions between all of these." It further clarifies this by noting that "For the purposes of the definition of environment in subsection (1), the social surroundings of man are his aesthetic, cultural, economic and social surroundings to the extent that those surroundings directly affect or are affected by his physical or biological surroundings". This definition is wide-ranging and incorporates impacts to aesthetics, culture, economics and social surroundings. The EP Act does not draw a distinction between positive and negative impacts in relation to social impacts.

The EPA's Environmental Factor Guideline relating to Social Surroundings (EPA 2016f) provides commentary that "for the EPA to consider social surroundings as a factor in EIA, a proposal's or scheme's effect on social surroundings, via its effect on the physical or biological environment, must be significant", this appears to be inconsistent with the definitions described within the EP Act itself. The Guideline also notes that "While the EP Act defines social surroundings to include a person's economic surroundings, this does not mean that a proposal's economic benefits, such as job creation or revenue generation, can be considered as part of EIA under Part IV of the EP Act." It further goes on to state that "While EIA of impacts to economic surroundings is not common, the EPA will consider significant economic impacts resulting from any significant impact of a proposal or scheme on the physical or biological surroundings." This approach appears to consider only the negative aspects of a project from a social (and economic) perspective and appears contrary to overall framework of the EP Act itself. Certainly the St Ives operations have a strong positive impact on the local community (and wider) and such impacts will continue with the B2018 project and should therefore be balanced against the negative impacts of the project.

The New South Wales (NSW) Government's Department of Planning and Environment's (DPE) 2017 "Social Impact Assessment Guideline" provides contemporary information as to their consideration of social impacts and how they should be considered within the framework of an EIA. What is interesting is that Guideline gives specific weight to the positive impacts a project might have and the fact that these should be considered within the EIA process just as much as the negative impacts are. Such positive impacts can include (DPE 2017):

- Community investment targeted at social development, and associated enhancements to sense of place,
- Health, wellbeing and community cohesion
- Local and regional employment (direct and indirect) opportunities, and associated increases in living
- Standards and community wellbeing
- Business and procurement opportunities for local and regional small and medium-sized enterprises
- Building local and regional workforce skills
- Contributions towards, or the development of, shared infrastructure
- Facilitating or supporting initiatives aimed at community development, capacity building and strengthening
- Community institutions
- The payment of royalties.

Such benefits are real and relevant to the B2018 project and should therefore be considered with respect to the overall EIA process given the commentary above in relation to local, regional and state-wide benefits.

2.3.2 Evaluation of Project Alternatives

There is limited potential for alternatives to the Beyond 2018 Project as proposed. These limitations include:

- The existing location of substantial infrastructure used for the mining program to date, including the Lefroy Mill and associated tailings and water storage facilities, power supply and transport infrastructure;

- The location of gold resources across SIGMC tenure, some of which are known and some of which are still being 'proven'; and

- The lack of viable alternative methods to existing approaches to mining and processing.

The general approach is essentially unchanged from that assessed in MS879. However, this document identifies some areas where particular initiatives not previously adopted can improve environmental management outcomes. The key initiatives are included as Commitments in this document.

2.3.2.1 Delineation of Development Envelope

The location of the B2018 pits will be dictated by the location of ore reserves and will reflect the exploration work that has been completed and the preliminary resource definition. During the Project referral stage and based on initial guidance from EPAS, SIGMC considered a number of development envelope options mainly based on the indicative location of ore. The aim was to minimise environmental impacts from the development and afford the EPA better clarity in terms of the overall project footprint and its potential for impact. Despite this, it became apparent that such definition afforded less flexibility to the B2018 Project and limited the opportunity for project development and refinement and took away from the original intent of the project. The location and extent of the final Development Envelope was then discussed and agreed in co-operation with the EPA, resulting in a change being approved pursuant to section 43A of the EP Act.

The final Development Envelope was settled on based on the work completed by SIGMC in terms of resource definition and affords the company both the flexibility to work within the Envelope as well as an opportunity to plan efficiently and appropriately from an environmental perspective. The outcome provides a flexible approach to operational continuity within a framework of rigorous environmental assessment and management.

2.3.2.2 Tailings Disposal

The main consideration for tailings disposal was whether the B2018 Project could utilise in-pit or above ground tailings storage facilities (TSFs). St Ives has four above ground TSFs, none of which were operational at the time of preparation of the ERD with active tailings deposition occurring in the Leviathan in-pit TSF. This TSF will also be utilised for the B2018 Project and has an estimated capacity of around eight years of tailings production.

More disposal capacity is therefore needed and options for other in-pit TSFs were considered as part of the B2018 Project planning for inclusion within the ERD. The studies completed to date have indicated there are no suitable sterilised open pits for tailings disposal so it is possible that further above ground storage capacity will be needed to accommodate tailings from the Project.

The location and design of the TSFs will be dictated by the following:

- Hydrogeology of the area;
- Hydrological and hydraulic factors;
- Geotechnical and geochemical factors; and
- Operational restrictions and distance to the Lefroy Mill.

Many of these aspects are considered and discussed elsewhere in this ERD. Furthermore, approval of these facilities (be they above ground or in-pit) will be subject to additional design requirements as required by the approval processes undertaken pursuant to Part V of the EP Act and the Mining Act.

2.3.2.3 Dewatering and Dewatering Discharge

Mining at St Ives generally requires the dewatering of both open pits and underground operations given the location of groundwater and the presence of a palaeochannel within the SIGMC tenure. Groundwater is hypersaline and has been, and is currently, discharged to the surface of Lake Lefroy via specific discharge structures in accordance with specific and approved SIGMC controls. This practice is proposed to continue for the B2018 Project. The main consideration for dewatering discharge is the location of the discharge points. Hydrological and hydrogeological modelling undertaken has considered different locations aiming to minimise potential environmental impacts. The final location of the discharge points will be decided as part of the detailed project design and the following will be considered:

- Impact to the surface hydrology on Lake Lefroy;
- Impact to the riparian section of Lake Lefroy;
- Impact on the thickness of salt crust; and
- Total discharge volume and its distribution on the lake surface.

As with other aspects of the B2018 Project, a longer-term, holistic view provides a much greater opportunity to manage the issues of dewatering discharge from a strategic perspective and allows for consideration of a conservative ‘worst-case’ outcome from a dewatering perspective. Discharges to Lake Lefroy can be considered over the entire project duration and a strategic and prospective approach to management can be developed and employed, thus resulting in a more sustainable and manageable environmental outcome.

2.3.2.4 Option Not to Implement the Project

SIGMC has considered various alternatives to the Project including the option not to proceed. It should be noted that the accessible ore reserves are currently limited and with the known reserves St Ives is only able to operate until the end of 2020.

In simple terms, this would result in a significant loss of jobs, loss of benefits detailed in Section 2.3.1 and a requirement to commence significant rehabilitation works in areas where further ore is accessible and the resources cannot be sterilised.

In the event that the B2018 Project does not go ahead as described in this ERD, SIGMC would be required to progress approvals for many of the components of the project as resource definition continues, resulting in a fragmented and piecemeal approvals approach. This would mean that expansion to operations is progressed via single small approvals, most likely via the Section 45C process. Consequently, no overall strategic assessment of operations and its impacts could be undertaken by the regulators and long-term project planning could not be considered by the SIGMC given the lack of long-term security around its operations.

In the worst case scenario, the option not to proceed with the Project would mean that the mine would have to shut down and the majority of the employees and contractors would lose their jobs. The closure of the SIGMC operations would also have local and wider impacts to the

community as the Town of Kambalda mainly relies on the mining within the area and St Ives is one of the biggest employers within the region. Such impacts would be immediate and largely unexpected given the understanding of the SIGMC operations and expectation of a long-term, sustainable operation. The economic and social implications of closure would be widespread - far wider than just Kambalda - given the likely loss of jobs, livelihood and the impacts to the wider business and community.

In DEP (2017), it is noted that the "positive social impacts of a project will be of relevance when assessing the merits of the proposal." A recognition of these benefits and seeking to enhance them can "help to enhance the social licence for, or community acceptance, of a project, among other potential benefits." Based on the work conducted in relation to the B2018 project, it is fair to say that there is general acceptance of the project at a local level and likely at a regional level. The project will continue to provide benefits to Kambalda over its duration and will afford some level of certainty to the local community in terms of the future of the mine and its operations. Where the project does not proceed, such benefits will be lost.

2.3.3 Optimisation of the Proposal

An evaluation of project alternatives has been undertaken in the previous sections. These alternatives have been considered on the basis of maximising the access to available resources and minimising the resulting environmental impacts. The B2018 Project as proposed provides the greatest opportunity for long term certainty of operations within a framework of sustainable operations and environmental management. It allows for strategic long term planning to be undertaken by SIGMC and a commensurate regulatory regime to be developed. As B2018 Project definition progresses, the project footprint and operational aspects will be further optimised in keeping with this approach, in order to:

- Reduce total project footprint;
- Optimise location of operational areas to avoid environmentally sensitive areas;
- Minimise the area of disturbance by undertaking progressive rehabilitation; and
- Improve energy, water and process efficiencies.

2.4 *Proposal Description*

2.4.1 Overview

The primary objective of the B2018 Project is to ensure the continuation of the St Ives Gold Mine beyond 2018. The B2018 Project will require an expansion outside of the existing MS879 approved disturbance footprint with the aim being to provide sufficient ore reserves to facilitate mining for a ten year period (i.e. to 2028). This continuation of operations is unlikely to require a change to the current mining or processing methods. Notwithstanding this, alternative methods for cost-effective and safe mining are always under consideration and in the event that a substantive change is desired that would alter the impacts of the B2018 Project, this will be discussed with relevant regulators at the time.

Given the difficulties in defining ore reserves over such a period of time, the proposal put forward by SIGMC is not based on a defined project footprint but rather an approach that includes both terrestrial and lake-based tenure within a set disturbance limit. This approach maximises operational flexibility over the 10-year operational timeframe for the proposal and minimises the need to revert back to the EPA as new resources and operational areas are defined. Such an approach also aligns with SIGMC's long-term approach to mine closure and rehabilitation and maximises the opportunity to take a strategic approach to approvals, operations and long-term plans for closure. The approach also provides some level of certainty for the stakeholders who benefit from the continuation of the operations (including the town of Kambalda).

The maximum proposed disturbance is up to 5,000 ha which consists of:

- Lake based disturbance of approximately 200 ha per year over a ten year period with a total maximum disturbance of up to 2,000 ha; and
- Land based disturbance of approximately 300ha per year over a ten year period with a total maximum disturbance of up to 3,000 ha.

Coupled with the existing, approved disturbance associated with the SIGMC operations, the proposed disturbance results in up to 9,146 ha of total disturbance consisting of 4,061 ha of lake disturbance and 5,085 ha of land disturbance within the Development Envelope.

The key elements of the B2018 Project are:

- New open cut pits;
- New underground operations;
- Expansions to existing open cut pits and underground operations;
- Construction of new waste rock landforms;
- Construction of new tailings facilities;
- Construction of mining and ancillary infrastructure (workshops, offices, laydown areas etc.);
- Construction of new dewatering discharge structures; and
- Increase in dewatering discharge volume.

Throughput in the Lefroy Mill may increase but will remain within the existing design capacity and licence limits currently applied under Part V of the EP Act.

2.4.1.1 Mining Method

Open pit mining within the B2018 Development Envelope will be conducted using conventional Drilling, Blasting, Loading and Hauling (DBLH) methods. “Drill and blast” is not generally required during the mining of the lake sediments and oxide material. Explosives are typically used only for blasting of transitional and fresh rock which can be encountered in both land-based and lake-based mining.

Examples of current land-based and lake-based open pit operations are shown in Plate 2-1 and Plate 2-2 below.

Plate 2-1: Athena open pit and TSF2 in background

Plate 2-2: Santa Ana, Bahama and Intrepid open pits and waste rock landforms

2.4.1.2 Gold Processing and Transport

The B2018 Project operations will be supported by existing infrastructure within and outside the Development Envelope. Milling and processing of the ore will be undertaken at the Lefroy Mill located on Lefroy Peninsula (Plate 2-3). The Lefroy Mill is a conventional ore processing facility comprising:

- Crushing and coarse ore storage;
- Grinding and classification;
- Gravity separation;
- Leaching and adsorption;
- Elution and electrowinning;
- Tailings thickening and disposal to a storage facility; and
- Reagent mixing and storage.

Plate 2-3: Lefroy Mill with Lake Lefroy in background

The current capacity of the Mill is approximately 4.8 Mtpa which allows production of up to 600,000 oz of gold per annum at a recovery rate of 94% (Gold Fields Limited 2013).

No additional source of water will be required for ore processing with existing sources adequate to meet requirements.

Access to the mine will be through the existing haul road network which will expand to connect with additional deposits as they are developed. Ore will be transported from the ROM pads by road trains to the Lefroy Mill.

2.4.1.3 Waste Rock and Tailings Management

Waste rock from the B2018 operations will be placed into waste rock landforms (WRLs) that are typically constructed close to the open pit and underground (UG) operations. The height of the WRLs will continue to be limited to 40 m both on land and on lake but are generally likely to be smaller than this. Where it aligns with mining operations, waste rock will be progressively backfilled into sterilised open pits. Sterilised pits are those pits in which little or no mineable resource remains and there is no prospect of further mining at a future date.

In accordance with the current site procedure based on MWH (2016a), waste rock is sampled regularly. In the event that Potentially Acid Forming (PAF) material is encountered, it will be selectively segregated and:

- Placed within open pits below the final water table level and capped with non-acid-forming (NAF) material, or
- Encapsulated within the WRLs under a minimum of 2 m layer of competent rock.

The risk assessment undertaken to determine the likelihood of encountering PAF material within the Development Envelope is contained in Section 4.6. This assessment shows that, of the tested lithologies, Kapai Slate had the highest overall AMD risk.

Tailings produced as a result of B2018 Project will be disposed of to one of the active TSFs (either those that are currently approved or one which will be approved in future). The residual tailings pulp from the gold processing is thickened to a pulp density of approximately 55% solids prior to discharge into the tailings pump hopper. Tailings are then pumped to the active TSF.

SIGMC currently utilises Leviathan in-pit TSF, but further tailings disposal options will be investigated during the B2018 Project. These are likely to include utilisation of other sterilised pits as an in-pit TSF or construction of new above-ground facilities. The lake environment will not be utilised for above-ground facilities.

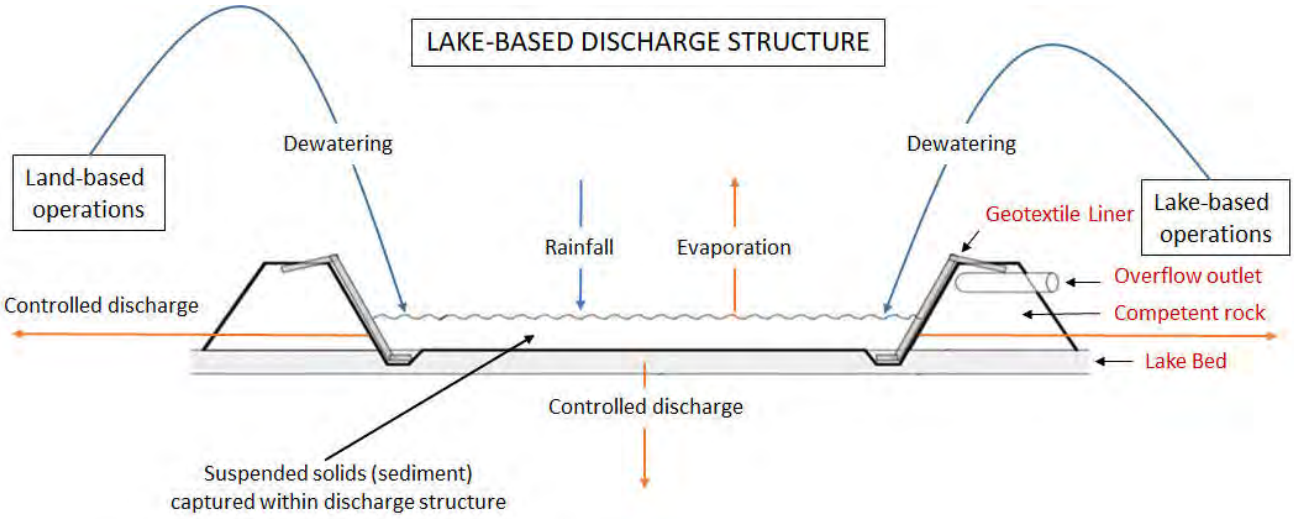
2.4.1.4 Mine Dewatering and Discharge

SIGMC currently discharges mine dewatering to the lake via discharge structures (Figure 2-1) that are designed to retain sediments and suspended solids while releasing ‘clean‘ water to the surface of the lake. The discharge is licensed under the *Environmental Protection Act 1986*.

The annual dewatering volumes will increase slightly as a result of expansion to the operations and processing facilities (refer to Section 4.5 for further detail on predicted volumes). While the current rate of discharge is well below 30 GL per annum, SIGMC expects the requirement for dewatering could increase under the B2018 Project, and seeks a 10 GL per annum increase to provide a conservative upper limit for dewatering discharge.

SIGMC is also proposing new discharge structures to allow expansion to operations. The locations of these structures will be determined based on the studies completed as part of the B2018 Project. Key considerations will be maximising operational efficiencies and minimising environmental impacts.

Figure 2-1: Current dewatering discharge practice which will continue under the Beyond 2018 Project proposal



2.4.2 Key Characteristics of the Proposal

The key characteristics of the proposal are set out in Table 2-1 and Table 2-2. The key proposal characteristics may change as a result of the findings of studies and investigations conducted and the application of the mitigation hierarchy by the proponent.

Table 2-1: Summary of the Proposal

Proposal title	St Ives Gold Mine - The Beyond 2018 Project (Revised Proposal)
Proponent name	St Ives Gold Mining Company Pty Ltd
Short description	The Beyond 2018 Project comprises expansion of the existing open-cut and underground gold mining developments at Lake Lefroy, approximately 20 kilometres south east of Kambalda. The total additional disturbance proposed is up to 5,000 ha over a ten year period, with a maximum of 2,000 ha of lake-based disturbance and 3,000 ha of terrestrial disturbance. The maximum annual dewatering volume is 40 GL.

2.4.3 Development Envelope

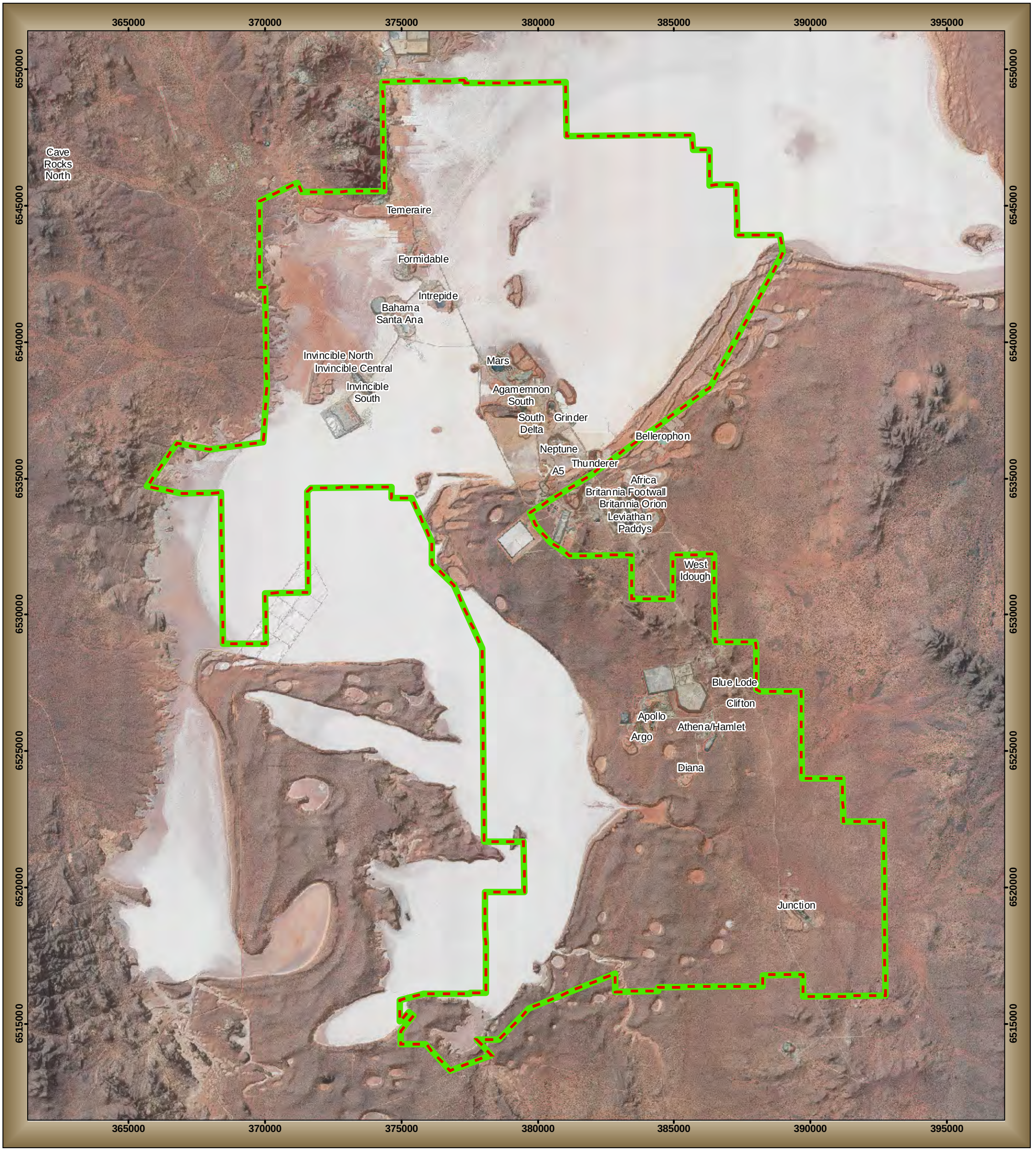
SIGMC has defined a 'Development Envelope' for the B2018 Project in accordance with the 'EPA Instructions on how to prepare an Environmental Review Document' (EPA 2016i). This area delineates the area in which SIGMC is seeking approval to implement the proposal. The total area of the Development Envelope is 45,013 ha. The boundary of the Development Envelope will constitute the boundary of the Project within the new MS if approved.

Figure 2-2 illustrates the extent of Development Envelope.

Table 2-2: Beyond 2018 Project - Location and Proposed Extent of Physical and Operational Elements

Element	Existing Approval (MS879)	Other Approval	Proposed Change	Total Proposed Extent
Physical Elements				
Lake-based operations	2,061 ha	N/A	2,000 ha	4,061 ha
Land-based operations	N/A	2,085 ha (under *Mining Act 1978*)	3,000 ha	5,085 ha
Operational Elements				
Mine dewatering and discharge	N/A	30 GL per annum (regulated under Part V of the *Environmental Protection Act 1986*)	Additional dewatering of up to 10 GL annually.	Up to 40 GL annually (regulated under Part V of the *Environmental Protection Act 1986*).
Area of direct riparian zone disturbance	Up to 90 ha	N/A	Additional 20 ha	Up to 110 ha
Waste rock disposal	A minimum of 95 million tonnes.	Approximately 118 million tonnes (regulated under *Mining Act 1978*).	Approximately 450 million tonnes.	Approximately 663 million tonnes (regulated under *Mining Act 1978*).
Height of waste rock landforms	Up to 40 m	Up to 40 m (regulated under *Mining Act 1978*)	No change.	Up to 40 m.
Ore processing	NA – regulated under Part V of the EP Act and Mining Act.	DWER licensed operational throughput up to 9 Mtpa.	No change.	DWER licensed operational throughput up to 9 Mtpa.
Tailings disposal	N/A	Four above ground TSFs and five in-pit TSFs (regulated under Part V of the *Environmental Protection Act 1986* and *Mining Act 1978*).	Additional above ground or in-pit tailings storage capacity.	Above ground and in-pit TSFs (regulated under Part V of the *Environmental Protection Act 1986* and *Mining Act 1978*).

Figure 2-2
Development Envelope



LEGEND

Development Envelope

0 3 6 9 12

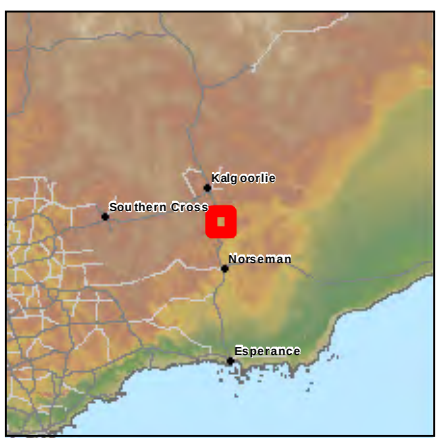
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	26/07/2018

LOCALITY MAP



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2.4.4 Development of the Mining Operations

SIGMC proposes to commence operations associated with the B2018 Project within the first Quarter of 2019 subject to all relevant approvals being granted. The mining is expected to span a period of ten years until the end of 2028. The mining schedule will be dependent on market conditions, receipt of the relevant regulatory approvals to allow mining, and the ongoing process of resource definition.

2.5 Local and Regional Context

2.5.1 Land Use

The Eastern Goldfields subregion totals 5,055,623 ha, with approximately 11.4% freehold (576,435 ha), and 88.4% Crown land. The primary land uses comprise Unallocated Crown Land (UCL) (42.1%, 2,128,895 ha), other Crown Reserves (4.8%, 243,185 ha), Conservation and Natural Environments (62.5% 3,159,827 ha), Production from Native Environments (37.4%, 1,893,206 ha), and Production from Dryland Agriculture and Plantations (0.04%, 1,899 ha) (IBRA 2016). Note the values for these 'land uses' do not add up as some of the categories overlap, for example some areas that are classified as UCL are also classified as Conservation and Natural Environments (MWH 2016b).

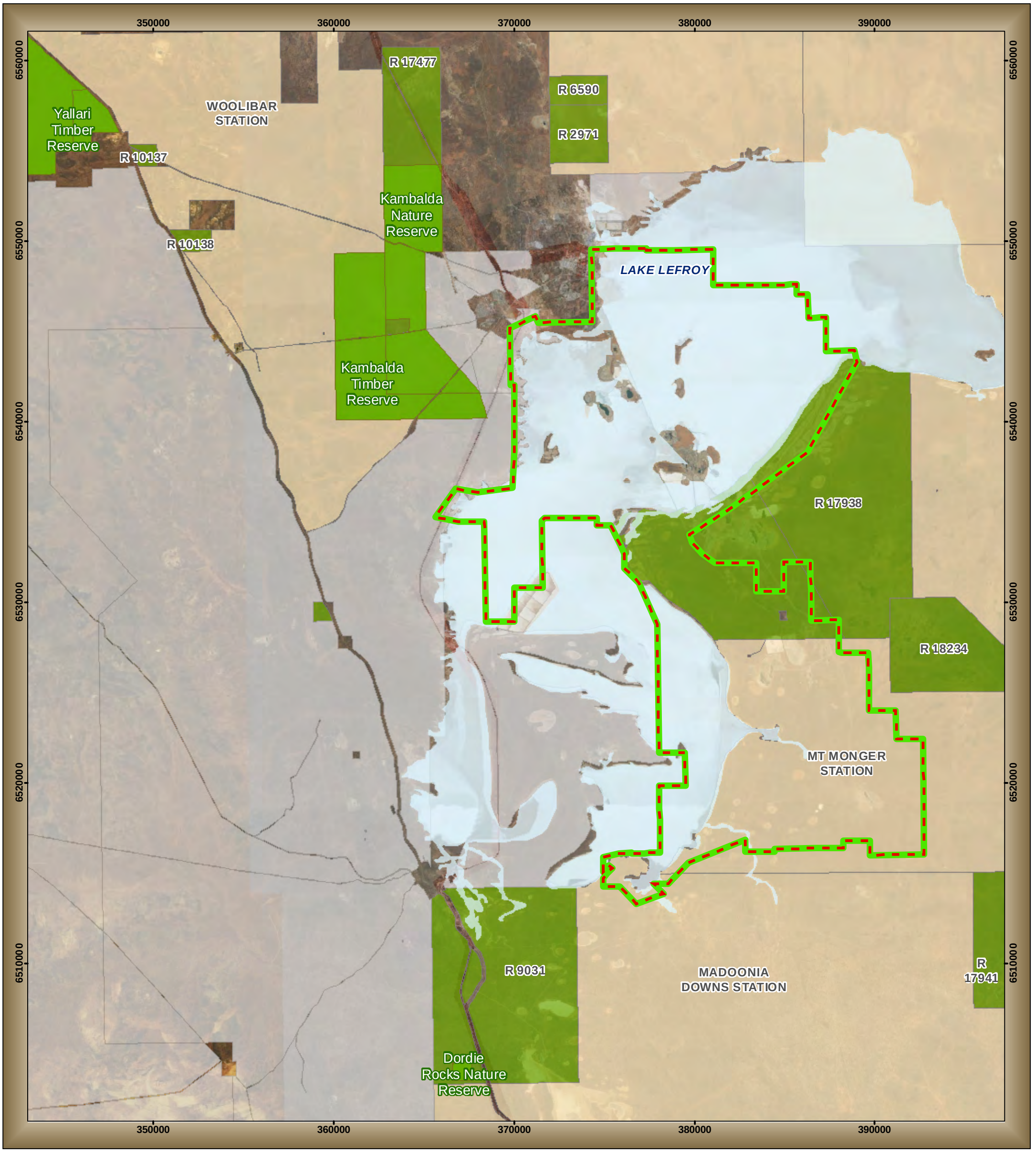
Mining and mineral exploration tenure covers the entire Development Envelope. However, activities associated with this tenure are currently confined to within the northern portion and to the east of Lake Lefroy. Land use around the B2018 Project is shown in Figure 2-3.

Past and present land uses within and around the Development Envelope include:

- Gold and nickel prospecting, exploration and mining activities since 1897;
- Salt mining which was conducted at the southern end of Lake Lefroy near Widgiemooltha during the 1940s. Lake Lefroy Salt Mining Pty Ltd harvested salt from evaporation ponds at the northern end of the Lefroy Peninsula between 1968 and 1982;
- Sand mining which was conducted periodically at the northern end of the Lake Lefroy Peninsula;
- Pastoral land located throughout the region and being the main land use other than mining in the vicinity, with the Project located within or adjacent to the Woolibar, Madoonia Downs and Mt Monger Pastoral Stations. Sheep grazing is also noted to occur in UCL and other Crown Reserves in the local area;
- Crown Reserves (R17938, R18234 and R9031) of which only R17938 occurs within the Development Envelope. The purpose of this reserve is "Common" and it is vested in the Department of Planning, Lands and Heritage;
- Conservation, outside the Development Envelope comprising the following:
    - C Class Kambalda Timber Reserve. The Cave Rocks development lies within this reserve; and
    - C Class Kambalda Nature Reserve. The Caves Haul Road lies within this reserve.
- Recreational activities associated with the lake and the surrounds, including wildlife photography, camping, walking and hiking, motorbike riding, and land yacht sailing.

Figure 2-3
Surrounding Land Use

GOLD FIELDS
ST IVES GOLD MINE



LEGEND

Development Envelope

Land Usage

- DBCA Conservation Park
- Other Reserves
- Pastoral Lease
- Vacant Crown Land

0 4.5 9 13.5 18

Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
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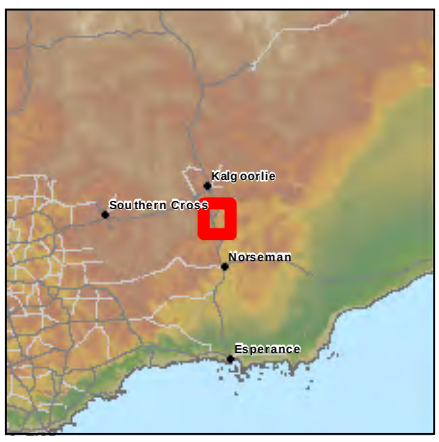
LOCALITY MAP



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2.5.2 Other Developments

Lake Lefroy and surrounds have a long history of mining operations and the area has been extensively mined over the years. There are number of other mining operations that are located in areas surrounding Lake Lefroy. The current operations close to B2018 Development Envelope include:

- Salt Lake Mining Pty Ltd – Beta Hunt UG operation (gold);
- ACH Global Pty Ltd – Foster and Jan Shaft Nickel Mines within SIGMC tenure (nickel);
- Independence Group NL (IGO), a wholly owned subsidiary of Lightning Nickel Pty Ltd – Long UG operation (nickel);
- BHP Nickel West – Kambalda concentrator (nickel);
- Panoramic Resources Ltd – Lanfranchi Nickel Mine (nickel); and
- Mincor Resources NL – Kambalda land holdings (gold and nickel).

Other developments within and around Lake Lefroy are shown in Figure 2-4.

2.5.3 Biophysical Environment

2.5.3.1 Regional Setting

The SIGMC tenure is located within the Eastern Goldfields Province in the Archaean Yilgarn Craton of Western Australia (Witt 1993). The regional topography is gently undulating with occasional ranges of low hills. Soils are principally brown calcareous earths and are poorly developed over the gold-bearing greenstone belts (Beard 1990). Saline and subsaline soils are common adjacent to drainage channels and salinas. Groundwater salinity in the region is generally in the range of 50,000 to greater than 300,000 mg/L Total Dissolved Solids (TDS).

The Project will operate on and around Lake Lefroy, a hypersaline lake covering an area of approximately 554 km^2. Playa lakes such as Lake Lefroy are prominent within the Salinaland Division and occur as dendritic and partly interconnected chains that outline fossil drainage systems (Dames and Moore 1999).

The B2018 Project falls within the Interim Biogeographic Regionalisation of Australia (IBRA) Eastern Goldfields (COO3) subregion – Coolgardie 3 (Thackway and Cresswell 1995) which is characterised by Cowan (2001) as:

- gently undulating plains interrupted in the west with low hills and ridges of Archaean greenstones and in the east by a horst of Proterozoic basic granulite;
- tertiary soils dominated by calcareous earths overlay eroded gneisses and granites;
- a series of large playa lakes, including Lake Lefroy, indicate the remnants of an ancient major drainage line in the western half;
- vegetation consisting of mallees, Acacia thickets and shrub-heaths on sandplains; and
- dwarf shrublands of samphires persist on salt lakes, surrounded by diverse Eucalyptus woodlands, which also occur on ranges and in valleys.

Figure 2-4
Other Developments Within the Lake Lefroy Region

ST IVES GOLD MINE

365000 370000 375000 380000 385000 390000 395000

6550000 6545000 6540000 6535000 6530000 6525000 6520000 6515000

ML 15/140 Mincor Kambalda (Mincor Resources NL)
ML 15/131
Long Underground (Independence Group NL)
M 15/1761
Nickel West – Kambalda Concentrator (BHP Billiton Nickel West Pty Ltd)
ML 15/150
Beta Hunt UG Operation (Salt Lake Mining Pty Ltd)
M 15/1529
Foster (ACH Nickel Pty Ltd)
M 15/1549
Jan (ACH Nickel Pty Ltd)
M 15/1556
Lanfranchi (Panoramic Resources Ltd)
ML 15/486

LEGEND

Development Envelope

Commodity

Gold

Nickel

Gold and Nickel

Tenement

0 3 6 9 12

Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
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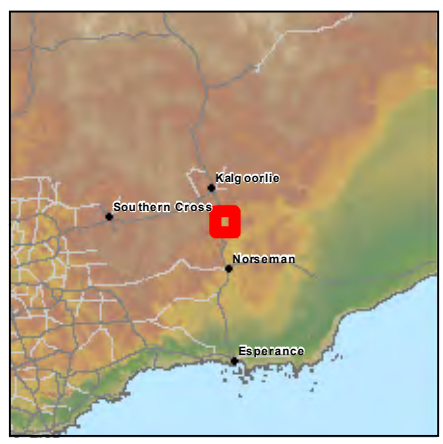
LOCALITY MAP



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The Eastern Goldfields subregion is known for its high floristic species and ecosystem diversity, in particular *Eucalyptus* spp., *Acacia* spp. and ephemeral flora communities (Cowan 2001). The western area of the subregion is characterised by several large salt lakes, the remnants of ancient major drainage lines. The subregion is a transitional vegetation zone where mulga and spinifex country is beginning to be replaced by eucalypt woodland (Bastin and ACRIS Management Committee 2008). The broad vegetation type comprises Mallee, *Acacia* thicket and shrubheath on sandplain, with a diverse *Eucalyptus* woodland around salt lakes, on ranges, and in valleys (Cowan 2001). The area is also rich in endemic Acacia species. Dwarf samphire shrubland (*Tecticornia* spp.) dominates the fringing vegetation of salt lake systems. Flora and fauna records from the subregion list more than 30 threatened mammal, bird and plant species (Cowan 2001), at risk through grazing by stock and the proliferation of feral animals including goats, foxes, rabbits, camels, cats and dogs.

No conservation reserves or environmentally sensitive areas (ESAs) are present within the Development Envelope. The nearest conservation reserve is Dordie Rock Nature Reserve situated approximately 14 km south-west of the B2018 Project. According to the results of the Department of the Environment and Energy (DEE) Protected Matters Search Tool and DBCA database searches, the Eastern Goldfields subregion contains no Ramsar wetlands (DoE 2013) or threatened ecological communities (TECs). The nearest priority ecological community (PEC) comprises the vegetation complexes of Lake Giles (~200 km to the northwest of Lake Lefroy), the plant assemblages of the Fraser Range vegetation complex (~140 km southeast) and the plant assemblages of the Woodline Hills (~100 km southeast) (DBCA 2016a). In the vicinity of St Ives, a number of tenements also overlap the C Class Kambalda Timber Reserve and the C Class Kambalda Nature Reserve but the Development Envelope for this proposal does not extend to these reserves.

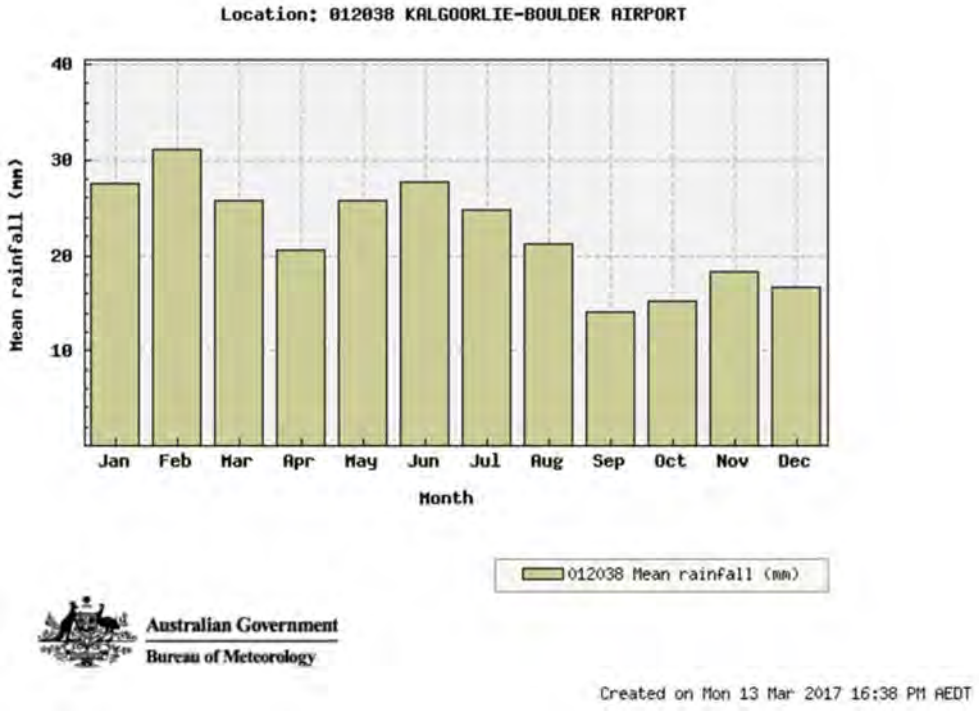
The only Western Australian wetland of national importance in the region, the Rowles Lagoon system (DoE 2010), is located more than 100 km northwest of Lake Lefroy in the 404 ha Rowles Lagoon Conservation Park (reserve no. 4274). This system is the largest semi-permanent, freshwater wetland in the Eastern Goldfields subregion (CALM 2000). It has a longer water retention period than any other wetland in the subregion (CALM 2000) and, following a major inundation event, comprises ponds and marshes that provide a range of feeding, breeding and sheltering habitat for large numbers of water birds. A number of wetlands of sub regional importance, listed within the literature, occur within 200 km of St Ives and include Swan Lake (~100 km northeast), Lake Cowan (~50 km south) and Lake Arrow (~80 km north northwest) (Cowan 2001).

2.5.3.2 Climate

The Eastern Goldfields bioregion is characterised by a semi-arid climate with hot summers and mild winters, often described as a Mediterranean climate. The mean maximum temperature for City of Kalgoorlie-Boulder (CKB) ranges between 33.6ºC in January and 16.7ºC in July, as recorded at the Bureau of Meteorology (BOM 2017) Kalgoorlie-Boulder Airport weather station (BOM Station 012038).

The region experiences a semi-arid climate, with 266.8 mm of rainfall received on average (Figure 2-5). The BOM 78-year rainfall record indicates that the highest daily rainfall recorded to-date is 177.8 mm (BOM 2017). February is the wettest month with 31.1 mm on average received, although rainfall patterns can be quite variable. Remnant tropical cyclones and thunderstorms associated with cyclonic activities in the North of the WA can occasionally bring heavy rains and result in flooding in the summer period. Annual evaporation rates of 2400 – 2800 mm/year exceed rainfall and are the highest during the summer months when humidity is the lowest. Heavy rains occasionally cause localised flooding but surface water bodies typically remain only for short periods of time after rainfall.

Figure 2-5: Mean Rainfall (1939-2017) (BOM 2017)



The average wind speeds within CKB vary between 11.8 – 17.1 km/h in the morning, to 13.7 – 17.8 km/h in the afternoon (BOM 2017). The dominant wind directions in spring and winter are from the west and northwest, and can exceed 30 km/h in the afternoon. The dominant wind directions in summer are from the east and south east and can reach speeds up to 30km/h. (BOM 2017).

2.5.3.3 Geomorphology

Regional topography is gently undulating with occasional ranges of low hills. Regional geomorphology within and around the Project consists of salt lakes and fringing saline plains, sandy plains and dunes with halophytic shrublands (Payne et al. 1998).

The Lake Lefroy area consists of erosional and depositional landforms with the flat bed of the lake occupying the lowest part of the landscape. The predominant landforms are broad, level or gently inclined plains with loamy surfaces, gently undulating plains with lateritic gravel mantles and occasional low hills and ridges on greenstone, basalt and (less frequently) granite (MWH 2016d).

In a geomorphological context, the Kalgoorlie Botanical Province consists of an extensive plateau of low relief; with flat to undulating plains with small valleys. Regionally, the plateau is occasionally broken up by rises of long, gentle slopes and abrupt erosional scars, with occasional narrow rocky hills and ridges (greenstone), and granitic tors and bosses. The slopes are generally level to gently undulating sandplains and gravelly sandplains with little defined drainage and some seasonal lakes. Lower in the landscape, the plains flatten to broad valley floors dominated by chains of salt-lakes and saline flats, with associated claypans, kopi dunes and sand (MWH 2016d).

More locally, the B2018 Project is dominated by gently undulating flat sandy plains sloping gently towards Lake Lefroy. Elevation generally decreases from the north towards the lake shore; and from Junction mine area in the south east towards the lake shore. Ephemeral drainage lines are poorly defined and generally lack incision. The flat lake surface is interrupted by islands of remnant bedrock highs supporting calcrete ridges and aeolian sandy soils. The

islands rise abruptly from the lake surface to form a flat plateau and have occasional gently sloping sandy plains that extend to the lake surface, generally on the lee-side of the island. The lake shoreline consists of depositional features (dune and beach ridges) along the eastern and southern margins, and erosional features (exposed rock of Archean age) along the northern and western margins (Clarke 1991).

2.5.3.4 Geology

The Kambalda - St Ives area lies within the Norseman-Wiluna Belt of the Kalgoorlie Terrane. The Norseman-Wiluna greenstone belt forms the major part of the Eastern Goldfields province. It is flanked to the east by lithologically and structurally distinct greenstones of the Laverton subprovince and to the west (across a major post-tectonic granitoid zone) by the Southern Cross granite-greenstone terrain. In comparison to the other greenstone belts, the Norseman-Wiluna belt is very highly mineralised, particularly in nickel and gold (Connors et al. 2005).

Stratigraphic and structural complexity in the Norseman-Wiluna belt contrasts with the flanking greenstone belts to the east and west, which in turn have much in common and whose stratigraphies can be correlated at regional scales. The Norseman-Wiluna belt is characterised by a paucity of banded iron formation (BIF), but a corresponding abundance of sulphidic sedimentary units, albitic sedimentary units and chert; an abundance of komatiitic rocks; and a chain of discrete felsic volcanic centres. The main stratigraphic units in the Kambalda-Kalgoorlie region include the following (Connors et al. 2005).

- Morgan‘s Island Sandstone;
- Newton Felsic Volcanics;
- Paringa Basalt;
- Kapai Slate;
- Devon Consols Basalt;
- Kambalda Komatiite; and
- Lunnon Basalt.

The style of metamorphism at Kambalda appears to be static, with good preservation of volcanic textures. The structure of the Kambalda-St Ives district is dominated by the broad, open Kambalda anticline which plunges very gently south from the Kambalda dome to the Junction area. This anticline overprints large early thrust wedges of mafic-ultramafic rocks (e.g. Foster, Tramways, and Democrat), and is bounded and abutted by NNW trending faults and shears, including the Boulder-Lefroy, Speedway, Merougil, and Mt Hunt (Yilmia) faults (Connors et al. 2005).

The Kambalda-St Ives area contains a large number of gold ore deposits. Gold mineralisation in the region is recorded in all parts of the Kalgoorlie Group succession, but is best-developed in the upper parts of the Kalgoorlie Group. The best host rocks are generally the more massive, iron rich metamorphosed basalts, dolerites, and sedimentary unit’s upsection of the Kambalda Komatiite Formation (Connors et al. 2005).

General geological descriptions for the B2018 Project area are summarised from internal geological notes (Table 2-3) (MWH 2016d).

Table 2-3: Geological Units of the B2018 Project Area

Geological Unit	Description
Lake Sediment	Occurs as an upper layer of saturated to semi-saturated saline sand and clay. The thickness of the unit varies up to 80 m, but is generally around 10 m thick over lake-based open pits.
Tertiary Sediment	Transported sand, silt and clay in consolidated and unconsolidated sequences up to 25 m thick. The sediments are generally associated with palaeochannels and for lake-based areas may be recorded as Lake Sediments in some geological logs. Rock types also include ferricrete duricrusts, laterite and minor calcrete.
Upper Saprolite	Included are rocks identified as oxide, saprolite, saprolitic clay and saprock. The unit is characterised by a typical deep weathered regolith profile of saprolitic clays with laterite and minor sands.
Merougil Creek Beds	Pale grey to cream volcanic quartz wacke, sandstone, and minor conglomerate units.
Black Flag Beds	Epiclastic and volcaniclastic mudstone, siltstone, sandstone/quartz wacke, conglomerate and breccias.
Interbedded Sediment	Generally a bedded sequence of siltstone and mudstone with minor sandstone and black shales.
Cave Rocks Sediment	Generally logged as siltstone and mudstone with minor sandstone and black shales.
Kapai Slate	Dark grey to black sulfidic volcaniclastic mudstone with cream-coloured siltstone.
Cave Rocks Dolerite / Condenser Dolerite / Defiance Dolerite	Cave Rocks, Condenser and Defiance dolerites are similar, exhibiting a zonation from aphyric (lacking in phenocrysts) to coarse cumulate-type textures. Chemically they are iron-rich and have undergone amphibolite facies metamorphism.
Lunnon Basalt	Dark grey to dark green massive and pillow basalt with lesser shear-associated breccia and rare interflow siltstone. Visually the Lunnon basalt is very similar to the Paringa and Devon Consols basalt.
Devon Consols Basalt	Dark grey to dark green massive and pillow basalt with minor dolerite. Compared to the Lunnon and Paringa basalt, it has higher magnesium and epidote alteration associated with varioles.
Paringa Basalt	Dark grey to dark green massive and pillow basalt with rare interflow sediments.
Tripod Hill Komatiite	This unit included samples logged as Silver Lake Peridotite (high-magnesium member) and ultramafic. The Tripod Hill Komatiite (also known as the Kambalda Komatiite) is a grey-green to grey-purple talc-rich komatiite. It is commonly zoned with a cumulate base and spinifex texture upper component.
Felsic Intrusive	The Felsic Intrusives generally cross cut the older stratigraphy and are dominated by quartz phenocrysts.
Intermediate intrusive	The units included in this lithology comprise Proterozoic dykes and flames porphyry. The intrusives generally cross cut the older stratigraphy and rock types vary from granodiorite to porphyritic units with large quartz phenocrysts in a mafic matrix.

Geological Unit	Description
Mafic Intrusion	Comprise dolerite, lamprophyre and minor Proterozoic age dykes.
Tailings	Generally dark green to dark grey with minor brown layers with mafic minerals, quartz, feldspar, and trace sulphides ranging from clay to fine sand sized (Mesh 2008).

2.5.3.5 Land Systems

A land system is defined as an area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation (Christian and Stewart 1953). The former Department of Agriculture and Food Western Australia (DAFWA), now Department of Primary Industries and Regional Development (DPIRD) has partially mapped the land systems of the Eastern Goldfields subregion from aerial photography. Land systems are grouped according to landform, soils, vegetation and drainage patterns (Payne et al. 1998).

The most common land system surrounding Lake Lefroy is the Gumland Land System which comprises extensive pedeplains supporting eucalypt woodlands with halophytic and non-halophytic shrub understoreys.

2.5.3.6 Hydrology

Lake Lefroy covers an area of 554 km^2 and is located within the Lake Lefroy catchment, which is approximately 3,950 km^2 in size (Clarke 1991). The lake is the major surface water body within the Development Envelope and is surrounded by numerous ephemeral drainage channels and creeklines. The lake is a system in transition between an ephemeral lake and a salt pan, with increased build-up of salts occurring via natural processes (Clarke 1994b), as well as dewatering discharge. It is estimated that as much as 2.4 million tonnes (Mt) of salt was added to Lake Lefroy annually in the past, as a result of dewatering activities by mines fringing the lake (Vasey 2001, Handley 2003), consistent with the present discharge rates of approximately 7 GL/yr. This volume is variable, as it is dependent on the extent of mining and associated dewatering. While the surface of Lake Lefroy varies in bathymetry over a large area, the playa is generally of low relief, sitting at approximately 286 m Australian Height Datum (AHD) (MWH 2016d).

Regional topography is low to gently undulating, with plains rising to in excess of 410 m AHD at the catchment divide surrounding Lake Lefroy. Surrounding catchments drain via ephemeral gullies and drainage lines, trending towards Lake Lefroy. Channels are generally poorly defined, with runoff largely occurring as sheet flow.

High infiltration capacities of sediments, coupled with high monthly evaporation rates in excess of the average monthly rainfall, result in limited pooling of surface water on the lake. The occurrence of freshwater in the landscape is highly infrequent, with the salinity of surface water on the lake ranging from 260,000 to 435,000 mg/L (TDS) (URS 2010b). Large freshwater influxes, due to tropical low pressure systems are unlikely to significantly reduce the salinity of surface water on Lake Lefroy, due to the thick salt crust on the playa surface. While bathymetry of the lake is generally flat, there are two shallow water accumulation areas in the northeast and central southerly areas of the lake (MWH 2016d).

As the majority of runoff does not reach the lake due to rapid terrestrial infiltration, and runoff provides only minimal lake surface flows, Lake Lefroy is rarely subject to major flooding, particularly to any substantial depth (Handley 1991). In addition, the persistence of a thick and expansive salt crust (estimated at covering 65% of the lake's surface) typically results in the extreme hypersalinity of any pooled surface water. However, the playa is capable of accommodating major inflows from cyclonic activity, in addition to dewatering discharge from SIGM, due to its expansive size (MWH 2016d).

Rainfall events greater than 30 mm in total, with an average of 5 mm per day, are likely to partially or wholly inundate Lake Lefroy, with two events of this magnitude likely to occur every year (URS 2010b). Following major rainfall events, flooding occurs in Lake Lefroy relatively quickly and surface water has been documented as persisting in the lake for comparably long periods following major runoff events (CSIRO Land and Water 2003). This was demonstrated during extensive flooding resulting from ex-tropical Cyclone Vance (March 1999) (BOM 2015b) and Cyclone Steve (February to March 2000) (BOM 2016), where Lake Lefroy held surface water for approximately nine months and a further five months following additional rainfall in February 2001. However, there is no evidence that delayed drainage to the lake occurs from the surrounding catchment for a prolonged period after these events (CSIRO Land and Water 2003).

The last significant flood event at Lake Lefroy occurred in 2014, when more than 150 mm of rain was received over a three day period in late January (BOM 2015a), as a result of local isolated storm activity. During flooding, fluctuations in water depth and movement are a dominant hydrological feature of the lake, due to its shallow nature and the action of prevailing winds (Clarke 1994b). In addition, due to the significant spatial variability in rainfall, the variable bathymetry of the lake surface and the location of existing mining infrastructure, the lake does not necessarily fill in its entirety (Clarke 1991; CSIRO Land and Water 2003).

The hydrology of Lake Lefroy has been substantially altered due to the construction of the primary causeway built in the late 1960s (SIGMC 2010), which bisects the centre of the lake and is used for access, mining and exploration purposes. The causeway has particularly altered the flow regime during major floods (MWH 2016d), with flow monitoring through the causeway culverts indicating no significant drainage of the lake from one side to the other (Stantec 2017b).

2.5.3.7 Hydrogeology

The occurrence of groundwater is primarily controlled by topography and geology. The region is underlain by Archaean granitoids and greenstones intruded by Proterozoic mafic dykes. Much of the Archaean basement is weathered, with the depth of weathering being greatest over felsic and sedimentary rocks and least over mafic and ultramafic rocks, which therefore tend to form topographic lows and highs (Thorpe 2014).

Fractured rock aquifers occupy the greater part of the Kalgoorlie, generally containing only minor groundwater supplies, which can be difficult to locate. Fresh groundwater does not occur in the Kalgoorlie region, but brackish groundwater exists in the upper reaches of some catchments (MWH 2016d).

The regional water table ranges from less than 1 m below the ground level (bgl) (beneath and adjacent to the playa), to more than 50 m bgl in elevated areas. External recharge is restricted, occurring only during heavy rainfall in areas containing outcrops of bedrock. Recharge from the playa into the underlying lacustrine sediments occurs, some of which is assumed to enter the palaeodrainage aquifer; however, regional hydraulic gradients are low within the palaeodrainage. Natural groundwater discharge occurs from the playa via evaporation (Kern 1995).

The B2018 Project is located within the Lefroy-Dundas Sub Area of the Goldfields Groundwater Management Area. Lake Lefroy forms the headwaters of the Lefroy Palaeodrainage, one of four main palaeodrainage systems in the area, (Timms 1992), which flows eastwards towards the Eucla Basin (Clarke 1994a). The majority of the B2018 Project is located in or along the margins of Lake Lefroy, within the Lefroy Palaeodrainage system. As a result, operations intersect variable thicknesses of Tertiary to recent alluvial, lacustrine and aeolian deposits, which overlay mineralised Archaean bedrock containing the gold deposits (Clarke 1991).

The most significant aquifer of the Lefroy Palaeodrainage in the Lake Lefroy area comprises a series of channelled, fine to coarse-grained sand horizons representing infilled palaeodrainage

channels. At Lake Lefroy, the palaeodrainage channel sand unit is generally underlain by clay, silt and lignite of the Pidinga Formation, locally interfingering with spongolitic silt and fine sand of the Princess Royal Spongolite. The upper part of the sedimentary sequence comprises clay, with silt, sandstone and pebbly lenses of the Revenge Formation and calcareous mudstones of the Cowan Dolomite and Gamma Island Formation (Clarke 1991).

Groundwater salinity within the vicinity of Lake Lefroy ranges between 274,000 and 423,000 mg/L TDS. Dissolved metal concentrations are reflective of the mineralogy in the region. Groundwater typically occurs in limited quantities, at depth of between 15 to 30 m bgl, outside of the margins of Lake Lefroy (URS 2010a). The natural (pre-mining) groundwater flow is towards the Lefroy Palaeodrainage (MWH 2016d).

2.5.3.8 Flora and Vegetation

The development of gold mining leading to a major alteration to the vegetation cover occurred in the early part of the 20th century. Deforestation was extensive to provide fuel for condensers, mines, and pump stations and to support pits, potentially affecting geological stability of the subsoils and hydrological regime. Tramways, locally known as woodlines, extended throughout the area, and major cutting occurred as late as the 1950's. The tree roots were left in place, and in many areas, regrowth can be seen from the original stumps (Commander et al. 1992)

The Development Envelope lies within the IBRA Coolgardie region and the Eastern Goldfields (COO3) subregion which is regarded for its high floristic species and ecosystem diversity, in particular, *Eucalyptus* spp., *Acacia* spp. and ephemeral flora communities (Cowan 2001).

Based on broad vegetation mapping by Shepherd et al. (2002), the Development Envelope includes seven vegetation types all occurring within the Binneringe system (Table 2-4). The most common vegetation type within the Development Envelope was Binneringe 125 with almost 27,000 ha present and described as bare areas and salt lakes.

Each of the vegetation types that occur in the Development Envelope has in excess of 90% or pre-European extent remaining and are therefore classed as Least Concern. Consequently, the majority of the vegetation in the Development Envelope represent communities that are well represented at a regional level (Phoenix 2018b).

Table 2-4: Extent and Conservation Status of the Vegetation Types defined by Shepherd et al. (2002) intersecting the Development Envelope (DPaW 2014)

Vegetation type	Pre-European extent (ha)	Current extent (ha)	% remaining	Amount of vegetation type within Development Envelope (ha)
9	101,297	100,103	98.8	1,521
125	1,659,377	163,564	98.6	26,817
221	7,713	7,541	97.8	161
502	32,795	32,737	99.8	3,575
521	90,090	90,090	100	3
676	117,074	117,057	100	2
936	586,792	584,334	99.6	12,935

The Development Envelope has been extensively surveyed for flora and vegetation over several years and seasons. The comprehensive body of work collected within the Development Envelope and surrounds has identified numerous conservation significant communities as well as flora, fauna and invertebrate species. This information was compiled by Phoenix

Environmental Sciences (Phoenix) and used to inform the further surveys undertaken as part of the B2018 Project and to address survey gaps identified in the baseline information and to verify the results of the previous surveys. As part of the surveys, Phoenix mapped the vegetation types across the Development Envelope and wider SIGMC tenure and identified five potentially significant flora species within the Development Envelope. These are further discussed in Section 4-2.

Database searches (DEE, DBCA) list a range of conservation significant species with the potential to occur in the region (MWH 2016d). While several at risk ecosystems exist within the region, only one community is associated with Lake Lefroy. The halophytic communities located on the southern margin of the lake, and adjacent to Madoonia Downs Station are outside the Development Envelope. This community consists of an unusual combination of Eucalyptus woodland over a halophytic shrubland, on sandy loam (Australia's Virtual Herbarium 2010).

2.5.3.9 Terrestrial Fauna

The Coolgardie bioregion is associated with a rich species assemblage of vertebrate fauna (Biological Surveys Committee et al. 1984). Terrestrial vertebrate fauna within the bioregion have adapted to survive in harsh semi-arid and arid climatic regions of the bioregion. Several avifauna species of conservation significance are known to occur within the bioregion, including the Malleefowl, Night Parrot, Peregrine Falcon, Carnaby's Black Cockatoo and some migratory shorebirds when water is retained in waterbodies following sufficient rainfall (Biological Surveys Committee et al. 1984, Burbidge 2004, Van Dyck and Strahan 2008).

A number of conservation significant mammal species historically known to occur within the Coolgardie bioregion have declined in distribution and abundance since European settlement with some now considered regionally extinct, including the Chuditch (*Dasyurus geoffroii*), Numbat (*Myrmecobius fasciatus*) and Bilby (*Macrotis lagotis*) (Biological Surveys Committee et al. 1984, Burbidge 2004, Van Dyck and Strahan 2008). The Coolgardie bioregion is not known to support any endemic vertebrate species.

2.5.3.10 Subterranean Fauna

Two factors predominantly determine the presence of subterranean fauna, i.e. the vugginess (porosity) of the geology and presence and quality (in particular salinity) of groundwater. Habitats likely to support troglofauna are karstic limestone, channel iron deposits (CIDs) (in particular pisolite in inverted landscape geomorphology), groundwater calcretes above the water table, alluvium/colluvium in valley-fill settings, BIFs and weathered and fractured sandstone. Stygofauna are likely where there are groundwater voids present, for example in karst limestone, calcretes, alluvial formations and fractured rock (EPA 2013).

Examples where troglofauna are unlikely to occur include geologies without cavities, voids or caves. These formations include sand- and clay-dominated substrates and areas that have been submerged during sea level rise in the Holocene. Stygofauna fauna are unlikely to occur in deep sands or clays (especially over solid rock) or hypersaline (exceeding marine concentration, i.e. 35,000 mg/L TDS) groundwater (EPA 2013).

Habitats likely to support subterranean fauna appear to be limited in the area. This is discussed in section 4.4.

2.5.3.11 Aquatic Biota

The diversity and productivity of algae and macrophytes within Lake Lefroy is low, in comparison to the peripheral wetlands (Stantec 2018a). This is considered typical of large inland salt lakes, attributable to the lower salinity occurring within the peripheral wetlands. The majority of the taxa that have been recorded from the area are widespread and common in waterbodies throughout the Goldfields region. However, while comprehensive studies have

been undertaken over time, the dataset for algae and macrophytes is patchy, with discrepancies between methodology, results and taxonomic resolution (Stantec 2018a).

In comparison to other salt lakes in the Goldfields, the aquatic invertebrate assemblage of Lake Lefroy is depauperate, due to the apparent lack of a low salinity phase during flooding. However, studies have been limited to only two flood events previously (Curtin University of Technology 1999, Phoenix Environmental Sciences 2014a). More than 100 taxa have been identified from the peripheral wetlands, with less than 15 taxa recorded from the lake (Stantec 2018a), primarily crustaceans and insects. Differing levels of taxonomic resolution employed in past studies suggest that the total taxa number from the area has been overestimated (Stantec 2018a).

2.5.4 Social Environment

2.5.4.1 Population Centres

The Goldfields region is relatively sparsely populated and extends from the deserts in the north and east all the way down to white pristine beaches in the South. The region supports a wide range of industry, including mining, agriculture, aquaculture and tourism. Mining is the predominant sector in the central and northern parts of the Region, with a well-established agricultural sector in the south. The largest population centre is City of Kalgoorlie-Boulder. Other significant towns in the region include Esperance, Leinster, Coolgardie, Wiluna, Leonora and Menzies.

The town of Kambalda which is located north of the SIGMC operations was a first nickel town, built by Western Mining Corporation in the 1960s. Today, it is a mining hub made up of two separate towns, Kambalda East and Kambalda West approximately seven kilometres apart. The population has been declining due to the slowing resources sector and increasing number of fly in fly out (FIFO) workers servicing the industry. The current population is approximately 2,700 (ABS 2017) and is largely dependent on mining within the area.

2.5.4.2 Aboriginal Heritage

The Ngadju group are the determined native title holders (Tribunal file number: WCD2014/004) over the majority of the SIGMC operational areas and all of the B2018 Development Envelope. Consultation with the Ngadju group on heritage matters is ongoing.

A number of Aboriginal ethnographic and archaeological site surveys have been completed for the area covered by the Development Envelope since the early 1990s. Sites identified over the course of these investigations include scar trees, gnamma holes and small to medium-sized artefact scatters.

A search of the Department of Planning, Lands and Heritage (DPLH) Aboriginal Heritage Inquiry System (AHIS) – GIS database indicate that there are five registered Heritage Sites within the Development Envelope (see Section 5). In addition to these sites, a SIGMC database also records another site of significance (recorded as Jarramur 1), as well as a number of other sites of lesser significance.

The most recent heritage survey undertaken within the Development Envelope (Dortch & Cuthbert 2017) provided an assessment of likelihood of presence of subsurface sites/remains on Lake Lefroy. It was concluded that Lake Lefroy can be considered to have little archaeological importance but is still subject to ongoing ethnographic consultation and dialogue in accordance with SIGMC's standard practices (refer to Section 5).

2.5.4.3 European Heritage

The earliest records of gold in the Kambalda area date back to 1896 when Percy Larkin discovered gold near Red Hill, located towards the southeast of Kambalda (Gresham 1991). The mines at Red Hill produced 31,000 oz of gold from 41,000 t of ore, but it was not until the discovery of the Ives Reward deposit in 1919 that strong interest in the area developed (MWH 2016d).

The small township of St Ives was established on the St Ives Peninsula in 1920 in an area adjacent to the old mill site. Ore was treated in a State Battery located to the north of this site. Land yachts (dinghies with wheels and sails) were used by the early miners to transport supplies across the lake, with the land yacht route closely following the alignment of the existing causeway. Alternative transport routes were located between Lake Lefroy and Lake Randall, and via Widgiemooltha. By 1927, all major mining activity had ceased, and the town of St Ives was abandoned (Gresham 1991).

Little exploratory work was undertaken in the region between the late 1930s and the 1960s, at during which time nickel exploration commenced. The discovery of a series of world class nickel ore bodies in, and on the shoreline of Lake Lefroy in 1965 resulted in the establishment of the town of Kambalda. Although the presence of gold was noted during the development of the Kambalda nickel reserves, it was not until the resurgence of the gold price in 1979 that mining began on the belt of favourable gold-bearing stratigraphy that occurs from the south of Kambalda to Norseman (MWH 2016d).

Online searches of the following databases were undertaken in 2017 to identify any European Heritage Sites within the Development Envelope.

- Heritage Council of Western Australia and the State Heritage Office
- Australian Heritage Places Inventory; and
- National Trust Heritage Register WA
- Municipal Heritage Inventory

No sites are registered within the Development Envelope but there are 10 European heritage places located within the region. These are summarised in Table 2-5.

Further to this, there are two gravesites located at an old cemetery just outside the Development Envelope. This site was discovered during exploration activities in the area as a result of discussions with Mt Monger station. The graves are suspected to be those of Edward James Ascott Spence (died 8 August 1923) and William W. Douglas (died circa. 12 August 1923). SIGMC has been proactive in protecting the site which is currently marked on the internal GIS database and is physically fenced.

Other areas of European heritage interest within the area include:

- Paris Mine site;
- Ives Reward township site; and
- Red Hill walking trail.

Table 2-5: European Heritage Places Recorded within the Region

Place	Description	Database listing
Kambalda Police Station & Courthouse	Located in Kambalda, outside the Development Envelope.	Heritage Council
Kambalda RSL Memorial, Town Square	Located in Kambalda, outside the Development Envelope.	Statewide War Memorial Survey
Kambalda Fire Station	Located in Kambalda, outside the Development Envelope.	Fire & Rescue Service Heritage Inventory
Stoney Hill Tanks (Well No.25)	Located north of Kambalda, outside the Development Envelope.	Wells of Explorer Charles Hunt Survey
White Peaks Tank (Saddle Hills) (Well No.26)	Located north of Kambalda, outside the Development Envelope.	Wells of Explorer Charles Hunt Survey
Slate Well Soak (Well No. 24)	Located north of Kambalda, outside the Development Envelope.	Wells of Explorer Charles Hunt Survey
Slate Tank (Well No.24)	Located north of Kambalda, outside the Development Envelope.	Wells of Explorer Charles Hunt Survey
King Battery	Located north of Kambalda, outside the Development Envelope.	Heitage Council State Register Shire of Coolgardie Municipal Inventory
St Peter's Anglican Church	Located in Kambalda, outside the Development Envelope.	Anglican Church Inventory
Rectory	Located in Kambalda, outside the Development Envelope.	Anglican Church Inventory

3 STAKEHOLDER ENGAGEMENT

3.1 *Key Stakeholders*

Based on the analysis of the Project location, affected land users and potential impacts and risks originating from the Project, SIGMC has identified the following stakeholders that are relevant to B2018 Project and have been and will be continued to be engaged throughout the life cycle of the Project:

State Government

Department of Water and Environmental Regulation – EPA Services (EPAS)

- Department of Mines, Industry Regulation and Safety (DMIRS)
- Department of Water and Environmental Regulation (DWER)
- Department of Biodiversity, Conservation and Attractions (DBCA)
- Department of Planning, Lands and Heritage (DPLH)

Local Government

- Shire of Coolgardie

Indigenous Groups

- Ngadju Traditional Owners
- Widji Traditional Owners
- Kalamaia Kabu(d)n Traditional Owners

Environmental Interest Groups

- Conservation Council of WA (CCWA)
- Wilderness Society (Western Australia)
- Wildflower Society of Western Australia
- National Malleefowl Recovery Team

Adjacent Landholders

- Mt Monger Station
- Madoonia Downs Station
- Woolibar Station
- Salt Lake Mining – Beta Hunt UG
- ACH Nickel – Foster and Jan Shaft UG
- IGO – Long Operations (UG)
- BHP Billiton - Nickel West, Kambalda
- Panoramic Resources – Lanfranchi

Other Local Stakeholders

- Residents and businesses of Kambalda
- Local Media

Recreational Clubs

- Lake Lefroy Land Sailing Club
- Horse Riding / Pony Club
- Kambalda Golf Course
- Kambalda Recreation Centre

3.2 *Stakeholder Engagement Process*

3.2.1 SIGMC's principles for stakeholder engagement

SIGMC recognises that stakeholders are an integral part of its business, day-to-day operations and their long-term viability. In recognition of this, an open and constructive engagement which allows participation of stakeholders and consequently informs decision making processes is initiated during the early stages of the EIA process and implemented throughout all new projects and operations. GFL's strategic pillars for stakeholder engagement and community development are described within Gold Field's Community Relations and Stakeholder Engagement Handbook (Gold Fields 2015):

- GFL's approach is strategic and not reactive. GFL is proactive. GFL engages early.
- GFL is transparent in our dealings and always comply with the law.
- GFL focuses on social investment/shared value rather than philanthropy or good will.
- GFL's approach to development is inclusive of all stakeholders (including staff members) and not exclusive or fragmented.
- GFL encourages continuous, transparent and constructive stakeholder engagement, rather than isolated engagement initiatives.
- GFL enables community development and not community dependency.
- GFL's community development plans capitalise on existing community assets and build on successful development initiatives in which the communities are already engaged.

3.2.2 Stakeholder engagement undertaken for the B2018 Project

SIGMC has, and will continue to, actively engage with the relevant stakeholders throughout the B2018 Project. Project consultation has been captured in the Stakeholder Engagement Register (refer to Appendix C) and has involved face-to-face meetings and phone conversations with the relevant regulatory agencies and indigenous groups, correspondence with environmental interest groups, adjacent landholders and other local interest groups. SIGMC has also held three open Community Information Sessions in October 2016, April 2017 and October 2017 for all key stakeholders and other interested parties in Kambalda and Kalgoorlie (Appendix C).

The objectives for stakeholder engagement can be summarised as follows:

- Assess and manage social impacts from the B2018 Project;
- Identify and consider the diverse range of views of different stakeholders;
- Establish communication and engagement mechanisms that are effective, timely and transparent;
- Keep stakeholders appraised about the B2018 Project and its social, financial and environmental implications;
- Integrate stakeholder expectations into operations and closure of the B2018 Project; and
- Strengthen new and established stakeholder relationships.

SIGMC has prepared a Stakeholder Engagement Plan (SIG-ENV-PL044) for the B2018 Project which details the stakeholder engagement process, level of engagement and grievance

mechanisms in the event of any stakeholder concerns or complaints. This sets the framework for any stakeholder consultation undertaken now and during the operations of B2018 Project.

SIGMC will continue to engage relevant stakeholders as the Project and the EIA process progress to ensure that all concerns have been addressed. SIGMC will also provide a Supplementary Report that provides a response to public submissions received by the EPA as part of the public review period.

3.3 *Outcomes of Stakeholder Engagement*

SIGMC has consulted with the relevant stakeholders and the outcomes of the stakeholder consultation have been captured in the Stakeholder Engagement Register (Appendix C).

Overall, few concerns have been raised. One concern raised by The Lake Lefroy Land Sailing Club was a request that SIGMC maintain a navigable path between proposed works at Incredible and Black Island and to maintain room to sail on the lake surface. Other issues raised did not relate to the environmental assessment of the B2018 Project e.g. housing in Kambalda.

Some stakeholders who were unable to attend the Community Information Sessions requested copies of the presentations which SIGMC has supplied. Those that were unable to attend the sessions and requested to schedule time for later discussions with SIGMC will be met at a time agreed upon with the relevant stakeholder.

At the Community Information Sessions various issues were raised by community members to whom SIGMC responded to at the sessions. A record of these issues and SIGMCs response has been captured in the Stakeholder Engagement Register (Appendix C).

4 ENVIRONMENTAL PRINCIPLES AND FACTORS

4.1 *Principles*

The principles of ecologically sustainable development are incorporated into the EP Act and therefore form part of the framework for environmental protection in WA (EPA 2016j) These principles are:

- The Precautionary Principle;
- The Principle of Intergenerational Equity;
- The Principle of the Conservation of Biological Diversity and Ecological Integrity;
- Principles in relation to Improved Valuation, Pricing and Incentive Mechanisms; and
- The Principle of Waste Minimisation.

The B2018 Project is somewhat unique in nature as there are no clear defined project footprints available at the time of preparation of this ERD. As such, to afford the flexibility being sought for the project, a significant amount of studies and surveys have been undertaken to address the principles of the ecologically sustainable development. This work has included studies, consultation and careful consideration of the mitigation hierarchy in terms of the proposed approach to development. From an EIA perspective, the hierarchy of mitigation of impacts is discussed further in this section and refers to the following:

- Avoid – through relocation or reduction of areas or actions to avoid impacts to certain environmental values;
- Minimise – where avoidance of impacts is not possible, a reduction of impacts to an environmental value may be achieved through relocation or reduction of areas or through appropriate project design and management;
- Rehabilitate – once impacts are avoided or minimised, the residual impacts may be responded to through employment of appropriate techniques to restore/rehabilitate areas of impact;
- Offset – where there are areas of residual impact that are assessed to be unacceptable, and after all other mechanisms have been employed to reduce these impacts as far as practicable, offsets may be employed in certain circumstances to counterbalance the impacts or risks.

The work that has been conducted by SIGMC to develop the B2018 Project has been framed by this hierarchy and has resulted in both ‘avoidance’ and ‘minimisation’ of impacts wherever practicable. This is discussed elsewhere in this ERD and aligns with SIGMC’s approach to operations whereby areas of significant environmental values are identified and retained wherever practicable. Further to this, employment of appropriate management and rehabilitation actions is also part of SIGMC’s standard approach to operations from an environmental perspective.

Such an approach aligns with the principles of ecologically sustainable development and every effort has been made to ensure that areas are studied appropriately and that impacts are avoided wherever practicable. Given the nature of the project, SIGMC has taken a precautionary approach to the surveys and assessments that have been conducted (and those that are proposed) to ensure that decisions regarding the project are made with the best-available information. SIGMC’s response to the principles of ecologically sustainable development is outlined in Table 4-1 below.

Table 4-1: EP Act Principles

Principle	Consideration
1. The precautionary principle *Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.* *In application of this precautionary principle, decisions should be guided by:* a) careful evaluation to avoid, where practicable, serious or irreversible damage to the environment; and b) an assessment of the risk-weighted consequences of various options.	The Precautionary Principle applies when "there is plausible evidence of possible harm but scientific uncertainty and ignorance makes it impossible to reliably quantify and characterize the risks" (UNESCO 2005). SIGMC acknowledges the potential for significant environmental impacts to occur if mining and processing occurred outside of a rigorous impact assessment process and regulatory framework. For the B2018 Project, the following applies: • The impacts associated with mining and processing generally are well known in Western Australia. • Mining activities on Lake Lefroy have been the subject of two previous major environmental impact assessments under the EP Act and multiple assessments under the Mining Act. • Mining and processing has proceeded for in excess of a decade without encountering unforeseen impacts of a material nature. • The previous assessments, together with the current proposal, include in excess of 100 technical reports and investigations into key environmental factors relevant to the Proposal. • As there was doubt about the precise locations of particular activities, SIGMC identified a conservative Development Envelope in which these activities will occur, and assessed the full area. • The current proposal has identified areas within the Development Envelope with particular environmental features that require further investigation. SIGMC has elected to exclude these areas from any activity, either permanently or until more data permits a more informed assessment. SIGMC considers that scientific uncertainty has been sufficiently reduced such that the Precautionary Principle is not triggered.

Principle	Consideration
2. The principle of intergenerational equity *The present generation should ensure that the health, diversity and productivity of the environment is maintained and enhanced for the benefit of future generations.*	In respect of the B2018 Project, SIGMC interprets the principle of intergenerational equity to require that: • Significant loss of biodiversity and ecological function should not occur. • Post-mining landforms are stable and non-polluting in the long term, and do not require ongoing maintenance or represent a liability to future generations. SIGMC has prepared a robust EIA to inform the EPA assessment process. The Project has been assessed at a regional and local scale to ensure that a rigorous assessment of impacts to health, diversity and productivity of the environment within and surrounding the Project have been considered. SIGMC has also provided a conceptual approach to rehabilitation and closure that complements existing approved plans for elsewhere in its operations and is consistent with industry standards for rehabilitation and closure.
3. The principle of the conservation of biological diversity and ecological integrity *Conservation of biological diversity and ecological integrity should be a fundamental consideration.*	To determine the potential impacts of the Project on biological diversity and ecological integrity, a significant number of baseline biological surveys have been undertaken by SIGMC in relation to the B2018 Project. Detailed and rigorous survey and assessment work has been completed to determine the potential impacts of the project on biological diversity and ecological integrity. Supplementary surveys will also be completed as part of the continuing approach employed by SIGMC to determine the impact of their operations on the environment. The work referred to in this ERD has resulted in adaptive management measures to mitigate biodiversity and ecological impacts associated with the implementation of the Project. Management measures and closure objectives have been developed to ensure the conservation of biological diversity within the Project footprint and decisions being made to exclude them from the Project footprint being made due to their elevated environmental value.

Principle	Consideration
4. Principles relating to improved valuation, pricing and incentive mechanisms i. Environmental factors should be included in the valuation of assets and services. ii. The polluter pays principles – those who generate pollution and waste should bear the cost of containment, avoidance and abatement. iii. The users of goods and services should pay prices based on the full life-cycle costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any waste. *Environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentive structure, including market mechanisms, which enable those best placed to maximise benefits and/or minimise costs to develop their own solution and responses to environmental problems.*	SIGMC currently carries the costs of environmental management associated with its operations and this will continue with the B2018 Project. These costs include: • Day-to-day environmental management using specialist personnel • Environmental investigation and survey costs • Water, soil, rock and vegetation sampling and testing • Safe storage of tailings • Works approval and licencing fees. • Management of hydrocarbon storage facilities and recycling of waste oils • Clean up costs associated with spills of hydrocarbons or chemicals. • Costs associated with land rehabilitation and provision for future rehabilitation and closure costs • Statutory contributions to the Western Australian Mining Rehabilitation Fund for rehabilitation of abandoned mines across the state. Contributions will increase with the additional disturbance associated the B2018 Project. With regard to provisions for future rehabilitation and closure costs, SIGMC's parent company makes financial provision for future costs associated with rehabilitation and closure. The provisions are based on the net present value of the estimated costs and are detailed in the company's annual reports. They are reviewed annually and adjusted for changes in legislation, technology, inflation, rehabilitation completed and new disturbance undertaken, or other circumstances. A royalty to the State Government is also payable, based on the amount of gold produced.

Principle	Consideration
5. The principle of waste minimisation *All reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment.*	A mining operation such as St Ives relies heavily on an appropriate approach to waste management and waste management measures are a key element of this Project. Whilst an operation like this can and does generate a range of wastes, SIGMC takes all reasonable and practicable measures to apply the waste management hierarchy to its operations (i.e. avoid, reduce, reuse, recycle, recover, treat, contain and dispose) and, where wastes are generated, takes appropriate (standard and best practice) steps to ensure that the hierarchy is followed. Ultimately, where waste is required to be disposed of, it is done so through a process of treatment and containment that minimises the risk to the environment as far as practicable. SIGMC works closely with statutory authorities and technical experts to continually re-evaluate its approach to waste management and make improvements to these practices wherever appropriate and practicable. This approach will continue to apply to the B2018 Project during its development, operation closure and post-closure.

SIGMC is committed to ensuring that the proposed B2018 operations (incorporating closure and rehabilitation) are progressed in accordance with the ecologically sustainable development principles referred to above whilst ensuring that the mitigation hierarchy forms a framework for the SIGMC response to identified environmental values.

Such an approach reflects SIGMC's operations to date and provides for a long-term, sustainable approach to mining rather than one that is piecemeal and provides little certainty for the company, nor to those stakeholders who rely on the benefits the operations afford.

4.2 *Flora and Vegetation*

4.2.1 EPA Objective

The EPA's environmental objective for the factor Flora and Vegetation is:

To protect flora and vegetation so that biological diversity and ecological integrity are maintained.

4.2.2 Policy and Guidance

The following policies and guidelines apply to Flora and Vegetation:

- EPA Environmental Factor Guideline – Flora and Vegetation (EPA 2016d);
- EPA Technical Guidance - Flora and Vegetation Surveys for Environmental Impact Assessment (EPA 2016n);
- Guidance Statement No. 6 – Rehabilitation of Terrestrial Ecosystems (EPA 2016h);
- Guidelines for Preparing Mine Closure Plans (DMP and EPA 2015);
- WA Environmental Offsets Policy (Government of Western Australia 2011); and
- WA Environmental Offsets Guidelines (Government of Western Australia 2014).

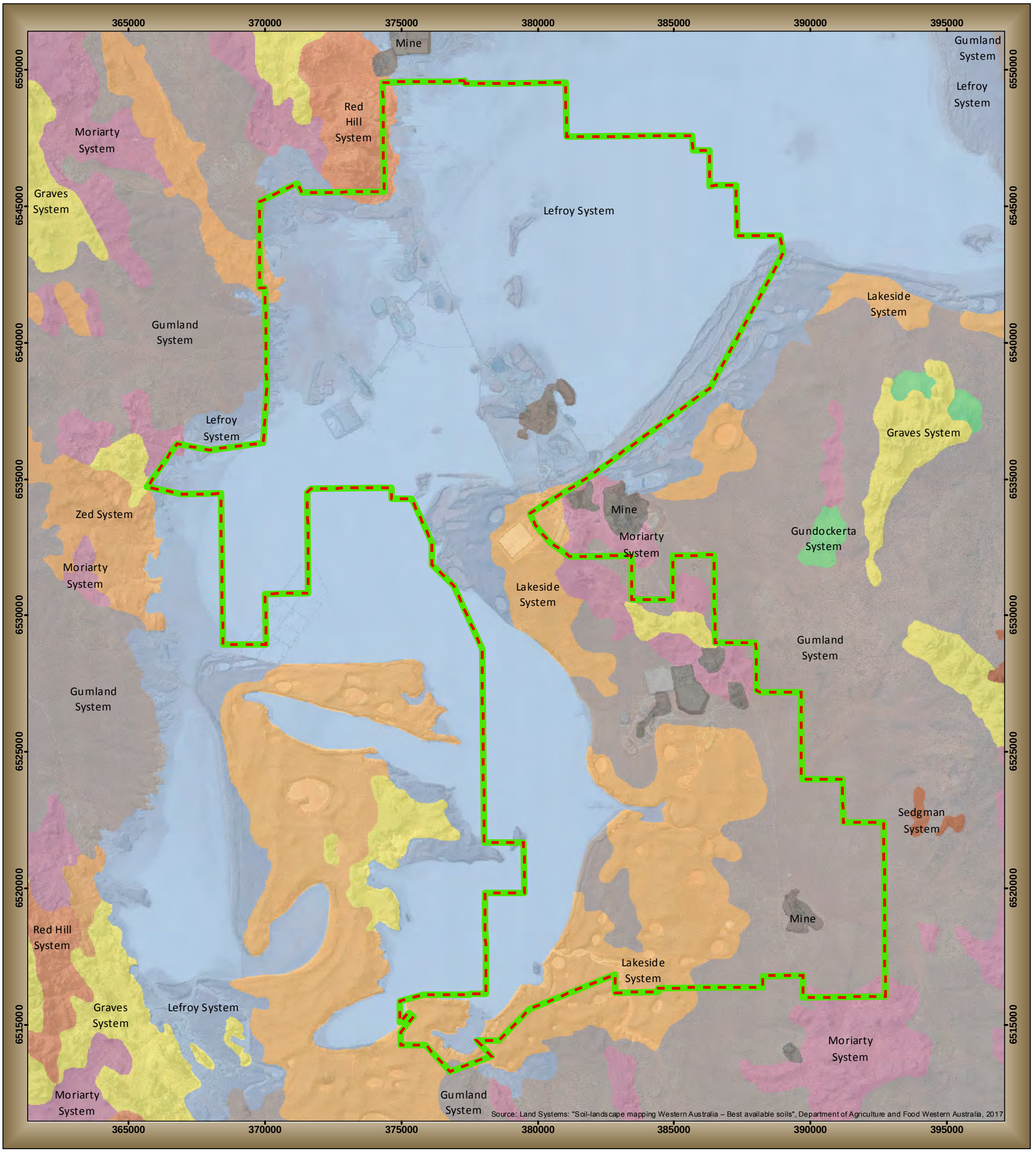
4.2.3 Receiving Environment

4.2.3.1 Land Systems

The Department of Agriculture and Food Western Australia (now Department of Primary Industries and Regional Development) has partially mapped the land systems of the Eastern Goldfields subregion from aerial photography. Land systems are grouped according to landform, soils, vegetation and drainage patterns (Payne et al. 1998).

The Development Envelope intersects seven land systems (Figure 4-1). It is dominated by the Lefroy land system (LEF), which covers almost two thirds of the Project area (Table 4-2), and largely comprises the bare lake surface. The Gumland (GML) and Lakeside (LAS) land systems are also well represented.

Figure 4-1
Land Systems within the Development Envelope



LEGEND

- Development Envelope

Land Systems

- Graves System
- Gumland System
- Gundockerta System
- Lakeside System
- Lefroy System
- Mine
- Moriarty System
- Red Hill System
- Sedgman System
- Zed System

0 3 6 9 12

Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	2/07/2018

LOCALITY MAP

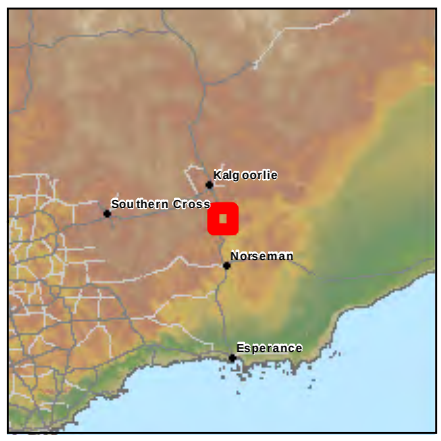


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Table 4-2: Extent of Each Land System Present in the Development Envelope

Land system	Description	Total area (ha)	Percentage (%)
Lefroy (LEF)	Salt lakes and fringing saline plains, sandy plains and dunes with chenopod low shrublands	29,217.1	64.9
Gumland (GML)	Extensive pedeplains supporting eucalypt woodlands with halophytic and non-halophytic shrub understoreys	7,243.1	16.1
Lakeside (LAS)	Sandplains with occasional sand dunes and prominent claypans, supporting mallee eucalypts and spinifex	6,599.8	14.7
Moriarty (MOR)	Low greenstone rises and stony plains supporting chenopod shrublands with patchy eucalypt overstoreys	1,347.2	3.0
Graves (GRV)	Basalt and greenstone rises and low hills supporting eucalypt woodlands with prominent saltbush and bluebush understoreys	285.2	0.6
Red Hill (RHL)	Basalt hills and ridges supporting acacia shrublands and patchy eucalypt woodlands with mainly non-halophytic undershrubs	225.4	0.5
Zed (ZED)	Low hills, rises and gently undulating stony plains based on metasedimentary rocks supporting acacia shrublands	95.7	0.2
Total:		**45,013.5**	**100**

4.2.3.2 Survey Effort

Previous surveys and summary of results

This section describes surveys undertaken prior to the B2018 Project proposal but which cover or partially cover the Development Envelope.

The Development Envelope and surrounding areas have been extensively surveyed for flora and vegetation during different years and seasons. The surveys undertaken since 1996 are summarised in Table 4-3. Figure 4-2 depicts the area over which these surveys have been conducted. Previous surveys were utilised in the most recent surveys undertaken by Phoenix Environmental Services (Phoenix) (2017b, 2018a, 2018b).

Three previous regional surveys conducted for the SIGMC tenements (Botanica Consulting 2012d; Jim's Weeds 2006; Mattiske 1996a) have mapped a varying number of vegetation types within the Development Envelope. Mattiske (1996a) mapped 28 vegetation types within a section of the Development Envelope, Jim's Seeds, Weeds and Trees (Jim's Weeds) (2006) mapped six broad vegetation types in a small section of the Development Envelope and Botanica Consulting (2012d) mapped all but a small section on the western edge of the Development Envelope and identified 19 vegetation types.

The vegetation types defined by Mattiske (1996a) and Botanica Consulting (2012d) broadly align and include:

- a variety of *Eucalyptus* woodlands over *Triodia* grasses or mixed shrublands;
- *Melaleuca* spp. thickets and shrublands;
- *Acacia* shrublands;
- chenopod and samphire shrublands; and
- low *Callitris* spp. woodlands.

Previous studies (Botanica Consulting 2012d; Jim's Weeds 2006; Mattiske 1996a; Paul Armstrong and Associates, 2016) identified 19 vegetation types as locally significant due to the presence of conservation significant flora (Table 4-4; Table 4-5).

Table 4-3: Summary of Previous Flora and Vegetation Surveys Relevant to the Project

Reference	Report Name	Location of Survey	Study Area Extent (ha)	Survey Date	Survey Effort	Conservation Significance[3]
Mattiske (1996)	Kambalda Nickel Operations (Western Mining Corporation): Flora and Vegetation Studies	Lake Lefroy and Cave Rocks	47,191	Apr-Aug 1993	43 quadrats (20 m x 20 m); three plots in *Tecticornia* communities	Undefined species of *Myrtaceae*
Mattiske (2001)	Flora and Vegetation Survey of Pistol Club Area Kambalda	Lake Lefroy (Pistol Club environs)	560	Feb 2001	Not available	None recorded
Datson (2004)	Lake Lefroy Shoreline Vegetation Monitoring	Lake Lefroy (riparian zone)	Not provided	Oct 2004	Seven baseline sites visited; five transects established (12 m to 24 m in length)	None recorded
Jim's Weeds (2005)	Flora Survey of the Vegetation within the St Ives Heap Leach Facility Expansion (M15/1540, M15/1564, M15/1565)	St Ives Heap Leach Facility	60	Oct 2005	6 relevés[4]	None recorded
Riparian vegetation monitoring 2005–2016 (various reports)		Lake Lefroy (riparian zone)	Not provided in the report	Various dates	30 transects	*Tecticornia mellarium* (P1), *Tecticornia flabelliformis* (P1), *Calandrinia* sp. Widgiemooltha (P1), *Ptilotus rigidus* (P1), *Pityrodia scabra* subsp. *dendrotricha* (P3)

[3] Some surveys recorded a number of species that were of conservation significance at the time of the survey but have since been 'delisted'. These species are excluded from this table.
[4] A relevé is an unmarked area within which flora data are collected. Relevés are a low intensity survey technique for gathering information for reconnaissance surveys. They are also useful for supplementing quadrat data to determine extent and boundaries of vegetation types within a study area.

Reference	Report Name	Location of Survey	Study Area Extent (ha)	Survey Date	Survey Effort	Conservation Significance[3]
Jim's Weeds (2006)	Regional Vegetation Survey within the Mining Tenements of St Ives Gold Mine	St Ives operational areas	43,818	Nov - Dec 2005	Traverses only	*Prostanthera splendens* (P1), *Trachymene pyrophila* (P2), *Eucalyptus websteriana* subsp. *norsemanica* (P1) and *Eremophila perglandulosa* (P1).
Botanica Consulting (2007)	Flora and Vegetation Survey of the Proposed Leviathan Haul Road	Leviathan Haul road area	8	Mar 2007	10 m strip on both sides of the road over a 4 km section	None recorded
Botanica Consulting (2009a)	Flora and Vegetation Survey of the Proposed TSF at St Ives Gold Mine	St Ives TSF4	322	Sep, Dec 2008	Seven relevés	None recorded
Botanica Consulting (2009b)	Flora Survey of St Ives Gold Mine AAA Project	AAA project area	1,072	Sept-Oct 2008	26 relevés	None recorded
Botanica Consulting (2009c)	St Ives Proposed Riparian Monitoring Methodology	Lake Lefroy (riparian zone)	Not provided in the report	Aug 2009	Two 10 m x 10 m transects at four sites	None recorded
van Etten (2009a)	Flora and Vegetation of Gold Fields Ltd St Ives Gold Mine, Proposed Pistol Club Pit Survey Area, Kambalda, Western Australia	Lake Lefroy (Pistol Club environs)	48	Nov 2009	Five relevés	None recorded
van Etten (2009b)	Flora and Vegetation of Gold Fields St Ives Gold Mine Exploration Area, south of Kambalda, Western Australia	Southern Area	174	Nov 2009	Six areas, two relevés	*Diocirea acutifolia* (P3)
Botanica Consulting (2010a)	Flora Survey of Diana, West Idough and Bellerophon Projects, March 2010	Diana, West Idough and Bellerophon	1,181	Sep 2009	26 quadrats	None recorded

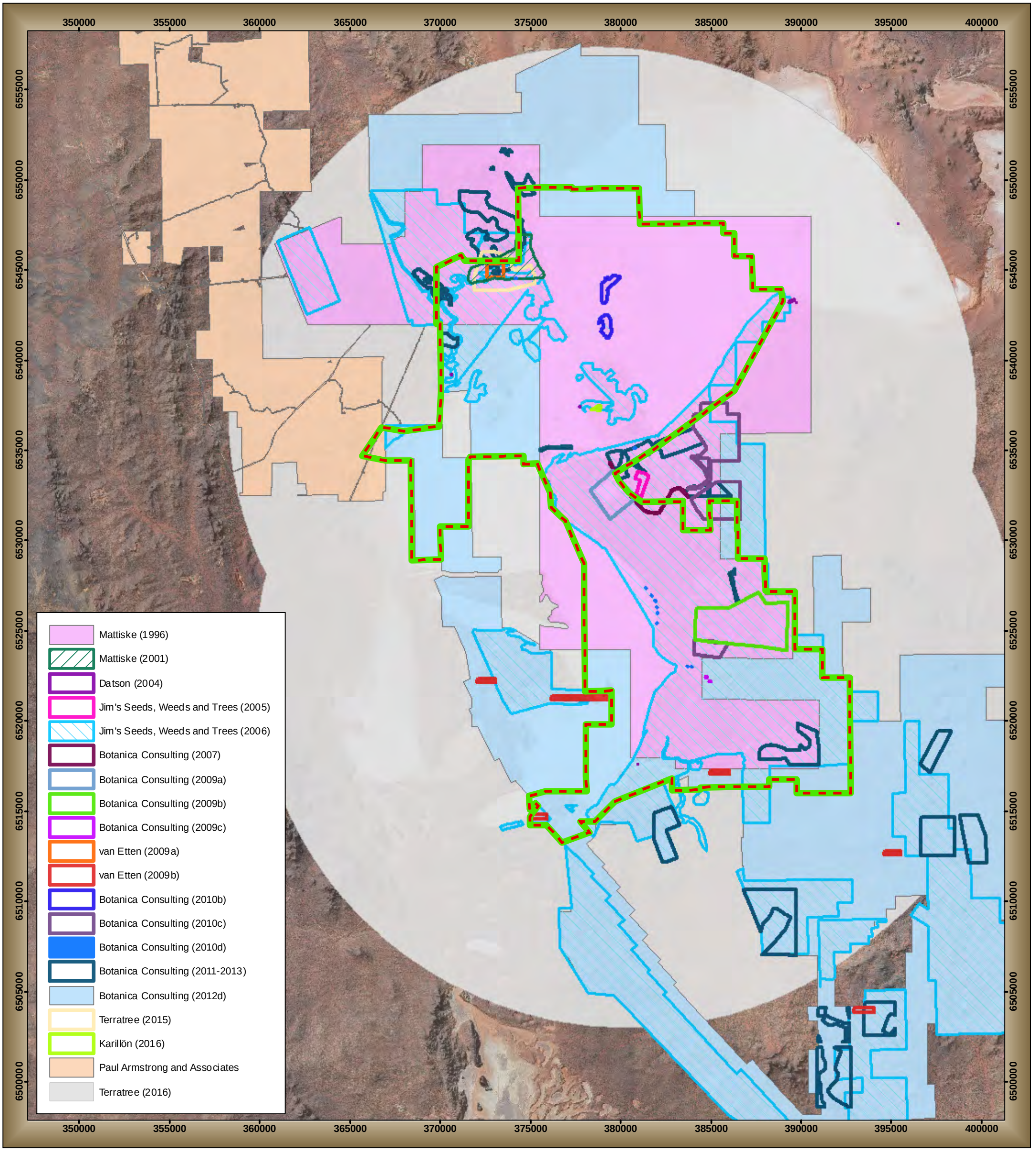
Reference	Report Name	Location of Survey	Study Area Extent (ha)	Survey Date	Survey Effort	Conservation Significance[3]
Botanica Consulting (2010b)	Lake Based Rehabilitation Interim Status Report for St Ives Gold Mine	Greater Intrepide Area and Greater Revenge Area and Islands	>50 ha	Apr 2010	18 transects	None recorded
Botanica Consulting (2010d)	Monitoring of Riparian Vegetation Fringing Lake Lefroy For St Ives Gold Mine	Lake Lefroy (riparian zone)	Not provided in the report	Sep 2009	14 monitoring sites established. 13 quadrats, 26 transects.	None recorded
Botanica Consulting (2010c)	Level 2 Flora Survey of Diana, West Idough and Bellerophon Projects for St Ives Gold Mine, November 2010	Diana, West Idough and Bellerophon	1,272	Sep 2010	26 20 m x 20 m quadrats	None recorded
Botanica Consulting (2011c)	Level 1 Flora Survey of Proposed 66kv Power line Extension Athena area	Athena area	12	Jan 2011	8 relevés	None recorded
Botanica Consulting (2011b)	Level 1 Flora and Vegetation Survey Thunderer Project	Thunderer	223	Sep 2011	32 relevés	None recorded
Botanica Consulting (2011a)	Level 1 Flora and Vegetation Survey of Proposed Workshop Area	M15/1622, M15/1623	88	Sep 2011	Not available	None recorded
Botanica Consulting (2012d)	Regional Level 1 Flora and Vegetation Survey within the mining tenements of St Ives Gold Mine	Majority of the SIGMC tenure	104,900	Sep to Nov 2011	Traverses only	A*cacia dorsenna* (P1), *Allocasuarina eriochlamys* subsp. *grossa* (P3), *Cyanthostemon divaricatus (P1), Austrostipa blackii* (P3), *Diocirea acutifolia* (P3), *Eucalyptus x brachyphylla* (P4), *Eucalyptus kruseana* (P4), *Eucalyptus websteriana subsp. norsemanica* (P1), *Pityrodia scabra subsp. dendrotricha* (P3), *Prostanthera splendens* (P1) Approx. 13,600 ha of the survey area was within the 100 km buffer of the P1 Fraser Range Vegetation Complex

Reference	Report Name	Location of Survey	Study Area Extent (ha)	Survey Date	Survey Effort	Conservation Significance[3]
Botanica Consulting (2012c)	Northern Exploration Areas Level 1 Flora and Vegetation Survey	Northern Exploration Areas	32	Jul 2012	Traverses only	None recorded
Botanica Consulting (2012a)	Idough Level 1 Flora and Vegetation Survey	Idough project area	124	Nov 2012	Traverses only	None recorded
Botanica Consulting (2012b)	Neptune Level 1 Flora and Vegetation Survey	Neptune Project Area	114	Nov 2012	Traverses only	None recorded
Botanica Consulting (2013a)	Invincible Road Level 1 Flora and Vegetation Survey	Invincible Road	13	Nov 2012	Traverses only	None recorded
Botanica Consulting (2013b)	Red Hill Leases Level 1 Flora and Vegetation Survey	Red Hill Project Area	1,015	Dec 2012	Traverses only	One priority species: *Cyanthostemon divaricatus* (P1).
Botanica Consulting (2013c)	Southern Leases Level 1 Flora and Vegetation Survey	Southern Leases area	2,800	Dec 2012	Traverses only	Two priority species: *Diocirea acutifolia* (P3) and *Prostanthera splendens* (P1) Located within the 100km buffer zone of the Fraser Range Vegetation Complexes Priority 1 Ecological Community.
Terratree (2015)	Level 1 Flora, Fauna & Vegetation Assessment	Pistol Club	526	Oct 2015	18 relevés, 2 transects	*Cyathostemon divaricatus* (P1)
Terratree (2016)	Desktop Assessment of Environmental Constraints & Opportunities within Delta Island South & Incredible Project Areas	Lake Lefroy (Delta Island, Incredible)	128	Apr 2016	Not applicable	Not applicable
Karillön (2016)	Notes on the flora of portions of Delta Island South	Delta Island	>20	Apr 2016	Traverses only	None recorded

Reference	Report Name	Location of Survey	Study Area Extent (ha)	Survey Date	Survey Effort	Conservation Significance[3]
Paul Armstrong and Associates (2016)	Vegetation Survey and Rare Flora Search of the Kambalda West Regional Survey	Goldfields Regional Survey Kambalda	19,640	Nov 2015	Traverses only	*Acacia crenulata* (P3), *Cyathostemon divaricatus* (P1), *Leucopogon* sp. Kambalda (P3), *Thryptomene* sp. Londonderry (P1)

Figure 4-2
Coverage of Previous Flora and Vegetation Surveys Undertaken over the Development Envelope

GOLD FIELDS
ST IVES GOLD MINE



LEGEND

Development Envelope

0 4.5 9 13.5 18

Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	2/07/2018

LOCALITY MAP

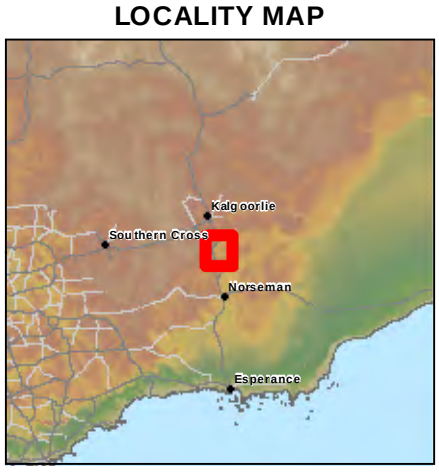


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Table 4-4: Conservation Significant Flora Recorded Previously within the Development Envelope

Species	Conservation status	Number of records	Date of record(s)
Tecticornia mellarium	P1	Unknown	As part of riparian vegetation monitoring.
Calandrinia sp. Widgiemooltha	P1	Unknown	As part of riparian vegetation monitoring.
Ptilotus rigidus	P1	Unknown	As part of riparian vegetation monitoring.
Melaleuca coccinea	P3	1	1961
Pityrodia scabra subsp. *dendrotricha*	P3	2	2004 (both)
Eucalyptus x *brachyphylla*	P4	1	1940
Sowerbaea multicaulis	P4	1	1891

Table 4-5: Vegetation Types Considered Locally Conservation Significant during the Previous Surveys

Vegetation type	Conservation significant species
Mattiske (1996)	
S2 - Open Shrubland dominated by *Jacksonia arida* and *Darwinia* aff. *diosmoides* on pale gritty sands on fringes of large salt lake systems	*Acacia kalgoorliensis* (formerly P3, subsequently removed from the Priority list)
F5 - Woodland of *Eucalyptus salubris* var. *salubris* over mixed low Chenopodiaceae and Asteraceae shrubs species on alkaline clay soils	*Acacia kalgoorliensis* (formerly P3, subsequently removed from the Priority list)
R1 - Mixed Open Shrubland over mixed Open Herbland (annual Asteraceae, Poaceae and Goodeniaceae species) on rocky hillslopes	Myrtaceae sp. VE 1119 (undescribed species)
Jim's Seeds, Weeds and Trees (2006)	
Eucalyptus stricklandii woodland on ridgelines and breakaways.	*Prostanthera splendens* (P1)
Eucalyptus over Spinifex sand plains	*Trachymene pyrophila* (P2)
Acacia shrublands on granite hill rises	*Eucalyptus websteriana* subsp. *norsemanica* (P1)

Vegetation type	Conservation significant species
Botanica Consulting (2012d)	
Thicket of *Acacia quadrimarginea* over mixed dwarf scrub	*Allocasuarina eriochlamys* subsp. *grossa* (P3) *Cyathostemon divaricatus* (P1) *Eucalyptus websteriana* subsp. *norsemanica* (P1)
Thicket of *Acacia* sp. narrow phyllode over mixed low scrub	*Austrostipa blackii* (P3) *Eucalyptus websteriana* subsp. *norsemanica* (P1)
Heath of *Melaleuca thyoides* over low scrub of *Jacksonia arida* on salt lake edge	*Pityrodia scabra* subsp. *dendrotricha* (P3)
Low woodland of *Eucalyptus lesouefii* and *Eucalyptus ravida* over scrub of *Acacia* sp. narrow phyllode in creekline	*Diocirea acutifolia* (P3)
Low forest of *Eucalyptus ravida*	*Acacia dorsenna* (P1) and *Diocirea acutifolia* (P3)
Low woodland of *Eucalyptus lesouefii* / *Eucalyptus salmonophloia* over mixed low scrub	*Diocirea acutifolia* (P3)
Open low woodland of *Eucalyptus salmonophloia* / *Eucalyptus salubris* over mixed low scrub	*Diocirea acutifolia* (P3)
Open low woodland of *Eucalyptus stricklandii* over low scrub of *Dodonaea lobulata* on breakaway	*Prostanthera splendens* (P1)
Open low woodland of *Eucalyptus stricklandii* over heath of *Dodonaea lobulata*	*Diocirea acutifolia* (P3)
Low woodland of *Eucalyptus lesouefii* over low scrub of *Eremophila scoparia* and *Dodonaea viscosa* subsp. *angustissima* on stony rise	*Diocirea acutifolia* (P3)
Open mallee of *Eucalyptus loxophleba* subsp. *lissophloia* and *Eucalyptus kruseana* (P4)	*Eucalyptus x brachyphylla* (P4) *Eucalyptus kruseana* (P4) *Austrostipa blackii* (P3)
Very open mallee of *Eucalyptus websteriana* over thicket of *Acacia quadrimarginea* / *Acacia* sp. narrow phyllode	*Allocasuarina eriochlamys* subsp. *grossa* (P3) *Austrostipa blackii* (P3)
Low heath of *Cratystylis microphylla*	*Cratystylis conocephala x microphylla*
Paul Armstrong and Associates (2016)	
Eucalyptus flocktoniae	*Leucopogon* sp. Kambalda
Rocky outcrops	*Acacia crenulata* (P3) *Cyathostemon divaricatus* (P1) *Leucopogon* sp. Kambalda (P3)

Current Surveys

This section describes the surveys conducted specifically for use in the B2018 Project assessment.

Phoenix Environmental Services ("Phoenix") was engaged to undertake a number of flora and vegetation assessments for the proposed Project. The objective of the flora and vegetation assessments was to define the botanical values of the B2018 Project Development Envelope and inform an EIA for the Project. The following summarises the surveys undertaken:

- A detailed phase flora and vegetation survey within the Development Envelope (45,013 ha) over two field trips in 28 September–6 October 2016 and 7–10 November 2016 (Phoenix 2018b);
- A lower intensity regional flora and vegetation survey (over 60,220 ha within St Ives tenements; regional study area) in 7–15 November 2016 (Phoenix 2017b);
- An additional flora and vegetation assessment over the potentially restricted riparian vegetation types around Lake Lefroy and targeted surveys for *Tecticornia mellarium*, *Calandrinia* sp. Widgiemooltha (F. Obbens & E. Reid FO 9/05), *Ptilotus rigidus* in 19–25 April 2017 (Phoenix 2018a); and
- Further *Tecticornia* targeted survey work undertaken in January 2018 (Phoenix 2018c).

Full reports of these surveys are provided in Appendices D to G. These surveys provide contextual information for the botanical values of the Development Envelope and build on the solid baseline obtained by the previous studies outlined in Table 4-3.

Due to the large amount of baseline data available, a single season survey over the Development Envelope was considered sufficient to inform the EIA and the regional survey was undertaken to provide regional context for the impact assessment. These surveys showed that clearing for the B2018 Project may have an impact on priority species as well as locally significant vegetation types. The objective of the additional flora and vegetation assessment (Appendix F) was therefore to increase local and regional knowledge of these flora and vegetation values identified in the B2018 Project Development Envelope.

Survey design, methodology and technical reporting adhered to relevant legislation, principles and guidelines, including:

- Position Statement No. 3: Terrestrial biological surveys as an element of biodiversity protection (EPA 2002);
- Guidance Statement No. 51: Terrestrial flora and vegetation surveys for environmental impact assessment in Western Australia (EPA 2004); and
- Technical guide: Flora and vegetation surveys for environmental impact assessment (EPA and DPaW 2015).

Where appropriate, all the reports were amended to reflect recent EPA guidance for the flora and vegetation, specifically:

- EPA Statement of Environmental Principles, Factors and Objectives EPA (EPA 2016j);
- EPA Environmental Factor Guideline: Flora and vegetation (EPA 2016d); and
- EPA Technical Guidance: Flora and vegetation surveys for Environmental Impact Assessment (EPA 2016n).

The methodology used for each of the surveys is summarised in Table 4-6. Detailed descriptions are provided in full survey reports (Appendices D to G). Survey site locations are provided in Figure 4-3.

Table 4-6: Summary of Flora and Vegetation Survey Methodology and Data Application

Reference	Report Name	Season	Level	Study area extent – Total (ha)	Survey intensity	Data application
Phoenix (2016a)	B2018 Project – Desktop review of biological data	NA	Desktop	NA	NA	Preliminary data only.
Phoenix (2016b)	Review of vegetation significance at proposed drill sites	NA	Desktop	NA	NA	Preliminary data only.
Phoenix (2018b)	Flora and vegetation survey for the St Ives Gold Mine Beyond 2018 Project	Spring	Level 2	45,014	95 quadrats (3 x 3 m or 20 x 20 m); 23 relevés; 3 transects; 70 riparian transects/sites	Inside Development Envelope - flora and core data for vegetation mapping.
Phoenix (2017b)	Regional flora and vegetation survey for St Ives Gold Mine	Spring	Level 1	60,224	3 quadrats; 92 relevés	Outside Development Envelope - flora and core data for vegetation mapping (regional).
Phoenix (2018a)	Additional flora and vegetation assessment for the B2018 Project	Autumn	Targeted	NA	10 quadrats; 19 transects; 9 relevés	Inside Development Envelope – additional flora collections. Outside Development Envelope - additional flora collections and supplementary data for vegetation mapping (regional).
Phoenix (2018c)	*Tecticornia* spp. targeted search	Summer	Targeted	NA	Revisit selected previous survey locations	Inside Development Envelope – additional collection of *Tecticornia* spp. from existing sample sites.

Figure 4-3
Flora and Vegetation Survey Sites for Beyond 2018 Project

GOLD FIELDS
ST IVES GOLD MINE

365000 370000 375000 380000 385000 390000 395000

6550000 6545000 6540000 6535000 6530000 6525000 6520000 6515000

LEGEND

B2018 Survey
- Opportunistic
- Quadrat
- Transect

Regional Survey
- Opportunistic
- Quadrat
- Transect
- Releve
- Quadrat Transect

Targeted Tecticornia Survey
- Opportunistic
- Quadrat
- Transect
- Releve

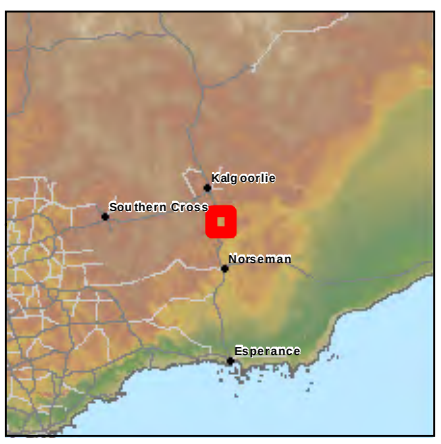
0 3 6 9 12
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	24/07/2018

LOCALITY MAP



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Several minor survey limitations were identified which included the lack of current aerial imagery (imagery from 2012 was used) and the inability to obtain full access to all parts of the Development Envelope due to a lack of access tracks. Some earlier survey work made collections that were difficult to identify due to a lack of flowers or fruits but subsequent survey work addressed this issue for key genera e.g. *Tecticornia*.

4.2.3.3 Vegetation Types

A total of 20 vegetation types were mapped for the Development Envelope (Table 4-7; Figure 4-4). Vegetation types were determined using a cluster analysis (Unweighted Pair Group Method with Arithmetic Mean - UPGMA) that split types based on floristic composition (see Appendix D, p41).

The data used to generate the cluster analysis used only data from the Beyond 2018 Project surveys and not previous surveys because:

- Not all previous flora data was available; and
- The surveys were conducted over an extended period (since 1996) and subsequently utilised several different data collection methods and quadrat/survey site shapes and sizes.

However, the vegetation types identified were matched, where possible, with vegetation types from previous studies (where dominant species in vegetation descriptions were the same).

The vegetation types comprised seven woodland communities, three chenopod shrublands, seven shrublands and three riparian (dune/beach) vegetation types. The woodland vegetation types were the most dominant representing 88.1% of the total area of vegetation in the Development Envelope with the most dominant vegetation type being W7 (Table 4-8). High resolution vegetation mapping is provided in Appendix D (refer to Phoenix (2018b)).

Table 4-7: Vegetation Types Recorded in the Development Envelope

Vegetation type	Vegetation description
Riparian vegetation	
R1	*Acacia ligulata*, *Jacksonia arida* and *Melaleuca* spp. mid isolated shrubs to open mixed shrubland occasionally with an overstorey of *Allocasuarina* spp. and/or *Callitris columellaris* low open woodland
R2	*Melaleuca thyoides* and *Jacksonia arida* mid to tall open shrubland over *Darwinia* sp. Karonie low sparse to open shrubland
R3	*Darwinia* sp. Karonie and *Tecticornia* spp. low sparse shrubland
Shrublands	
C1	Isolated mid to tall mixed shrubs over *Frankenia* and *Tecticornia* spp. over low open shrubland
C2	*Tecticornia* and *Frankenia* spp. low shrubland
C3	*Cratystylis* and *Eremophila* spp. mid open shrubland over low sparse to open mixed shrubland
S1	*Leptospermum roei* tall shrubland over *Jacksonia arida*, *Leucopogon* sp. Clyde Hill (M.A. Burgman 1207) and *Melaleuca thyoides* mid sparse shrubland over *Calytrix watsonii* and *Darwinia* sp. Karonie (K. Newbey 8503) low open shrubland

Vegetation type	Vegetation description
S2	*Acacia, Eremophila* and *Dodonaea* spp. mid sparse to open shrubland occasionally with an overstorey of *Eucalyptus* spp. over *Atriplex, Maireana* and *Tecticornia* spp. low sparse to open chenopod shrubland
S3	*Acacia quadrimarginea* tall shrubland over mid sparse mixed shrubland over *Enchylaena tomentosa* and *Rhagodia drummondii* low sparse chenopod shrubland
S4	*Melaleuca hamata* tall closed shrubland over isolated low mixed shrubs and sedges
S5	*Melaleuca hamata*, *M. lanceolata* and *M. sheathiana* tall open shrubland over *Eremophila decipiens* subsp. *decipiens, Exocarpos aphyllus* and *Melaleuca thyoides* mid sparse shrubland
S6	*Eremophila oppositifolia* and *Melaleuca laterifolia* tall shrubland over *Grevillea acuaria* low sparse shrubland
S7	*Acacia ligulata* tall open shrubland over *Triodia irritans* low open hummock grassland
Woodlands	
W1	*Eucalyptus salmonophloia* isolated trees over *Eremophila decipiens* subsp. *decipiens* and *E. rugosa* mid shrubland over low sparse chenopod shrubland
W2	*Callitris columellaris* tall shrubland over *Acacia ligulata, Cratystylis* spp. and *Eremophila* spp. mid open shrubland over low sparse chenopod shrubland
W3	*Eucalyptus salubris* mid woodland occasionally with other *Eucalyptus* trees present over patches of *Melaleuca sheathiana* tall shrubland over *Cratystylis conocephala, Senna artemisioides* subsp. *petiolaris* and *Eremophila* spp. mid sparse to open shrubland over low sparse mixed shrubland
W4	*Eucalyptus lesouefii* and/or *E. oleosa* subsp. *oleosa* mid woodland over *Cratystylis conocephala, Eremophila scoparia* and *Scaevola spinescens* mid shrubland occasionally with *Triodia scariosa* or *T. irritans* low sparse hummock grassland
W5	*Eucalyptus griffithsii* mid woodland frequently with other *Eucalyptus* spp. over *Acacia* and *Eremophila* spp. tall shrubland over mixed low shrubs
W6	*Eucalyptus striaticalyx* mid woodland over *Acacia ligulata* mid sparse to open shrubland over *Triodia irritans* low hummock grassland
W7	Mosaic of *Eucalyptus* spp. mid woodland over sparse mixed shrubland over *Triodia irritans* hummock grassland

Figure 4-4
Vegetation Types

365000 370000 375000 380000 385000 390000 395000

6550000 6545000 6540000 6535000 6530000 6525000 6520000 6515000

LEGEND

- Development Envelope
- Disturbed/ developed
- Salt lake playa

Vegetation Type

(A description of each vegetation type is given in Table 4-7)

- C1
- C2
- C3
- R1
- R2
- R3
- S1
- S2
- S3
- S4
- S5
- S6
- S7
- W1
- W2
- W3
- W4
- W5
- W6
- W7

0 3 6 9 12

Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	B
Date:	24/07/2018

LOCALITY MAP

Document Path: \\server\talis\SECTIONS\Environment\Projects\TE2016\TE16034 - SIGM B2018 EPA Process\10. GIS\Maps\ERD_Mapping\TE16034_ERD_4-4_VegAssocs_RevB.mxd

Table 4-8: Extent of Vegetation Types in the Development Envelope

Vegetation type	Vegetation code	Area (ha)	Area (%)	Proportion within vegetated areas within DE (%)
Riparian vegetation	R1	416.4	0.93	2.69
Riparian vegetation	R2	261.3	0.58	1.69
Riparian vegetation	R3	1.9	0.00	0.01
Shrubland	C1	286.5	0.64	1.85
Shrubland	C2	172.5	0.38	1.11
Shrubland	C3	9.8	0.02	0.06
Shrubland	S1	52.3	0.12	0.34
Shrubland	S2	181.4	0.40	1.17
Shrubland	S3	24.9	0.06	0.16
Shrubland	S4	2.8	0.01	0.02
Shrubland	S5	229.6	0.51	1.48
Shrubland	S6	233.8	0.52	1.51
Shrubland	S7	14.1	0.03	0.09
Woodland	W1	1,765.9	3.92	11.39
Woodland	W2	162.3	0.36	1.05
Woodland	W3	3,439.7	7.64	22.19
Woodland	W4	3,170.5	7.04	20.45
Woodland	W5	159.6	0.35	1.03
Woodland	W6	53.8	0.12	0.35
Woodland	W7	4,861.9	10.8	31.37
Salt lake playas and pans		25,338.2	56.29	
Disturbed/developed		4,174.3	9.27	
Total:		**45,013.5**	**100.00**	**100.00**

Typically, the cluster analysis of the sites produced distinct super groups and floristic groups based on species composition and structure. In assigning the vegetation types, three sites were omitted from the grouping in the dendrogram and assigned a different vegetation type as their structure and species composition clearly did not reflect that of the floristic group in which they were placed by cluster analysis:

- Site SI008 named as shrubland S1; originally grouped by UPGMA with riparian vegetation R1;
- Site SI003 named as woodland W1; originally grouped by UPGMA with chenopod shrubland C2; and
- Site SI017 named as shrubland S5; originally grouped by UPGMA as woodland W4.

Much of the Development Envelope (65.3%) consists of the unvegetated Lake Lefroy salt lake and a number of smaller wetlands on the periphery of Lake Lefroy.

4.2.3.4 Regionally and Locally Significant Vegetation

None of the vegetation types mapped within the Development Envelope are considered regionally significant as they do not represent habitat for Federal- or State-listed Threatened Flora or are representative of vegetation with less than 30% pre-European extent remaining (Phoenix 2018b). However, vegetation types may be considered to have local conservation significance for one or more of the following reasons:

- Represents habitat for Priority Flora; and/or
- Uncommon or restricted within the regional or local context.

With the exception of the S5 shrubland community which to date has only been recorded from the Development Envelope, all vegetation types mapped in the Development Envelope in the spring 2016 survey (Phoenix 2018b) have also been recorded outside this area during the regional or additional riparian survey (Phoenix 2017b, 2018a) . However, the S5 shrubland was not considered locally significant vegetation (Phoenix 2018b) as it covered an area greater than 100 ha and did not contain any significant flora.

Based on the results of the spring 2016 survey (Phoenix 2018b) a total of 12 vegetation types within the Development Envelope were determined to have restricted distribution (C1, C2, C3, R1, R2, R3, S1, S2, S3, S4, S7 and W6) (Phoenix 2018b). The regional and additional riparian surveys undertaken provided further definition on the local significance and of the originally mapped vegetation types five (R3, S1, S3, S4 and S7) were considered to have restricted distribution (Phoenix 2018a). Further to this C1, C2, C3, S2, R1, R2 and R3 vegetation types are considered locally significant within the Development Envelope as they represent habitat for Priority Flora. The W6 vegetation type was originally considered to have restricted distribution, but the vegetation type was recorded in high abundance in the regional study area and is not now considered restricted.

Of the locally significant vegetation types, only S1 occurs predominantly (~85.7%) within the Development Envelope. This vegetation type occupies 61 ha across all three surveys undertaken and is considered locally and potentially regionally restricted (Phoenix 2018a). The R3 vegetation type appears to be highly restricted, with 1.9 ha mapped in the Development Envelope and 2.0 ha mapped outside the envelope. The S4 vegetation type also occupies a small extent with 10.9 ha mapped of which 2.1 ha occurs in the Development Envelope.

The S7 vegetation type is also considered locally restricted with a total of 57.7 ha mapped, although the majority of this (approximately 75%) occurs outside the Development Envelope. The S3 occupies 80.8 ha across all surveys undertaken with 32.2% within the Development Envelope.

The C1, C2, C3, S2, R1, R2 and R3 vegetation types are considered locally significant as they represent habitat for Priority Flora and two indeterminate taxa (Phoenix 2018b). The R1 vegetation type contains populations of *Tecticornia mellarium* and *Ptilotus rigidus* within the Development Envelope. The R2 vegetation type represents habitat for *Tecticornia mellarium* and *Tecticornia* SIGMb. The C1 and C2 vegetation types contain populations of *Tecticornia mellarium* and C3 and S2 host populations of *Calandrinia* sp. Widgiemooltha. The R3 vegetation type represents habitat for *Ptilotus rigidus*. C3 also contains *Tecticornia* SIGMq.

Table 4-9 below provides a summary on the locally significant vegetation types. These are also shown in Figure 4-5.

Table 4-9: Locally Significant Vegetation Types

Vegetation type	**Local significance criteria**		
	Restricted distribution	**Habitat for significant flora**	
R1		✓	*Tecticornia mellarium* *Ptilotus rigidus*
R2		✓	*Tecticornia mellarium,* *Tecticornia* SIGMb
R3	✓	✓	*Ptilotus rigidus*
C1		✓	*Tecticornia mellarium*
C2		✓	*Tecticornia mellarium*
C3		✓	*Calandrinia* sp. Widgiemooltha, *Tecticornia* SIGMq
S1	✓		
S2		✓	*Calandrinia* sp. Widgiemooltha
S3	✓		
S4	✓		
S7	✓		

Figure 4-5
Locally Significant Vegetation Types

365000 370000 375000 380000 385000 390000 395000

6550000 6545000 6540000 6535000 6530000 6525000 6520000 6515000

LEGEND

Development Envelope

Vegetation Type

(A description of each vegetation type is given in Table 4-7)

- C1
- C2
- C3
- R1
- R2
- R3
- S1
- S2
- S3
- S4
- S7

0 3 6 9 12

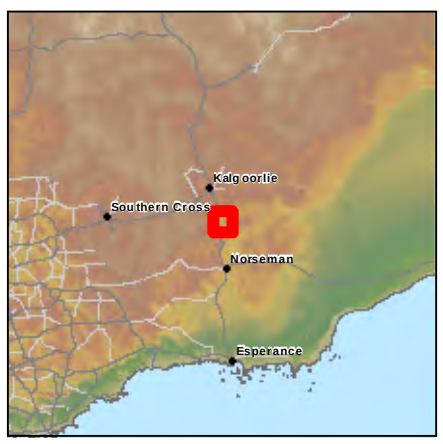
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	B
Date:	24/07/2018

LOCALITY MAP



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4.2.3.5 Threatened and Priority Ecological Communities

No vegetation types were classified as either a Threatened Ecological Community (TEC) or a Priority Ecological Community (PEC). The nearest TEC or PEC to the Development Envelope is the Priority 1 Fraser Range Vegetation Complex PEC. None of the vegetation types within the Development Envelope are floristically representative of this PEC.

4.2.3.6 Groundwater Dependent Ecosystems

Phoenix (Appendix D) considered the likelihood of groundwater dependent ecosystems occurring at Lake Lefroy. They noted that there are suggestions some *Tecticornia* species may have a degree of reliance on groundwater (Moir-Barnetson 2014; Niche Environmental 2011). However, a recent review by Ecologia (2016) in relation to *Tecticornia* spp. occurring at Lake Maitland, near Wiluna, Western Australia, noted that:

- *Tecticornia* species have morphological and physiological characteristics (i.e. low leaf area index (LAI), low transpiration rate, shallow root architecture) associated with plant drought tolerance and are not typical of groundwater dependent species;
- Published and unpublished technical literature suggests possible linkages between *Tecticornia* zonation and submergence tolerance;
- It is likely that the environmental water requirements of *Tecticornia* species are met by periodic surface recharge of the vadose zone; and
- Other environmental water requirements (related to seedling emergence, for example) are triggered by fresh water inputs from rainfall events and are not influenced by changes in groundwater regimes.

The findings of the review strongly suggest *Tecticornia* spp. are dependent on surface flooding and infiltration of runoff into the vadose zone rather than groundwater.

Other genera occur at Lake Lefroy, e.g. *Melaleuca* and *Eucalyptus* spp., which are sometimes associated with groundwater dependency. However, with groundwater quality within the vicinity of Lake Lefroy ranging between 274,000 and 423,000 mg/L TDS and occurring at depths between 15-30 m bgl, groundwater dependency in any species is an unlikely prospect.

On this basis, SIGMC concludes groundwater dependency is not a factor at Lake Lefroy.

4.2.3.7 Riparian Vegetation

Riparian vegetation (vegetation types R1, R2 and R3) has been subject to annual monitoring since the establishment of a riparian vegetation monitoring program in 2005 (Outback Ecology 2005). Baseline studies of the riparian zone of Lake Lefroy were first completed in 1999 (Curtin University of Technology 1999a), during which eight vegetation units were mapped, and 60 species (from 25 families and 32 genera), were identified. The dominant taxa were from the Chenopodiaceae, Myrtaceae, Scrophulariaceae and Frankeniaceae families, forming halophytic plant communities considered to be well represented in the wider area. Subsequent studies have indicated the presence of two main vegetation associations; samphire and shrubland (Botanica Consulting 2014; Jim's Weeds 2006; MWH 2017). The samphire association is dominated by *Tecticornia* species, while the shrubland association is dominated by *Jacksonia*, *Darwinia* and *Melaleuca* species (Stantec 2017c).

A study by Jim's Weeds (2006) classified the riparian zone as the vegetation community within five metres of the Lake Lefroy shoreline (riparian shrubland), from which 19 families were recorded. The findings were consistent with the 1999 study, with vegetation dominated by *Jacksonia arida*, *Casuarina obesa* and *Darwinia* sp. Karonie (Jim's Weeds 2006). Other species included *Disphyma crassifolium*, *Gunniopsis quadrifida*, *Tecticornia doleiformis*, *Tecticornia halocnemoides*, *Maireana glomerifolia*, *Scaevola spinescens* and *Dodonaea viscosa* subsp. *angustissima*. Minesite Environmental Pty Ltd (2009) have also previously recorded the

samphire species *Tecticornia halocnemoides* subsp. aff. *halocnemoides* and *Tecticornia indica* subsp. *bidens* from the lake shoreline.

The Botanica Consulting (2012d) study included approximately 24,600 ha of riparian habitat. Within this zone, the Riparian/Creekline vegetation unit was described as “heath of *Melaleuca thyoides* over low scrub of *Jacksonia arida* on salt lake edge”, consisting of seven families. The Priority 3 species *Pityrodia scabra* subsp. *dendrotricha* was also recorded from this vegetation unit (Botanica Consulting 2012d), and was listed in the database searches. While several taxa are likely to occur within the riparian vegetation zone adjacent to Lake Lefroy, particularly where white, grey, yellow, orange or brown sandy soils occur (Western Australian Herbarium 2016a), only two taxa from the family Chenopodiaceae have the potential to be impacted by dewatering discharge. These are *Tecticornia flabelliformis* (bead glasswort) (Priority 1) and *Tecticornia mellarium* (Priority 1) (DPaW 2015)

Since 2010, the most recent comprehensive annual monitoring of the riparian zone of Lake Lefroy has been undertaken by Stantec (previously MWH and Outback Ecology), Botanica Consulting, and Native Vegetation Solutions (Botanica Consulting 2010d; 2013; 2014, MWH 2016b; 2017, Native Vegetation Solutions 2014, Outback Ecology 2006;2007;2009a). Based on the collation of this data, a total of 77 confirmed plant taxa have been recorded between 2010 and 2016. During the monitoring associated with the MS879, the most frequently occurring taxon has been *Darwinia* sp. Karonie (524 occurrences), followed by *Tecticornia indica* (283 occurrences), *Jacksonia arida* (249 occurrences), and *Melaleuca thyoides* (205 occurrences).

4.2.3.8 Vegetation Condition

The condition of vegetation was mapped across the Development Envelope based on the Keighery (1994) scale, which is the appropriate condition rating scale for the Interzone Botanical Province in which the Eastern Goldfields subregion is located (EPA 2016n).

The vegetation condition ratings relate to vegetation structure, the level of disturbance and weed cover at each structural layer and the ability of the vegetation unit to regenerate. Mine areas and infrastructure were rated as Completely Degraded. Some areas that had been previously disturbed for sand mining but which now have the appearance and structure of naturally-occurring vegetation were scored accordingly.

Vegetation condition within the Development Envelope ranges from Pristine to Completely Degraded. The majority of the Development Envelope comprised the Lake Lefroy salt lake playa with no vegetation (Table 4-10; Figure 4-6). High resolution condition mapping of vegetation condition is provided in Appendix D.

Table 4-10: Vegetation Condition in the Development Envelope

Condition (Keighery 1994)	Area (ha)	Percentage (%) of Development Envelope
Pristine – Pristine or nearly so, no obvious signs of disturbance	8,821.0	19.6
Excellent – Vegetation structure intact, disturbance affecting individual species, weeds are non-agressive	6,542.8	14.5
Very Good – Vegetation structure altered, obvious signs of disturbance	133.9	0.3
Good – Vegetation structure significantly altered by very obvious signs of multiple disturbances, retains basic vegetation structure or ability to regenerate it	-	-
Degraded – Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not in a state approaching good condition without intensive management	-	-
Completely Degraded – The structure of the vegetation is no longer intact and the area is completely or almost without native species	4,174.5	9.3
Unvegetated salt lake playa	25,341.3	56.3
Total:	**45,013.5**	**100.00**

Figure 4-6
Vegetation Condition within the Development Envelope

365000 370000 375000 380000 385000 390000 395000

6550000 6545000 6540000 6535000 6530000 6525000 6520000 6515000

LEGEND

Vegetation Condition

- Pristine
- Excellent
- Very good
- Completely degraded
- Unvegetated

0 3 6 9 12

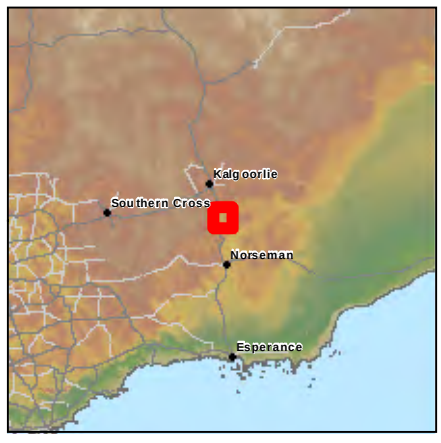
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	24/07/2018

LOCALITY MAP



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4.2.3.9 Flora

A total of 284 flora species and subspecies representing 44 families and 120 genera were recorded during the field surveys over the Development Envelope (refer to Appendix D, Phoenix 2018b). Species diversity was highly variable between sites. This included 226 perennial species and 58 annual or short-lived species. The most prominent families recorded in the Development Envelope were Chenopodiaceae, Asteraceae, Myrtaceae and Fabaceae.

No State-listed Threatened Flora were recorded in the Development Envelope or over wider SIGMC tenure (Phoenix 2017b, 2018a, 2018b). All previous records of conservation significant flora within and in close proximity to the Development Envelope were revisited during field studies. Three Priority Flora species were recorded during the field survey to occur within the Development Envelope (Phoenix 2018b) (Figure 4-7):

- *Calandrinia* sp. Widgiemooltha (F. Obbens & E. Reid FO 9/05)[5] (P1);
- *Ptilotus rigidus* (P1); and
- *Tecticornia mellarium* (P1).

Two *Tecticornia* taxa originally identified as potentially new species were revisited in the targeted *Tecticornia* survey and were subsequently identified as common species. However, two other collections – *Tecticornia* SIGMb and *Tecticornia* SIGMq – are only known from sterile material despite being collected on at least two occasions. Furthermore, possible species identities for these collections could not be confidently attributed. Consequently, as a precaution, these two taxa have been regarded as conservation significant for impact assessment purposes. The locations of these taxa are also shown in Figure 4-7.

A total of eight additional species of conservation significant flora were recorded outside the Development Envelope during the regional and riparian surveys (Phoenix 2017b, 2018a), including one species listed as Vulnerable under the EPBC Act. These species were:

- *Allocasuarina eriochlamys* subsp. *grossa* (P3).
- *Cryptandra crispula* (P3);
- *Cyathostemon divaricatus* (P1);
- *Cyathostemon divaricatus* (P1);
- *Diocirea acutifolia* (P3); and
- *Pityrodia scabra* subsp. *dendrotricha* (P3);
- *Prostanthera splendens* (P1);
- *Tecticornia flabelliformis* (Vulnerable);

Populations of all three Priority Flora recorded in the Development Envelope, *Tecticornia mellarium*, *Ptilotus rigidus* and *Calandrinia* sp. Widgiemooltha, were also recorded outside the Development Envelope either as part of the regional survey or targeted riparian survey (Phoenix 2017b, 2018a), identifying distributions for each species beyond the B2018 Project area.

Commonwealth listed species from the region *Gastrolobium graniticum* was not recorded within the Development Envelope or wider SIGMC tenure. There is no suitable habitat available for *Gastrolobium graniticum* so this species is unlikely to occur within the Development Envelope.

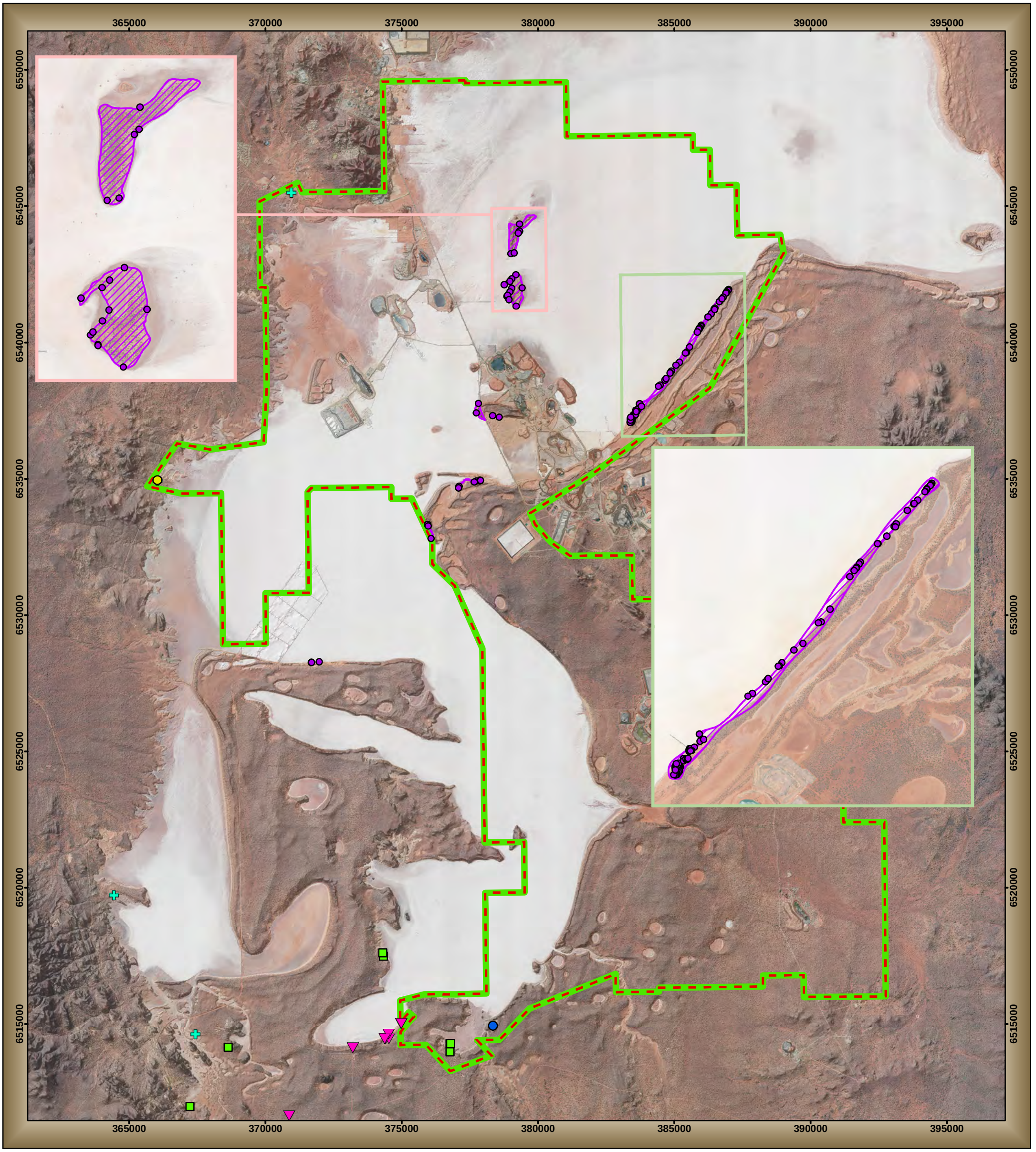
Profiles of each of the three Priority Flora P1 species are presented in Table 4-11 through to Table 4-13.

[5] Note that this species is now known as *Calandrinia lefroyensis* but the synonym *Calandrinia* sp. Widgiemooltha (F. Obbens & E. Reid FO 9/05) has been retained here to maintain consistency between this document and the supporting appendices.

Regarding other Priority species, *Pityrodia scabra* subsp. *dendrotricha* (P3) was recorded in desktop studies but was not recorded in surveys within the Development Envelope, although it does occur nearby. Records of other significant flora that were identified from the desktop assessment including *Eucalyptus x brachyphylla* (P4), *Melaleuca coccinea* (P3) and *Sowerbaea multicaulis* (P4) are considered erroneous and are excluded from the impact assessment.

Other than *Calandrinia* sp. Widgiemooltha and *Tecticornia mellarium*, collections of five other species occurring within the Development Envelope represented range extensions (Table 4-14; Figure 4-8) (Phoenix 2018a,b). Each is regarded as locally significant.

Figure 4-7
Locations Of Conservation Significant Flora Species



Conservation Significant Flora Species

- *Calandrinia sp. Widgiemooltha*
- *Pityrodia scabra subsp. dendrotricha*
- *Ptilotus rigidus*
- *Tecticornia mellarium*
- *Tecticornia SIGMb*
- *Tecticornia SIGMq*
- *Tecticornia mellarium* Population

0 3 6 9 12

kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	B Harvey
Reviewed:	N King
Checked:	G Barrett
Project No:	TE16034
Revision:	E
Date:	27/09/2018

LOCALITY MAP

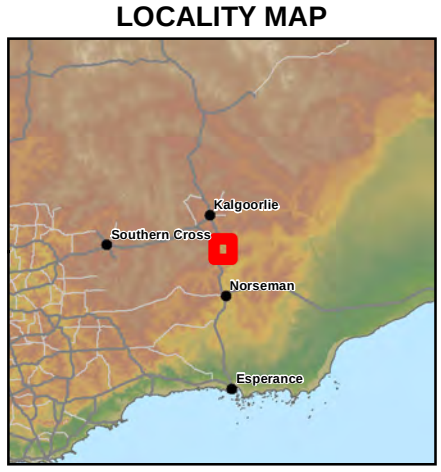


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Table 4-11: **Calandrinia *sp. Widgiemooltha (F. Obbens & E. Reid FO 9/05)***

Feature	Details
Status	Priority 1 (DBCA)
Description	Erect scrambling perennial herb. 
Distibution and ecology	Previously recorded in the Eastern Goldfields subregion of the Coolgardie bioregion (DPaW 2015).The species is known from 2 records (ALA 2016) with habitat descriptions including: • extensive saline flats, brown silty loam with some scattered quartz; and • samphire community. A tree layer of scattered *Casuarina obesa* with understorey of *Frankenia setosa*, *F. interioris, Carpobrotus* sp., *Tecticornia doleiformis* and *Maireana glomerifolia.*
Records and distribution in the Development Envelope	The specimens were collected from five locations (Figure 4-7) (Phoenix 2017d). The species was recorded on: • low lying plain in brown clay-loam soil with scattered quartz in a mid-sparse *Cratystylis subspinescens* and *Eremophila oldfieldii* shrubland over low open *Atriplex vesicaria*, *Maireana glomerifolia*, *Maireana oppositifolia* and *Tecticornia* sp. chenopod shrubland; and • undulating plain in sandy clay/clay-loam in a mid-sparse *Acacia kalgoorliensis*, *Dodonaea viscosa* and *Scaevola spinescens* shrubland over low open *Atriplex vesicaria*, *Tecticornia triandra* and *Tecticornia disarticulata* chenopod shrubland over isolated low *Disphyma crassifolium* forbs. The species was not identified in the field and as such the size and distribution of the populations was not recorded. There has been a paucity of survey effort for *Calandrinia* sp. Widgiemooltha and it is considered likely that the species is locally common around Lake Lefroy (F. Obbens 2016, pers. comm. to G. Wells). This position is supported by the results of the B2018 surveys. Prior to the surveys conducted for the B2018 Project, the species was known from two records (ALA 2017) with population sizes recorded as locally common, and occasional and scattered (DPaW 2017). The B2018 Project surveys have identified a further five populations around Lake Lefroy, two in the Development Envelope and three outside the Project area.

Table 4-12: Ptilotus rigidus

Feature	Details
Status	Priority 1 (DBCA)
Description	Erect shrub to 20 cm high, 25 cm wise with pink flowers. 
Distibution and ecology	Previously recorded in the Coolgardie and Murchison bioregions and the Eastern Goldfields sub-region (DPaW 2015). The species is known from 10 records (ALA 2016) from five known populations, with habitat descriptions including: • small quartz hill near a large salt lake; and • kopi (raised dune system associated with saline areas) vegetation.
Records and distribution in the Development Envelope	The species was recorded in two quadrats conducted on a single physical landform (breakaway vegetated by two distinct vegetation types) (Figure 4-7) within the Development Envelope. The species was recorded in pockets of shallow yellow sandy loam on a sandstone breakaway in vegetation comprising isolated tall *Allocasuarina acutivalvis* subsp. *acutivalvis* shrubs over mid sparse *Jacksonia arida* and *Melaleuca hamata* mid shrubland over low open *Darwinia* sp. Karonie (K. Newbey 8503), *Grevillea acuaria* and *Leucopogon* sp. Clyde Hill (M.A. Burgman 1207) shrubland. A population count of the single known location of *Ptilotus rigidus* in the Development Envelope determined a population size of approximately 500 individuals. The presence of several different age groups within the population indicates it is healthy. The second smaller population (34 individuals) recorded outside the Development Envelope was from very similar habitat to that of the Development Envelope population. Only one other area of similar habitat was sighted during the current survey but no further plants of the species were recorded at this location. Prior to the surveys conducted for the B2018 Project, *Ptilotus rigidus* was known from five populations with a broad distribution (records from the Coolgardie and Murchison bioregions). The population within the Development Envelope is considered a significant population as it is one of only seven recorded and also represents one of the larger populations for the species, with previous records providing population sizes of 47, 100, 150 and ‘several hundred’ individuals (DPaW 2017). Avoidance of impacts to this population is therefore recommended where practicable. Both of the recorded populations occur well to the south of current mining operations. The habitat recorded for the species is conspicuous facilitating identification and the capacity to avoid disturbance to these areas thereby minimising impacts to the species from future operations.

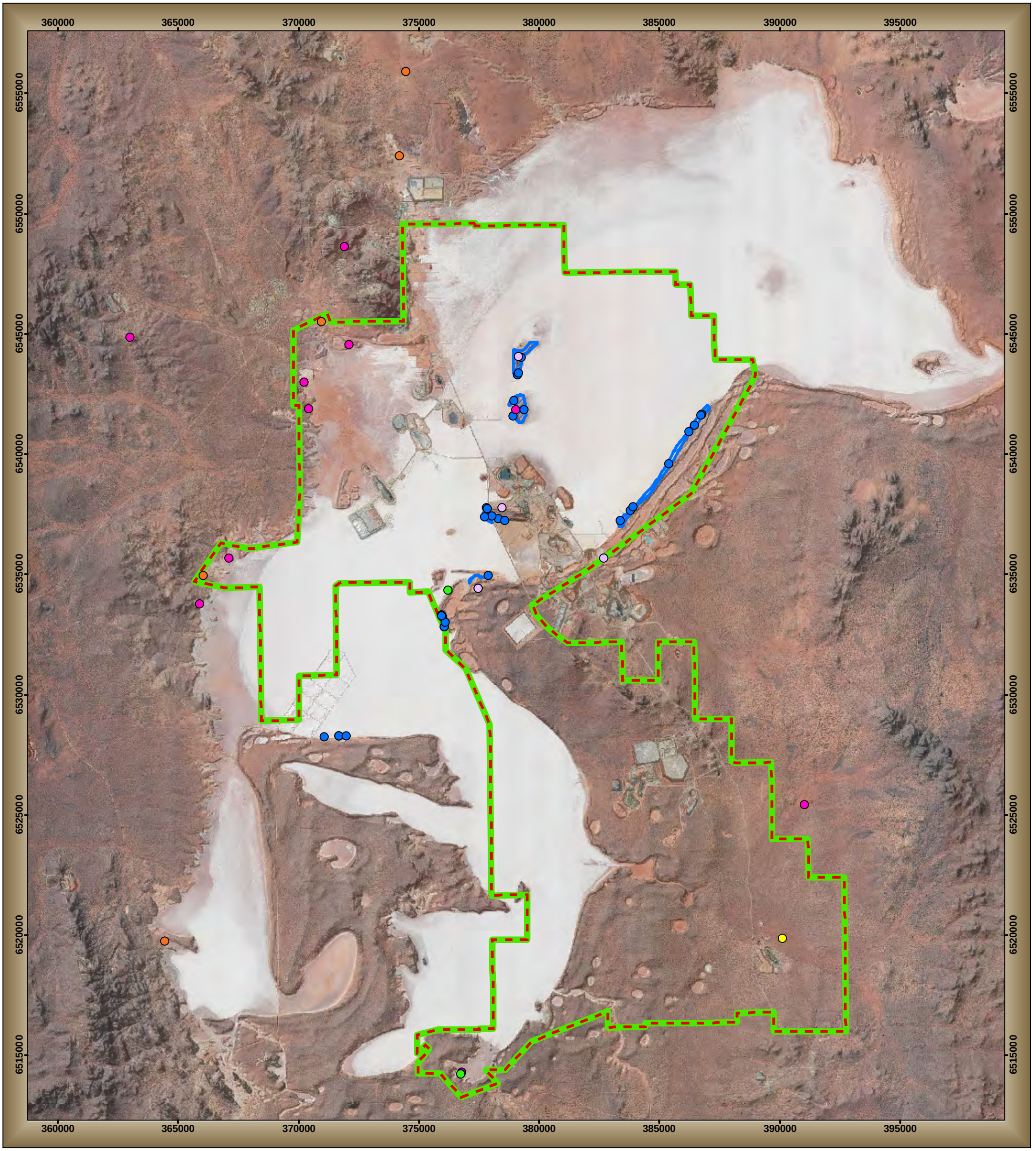
Table 4-13: Tecticornia mellarium

Feature	Details
Status	Priority 1 (DBCA)
Description	Succulent shrub to 40 cm tall and up to 1 m wide. 
Distibution and ecology	Previously recorded in the Eastern Murchison subregion of the Murchison bioregion (DPaW 2015).The species is known from 12 records (ALA 2016), with habitat described as gypsiferous dunes, growing close to salt lake
Records and distribution in the Development Envelope	Specimens were collected from numerous locations (Figure 4-7). Habitat for the species included: • riparian zone in red-brown sandy-clay with isolated *Frankenia fecunda*, *Maireana radiata* and *Tecticornia indica* shrubs; • riparian zone sand dune in red-brown sand with vegetation comprising isolated tall *Acacia ligulata* over low open *Darwinia* sp. Karonie and *Tecticornia* spp. Shrubland; and • riparian zone sand dune in yellow-brown sand with vegetation comprising tall sparse *Melaleuca thyoides* and *Acacia ligulata* shrubland over mid sparse *Jacksonia arida* and *Darwinia* sp. Karonie shrubland. Typically, the species was located on the sandy beach/dunes within a few metres of the salt lake playa. The population size ranged from three plants to hundreds. During the riparian survey two populations that were accessible contained substantially higher numbers of plants (194 and 249) compared with the population identified in the additional study area (56). A large number of records of *Tecticornia mellarium* has been identified at Lake Carey, a regional salt lake located approximately 220 km north-east of Lake Lefroy. However, no population sizes are provided in records of those species (DPaW 2017) with the exception of one observation of 'frequent'. It is therefore not possible to determine what proportion of the total regional population of this species occurs within the Development Envelope. *T. mellarium* was recorded in vegetation types R1 and R2 in the Development Envelope (Phoenix 2018b) both of which were also recorded in the regional and riparian survey (Phoenix 2017b, 2018a). The entire extent of these vegetation types has not been searched for the presence of the species and it is possible that further populations occur on Lake Lefroy outside of the Development Envelope. In addition, the extent of the range extension of this species (from Lake Carey to Lake Lefroy) as a result of the B2018 Project surveys, suggests the potential for further populations to be present in suitable habitat across this range.

Table 4-14: Flora – range extensions

Species	Approximate distance and direction of range extension (km)	Comments
Acacia quadrimarginea	100 km south	Broad distribution in central Western Australia, known from 101 records on Florabase and has previously been recorded in the north-west corner of the Coolgardie bioregion with other records in the Gascoyne, Gibson Desert, Great Victoria Desert, Murchison and Yalgoo bioregions.
Calandrinia baccata	150 km east	Broad distribution in Western Australia, is known from 64 records on Florabase and has previously been recorded in the north of the Coolgardie bioregion with other records in the Avon Wheatbelt, Carnarvon, Geraldton Sandplains, Murchison, Swan Coastal Plain and Yalgoo bioregions.
Grevillea juncifolia subsp. *temulenta*	90 km south	Broad distribution in central Western Australia, is known from 86 records on Florabase and has previously been recorded in the north of the Coolgardie bioregion with other records in the Avon Wheatbelt, Gibson Desert, Great Victoria Desert, Murchison and Yalgoo bioregions.
Leucopogon sp. Kau Rock (M.A. Burgman 1126)	80 km north-east	Broad distribution in southern Western Australia, is known from 64 records on Florabase and has previously been recorded in the south-west of the Coolgardie bioregion with other records in the Avon Wheatbelt, Esperance Plains and Mallee bioregions.
Ptilotus symonii	220 km north-west	Known from 22 records on Florabase and has previously been recorded in the south-west corner of the Coolgardie bioregion with other records in the Eastern Mallee, Hampton and Nullarbor bioregions. The records for the study area represent isolated outliers in the current recorded distribution for the species.

Figure 4-8
Range extensions for flora recorded in the Development Envelope



LEGEND

Development Envelope

Species

- *Acacia quadrimarginea*
- *Calandrinia baccata*
- *Calandrinia sp. Widgiemooltha (F. Obbens & E. Reid FO 9/05)*
- *Grevillea juncifolia subsp. temulenta*
- *Leucopogon sp. Kau Rock (M.A. Burgman 1126)*
- *Ptilotus symonii*
- *Tecticornia mellarium*
- *Tecticornia mellarium* population

0 3.5 7 10.5 14

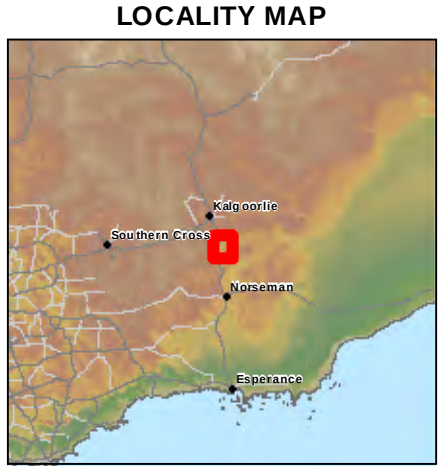
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	24/07/2018

LOCALITY MAP



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4.2.3.10 Introduced Flora

The desktop assessment identified records for 30 weed species within and in the vicinity of the B2018 study area (Table 4-15).

A total of nine introduced species were recorded in the Development Envelope during the survey (Table 4-15) with an additional species observed by mine personnel. All of these have wide distributions in WA and there were no apparent range extensions. None of the introduced species are declared pests or Weeds of National Significance. None of the introduced species were widespread in the Development Envelope with each species only recorded at single locations.

Locations of introduced flora species recorded during the survey of the Development Envelope are detailed in Figure 4-9.

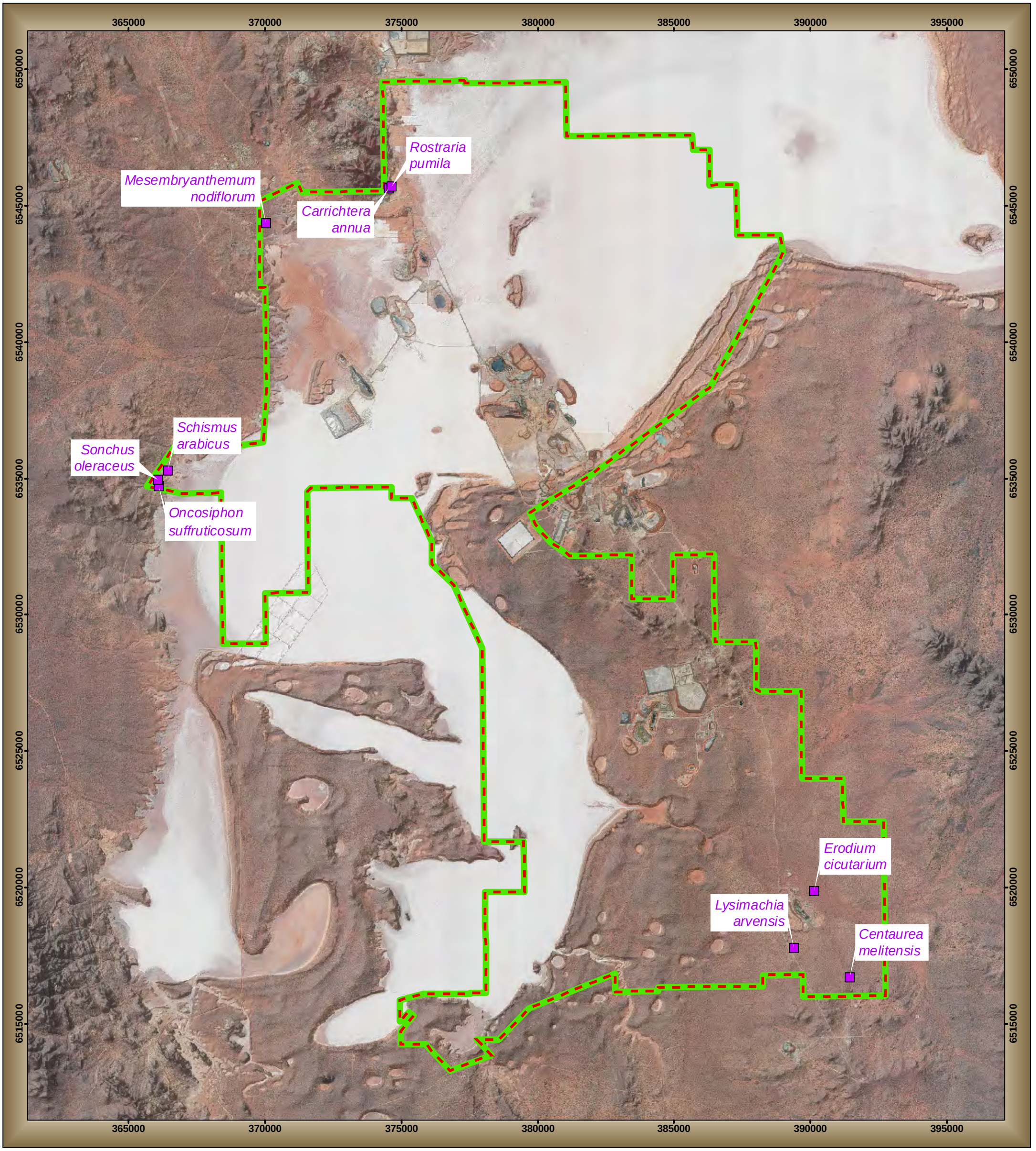
Table 4-15: Weed Species Records - Desktop Assessment and Field Surveys

*Species with an * are listed under the* Biosecurity and Agriculture Management Act 2007

Family	Species	Common name	Recorded in surveys in DE?
Aizoaceae	*Mesembryanthemum crystallinum*	Iceplant	
Aizoaceae	*Mesembryanthemum nodiflorum*	Slender Iceplant	Y
Asphodelaceae	*Asphodelus fistulosus*	Onion Weed	
Asteraceae	*Carthamus lanatus*	Saffron Thistle	
Asteraceae	*Gazania linearis*		
Asteraceae	*Centaurea melitensis*	Maltese Cockspur	Y
Asteraceae	*Carduus nutans**	Nodding Thistle	
Asteraceae	*Sonchus oleraceus*	Common Sowthistle	Y
Asteraceae	*Matricaria recutita*	Wild Chamomile	
Asteraceae	*Oncosiphon suffruticosum*	Calomba Daisy	Y
Boraginaceae	*Heliotropium europaeum**	Common Heliotrope	
Brassicaceae	*Carrichtera annua*	Ward's weed	Y
Brassicaceae	*Sisymbrium irio*	London Rocket	
Brassicaceae	*Sisymbrium orientale*	Indian Hedge Mustard	
Brassicaceae	*Brassica tournefortii*	Mediterranean Turnip	
Cucurbitaceae	*Citrullus lanatus*	Pie Mellon	
Cucurbitaceae	*Cucumis myriocarpus*	Prickly Paddy Melon	
Fabaceae	*Medicago minima*	Small Burr Medic	
Fabaceae	*Medicago polymorpha*	Burr Medic	
Geraniaceae	*Erodium cicutarium*	Common Storksbill	Y
Lamiaceae	*Salvia reflexa**	Mintweed	
Lamiaceae	*Salvia verbenaca*	Wild Sage	
Poaceae	*Pentameris airoides* subsp. *airoides*		
Poaceae	*Hordeum leporinum*	Barley Grass	
Poaceae	*Rostraria pumila*		Y
Poaceae	*Schismus arabicus*	Araby Grass	Y
Polygalaceae	*Rumex vesicarius*	Ruby Dock	Y[6]
Primulaceae	*Lysimachia arvensis*	Pimpernel	Y
Solanaceae	*Lycium ferocissimum*	African Boxthorn	
Solanaceae	*Solanum hystrix*	Afghan Thistle	
Solanaceae	*Solanum nigrum*	Black Berry Nightshade	

[6] Not recorded during surveys but known population occurs along causeway.

Figure 4-9
Locations of Introduced Flora Species Recorded within the Development Envelope



LEGEND

- Development Envelope
- Introduced Species

0 3 6 9 12

Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
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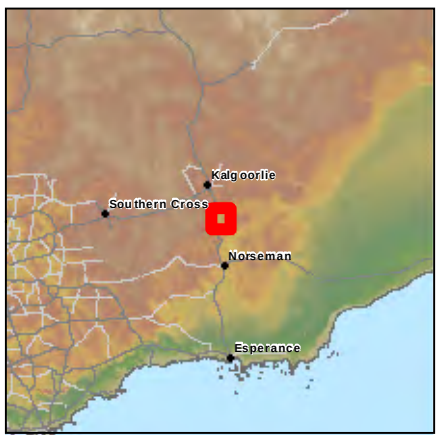
LOCALITY MAP



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4.2.4 Potential Impacts

4.2.4.1 Clearing of native vegetation including riparian vegetation

The single most widespread environmental impact arising from the B2018 Project is the clearing of native vegetation in areas proposed for mine development.

SIGMC notes that none of the vegetation types mapped within the Development Envelope are considered regionally significant, no vegetation types were classified as either a TEC or PEC, and no threatened species were recorded in surveys. However, there is potential for clearing to occur in areas that includes locally significant vegetation types, including riparian vegetation, or species potentially of conservation significance, included Priority-listed species.

4.2.4.2 Introduction or spread of weed species

Introduced flora, if uncontrolled, can potentially degrade the quality of native vegetation and, in the case of serious environmental weeds, impact the success of rehabilitation. These direct impacts can occur via the spread or introduction of weed seeds as well as the clearing of native vegetation allowing for the colonisation of weed species to occur.

4.2.4.3 Increase in inundation of riparian vegetation

Increased dewatering discharge onto the lake may increase the water depth and inundated area across the lake which may lead to the inundation of the riparian zone. Plants in the riparian zone are adapted to naturally saline conditions and they can persist in waterlogged conditions for short periods. This potential impact is discussed in section 4.5.

4.2.4.4 Other potential indirect impacts

In addition to direct impacts, the proposal has the potential to indirectly impact flora and vegetation via dust generation, weed introduction and changes in fire regimes.

Potential impacts associated with surface water are discussed in section 4.5.

4.2.5 Assessment of Impacts

4.2.5.1 Overview of impacts

The Proposal is likely to have an impact on particular environmental values of flora and vegetation as defined in the EPA's factor guideline for flora and vegetation (2016d) and as outlined in Table 4-16.

Compliance with survey guidelines for impact assessment (EPA 2002, EPA 2004, EPA and DPaW 2015, EPA 2016n) is discussed in section 4.2.3.2.

Table 4-16: Flora and vegetation – relevant environmental values

Aspect		Relevant to Proposal?	Comments
Flora	Threatened or priority species	✓	Three Priority species recorded. No Threatened species listed under the *Wildlife Conservation Act 1950* (WA) or the *Environment Protection and Biodiversity Act (1999)* (Commonwealth).
	Locally endemic or associated with a restricted habitat type (e.g. surface water or groundwater dependent ecosystems).	✓	Some *Tecticornia* spp. associated with riparian vegetation restricted to the lake margins.
	New species or anomalous features that indicate a potential new species.	✓	Two taxa were collected – *Tecticornia* SIGMb and *Tecticornia* SIGMq – for which only sterile material was recorded. These collections could not confidently be attributed to known taxa, although they may well be. For assessment puposes, they are treated as conservation significant in this document.
	Representative of the range of a species (particularly, at the extremes of range, recently discovered range extensions, or isolated outliers of the main range).	✓	Seven species recorded range extensions.
	Unusual species, including restricted subspecies, varieties or naturally occurring hybrids.	×	Not recorded during surveys.
	Relictual status, being representative of taxonomic groups that no longer occur widely in the broader landscape.	×	Not recorded during surveys.
Vegetation	Identified as threatened or priority ecological communities.	×	No communities listed under the *Wildlife Conservation Act 1950* (WA) or the *Environment Protection and Biodiversity Act (1999)* (Commonwealth).No Priority communities known.
	Restricted distribution.	✓	Some locally significant vegetation types recorded.

Aspect		Relevant to Proposal?	Comments
	Degree of historical impact from threatening processes.	×	Vegetation in the region is largely intact.
	Role as a refuge.	×	No known role as a refuge.
	Providing an important function required to maintain ecological integrity of a significant ecosystem.	✓	Riparian vegetation forms part of peripheral wetlands.

4.2.5.2 Clearing of native vegetation including riparian vegetation

Clearing of native vegetation, in particular vegetation with conservation values, is potentially significant.

Three conservation significant species have been confirmed within the Development Envelope:

- *Tecticornia mellarium* (P1);
- *Calandrinia* sp. *Widgiemooltha* (P1); and
- *Ptilotus rigidus* (P1).

An additional five species were recorded that were range extensions i.e. they were found to have a wider distribution than was previously known.

Along with the above species, the following vegetation types occurring within the Development Envelope are locally significant, either because they contain Priority species or they are likely to have a restricted distribution:

- R1
- R2
- R3
- C1
- C2
- C3
- S1
- S2
- S3
- S4
- S7

Vegetation associated with the riparian areas of the lake system was regionally restricted due to the site-specific requirements for these vegetation types and that disturbance to the lake foreshore had already reduced their distribution (Mattiske 1996a; Phoenix 2018a).

With further regard to riparian vegetation, the assessment conducted for the Beyond 2010 Project used an approximation of the riparian zone that comprised a zone of approximately 100 m around the main body of Lake Lefroy. Since then, vegetation mapping conducted for the 2018 assessment identified three riparian vegetation types (R1, R2 and R3) occurring within the Development Envelope. These three vegetation types and a further three vegetation types (R4, R5 and R6) also occur outside of the Development Envelope. The riparian vegetation types identified in the mapping conducted for the current assessment are considered a much better representation of the “riparian zone” than the coarse 100 m zone used previously, with riparian vegetation types ranging from absent at the lake edge to occurring in a band of up to several hundred metres from the lake edge, sometimes discontinuously.

Disparities in mapping of the riparian zone in previous flora and vegetation assessments make it difficult to accurately determine the extent of previous clearing in each of the regionally restricted vegetation types.

4.2.5.3 Introduction or spread of weed species

While there are a number of weed species occurring within the Development Envelope, there are no known significant populations. Nonetheless, land-based activities will require management to ensure new species are not introduced and existing populations are controlled and not spread.

4.2.5.4 Cumulative impacts

Phoenix (2018b) conducted an assessment and comparison of the broadly mapped native extents and types in WA against those within the Development Envelope. This review was conducted using data from Shepherd et al. (2002) and identified that there are seven vegetation types within the Binneringe system occurring within the Development Envelope. These vegetation types are given numerical values in Table 4-17 below, noting that type 125 refers to bare areas and salt lakes.

Table 4-17: Extent and conservation status of the Shepherd et al. (2002) vegetation types intersecting the B2018 Project Study Area (Department of Parks and Wildlife 2014)

Vegetation type	Pre-European extent (ha)	Current extent (ha)	% remaining	Status	Extent of vegetation type within B2018 Project Study Area (ha)
9	240,509.3	235,161.94	97.8	Least concern	1,521.8
125	3,485,786.6	3,146,496.1	90.3	Least concern	26,816.8
221	63,720.1	59,923.1	94.0	Least concern	160.7
502	46,196.1	46,004.2	99.6	Least concern	3,574.8
521	122,059.5	122,059.3	100.0	Least concern	2.9
676	2,063,413.9	1,963,861.6	95.2	Least concern	1.8
936	698,752.0	676,690.8	96.84	Least concern	12,934.7

Each of the vegetation types that occur in the Development Envelope have in excess of 90% or pre-European extent remaining and are therefore classed as Least Concern. Consequently, the majority of the vegetation in the Development Envelope features communities that are well represented at a regional level (Phoenix 2017a).

In light of the above, the cumulative impacts as a result of the implementation of the B2018 Project are considered negligible with regard to broad vegetation types.

4.2.5.5 Other potential impacts

Operations on the lake may affect the extent and duration of flood events as well as impact water quality, with potential impacts on shoreline vegetation. This issue is considered in detail in Section 4.5.

Dust associated with mining may adversely impact vegetation especially in areas close to drill, blast and haulage operations. Dust within the Development Envelope is largely likely to be chemically inert although there may be a risk of elevated salinity in some areas due to wind-blown salts. Impacts from dust are most likely to be associated with its physical properties which may include leaf abrasion and reduction in ability to absorb sunlight, thereby influencing

photosynthetic rates. Dust accumulation on vegetation can be cyclical with increases in dust load occurring during dry conditions and decreases occurring as a result of rainfall and replacement of affected leaves by new growth. Degradation of native vegetation due to foliar dust deposition has not been recorded in operations to date. However, it remains important to minimise dust generation by transport activities, typically through application of water to suppress wheel-generated dust.

The introduction of weed species to otherwise pristine areas can occur both directly and indirectly. Indirect introduction may occur via the gradual spread of weeds through natural processes (e.g. seed dispersal by wind or animals). Typically, native vegetation condition declines as structure and composition is altered through competition by weeds with native plants for natural resources.

Notwithstanding this, existing operations have effectively managed the introduction of weeds species through both the prevention (quarantine) and control (targeted management and progressive rehabilitation). To this effect, provided the existing management measures continue to be employed, a significant increase in the risk of indirect impact of weed species introduction is considered unlikely to occur throughout implementation of this proposal.

A change in fire regimes is often associated with increased human activity, leading to degradation of natural ecosystems. While fires occur naturally in the Lake Lefroy area, usually associated with lightning strikes from summer thunderstorms, the mine operations include some potential ignition sources. Despite this, the increased risk posed by the implementation of this proposal is considered to be manageable and is not significant. The main focus is on identification of activities involving ignition sources with the potential to lead to fire occurring in areas of native vegetation, and the adoption of preventative measures.

Infrastructure may change local surface water patterns and lead to localised scouring and erosion.

4.2.6 Mitigation

Whilst SIGMC is of the view that there are no environmental values within the Development Envelope that would potentially preclude approval of the B2018 Project, SIGMC has identified environmental values at particular locations (conservation-significant species and locally significant vegetation types) where a reduction in impacts would be desirable. SIGMC proposes to exclude development within a number of areas (“exclusion zones”) to protect these flora and vegetation values. The concept has been extended to terrestrial fauna (see section 4.3) and to inland waters environmental quality (section 4.6).

Five exclusion zones have been identified (Table 4-18; Figure 4-10). Within the Development Envelope of 45,019 ha, the exclusion zones cover a total of 5,204 ha (11.6%).

Table 4-18: Proposed exclusion zones

Exclusion Zone	Area (ha)	Proportion of Development Envelope (%)
Exploration 1	894.8	1.99
Coral and Oyster Islands	108.1	0.24
Pistol Club West	1543.8	3.43
Pilbailey	264.9	0.59
Implacable[7]	2392.6	5.32
Total	**5204.2**	**11.6**

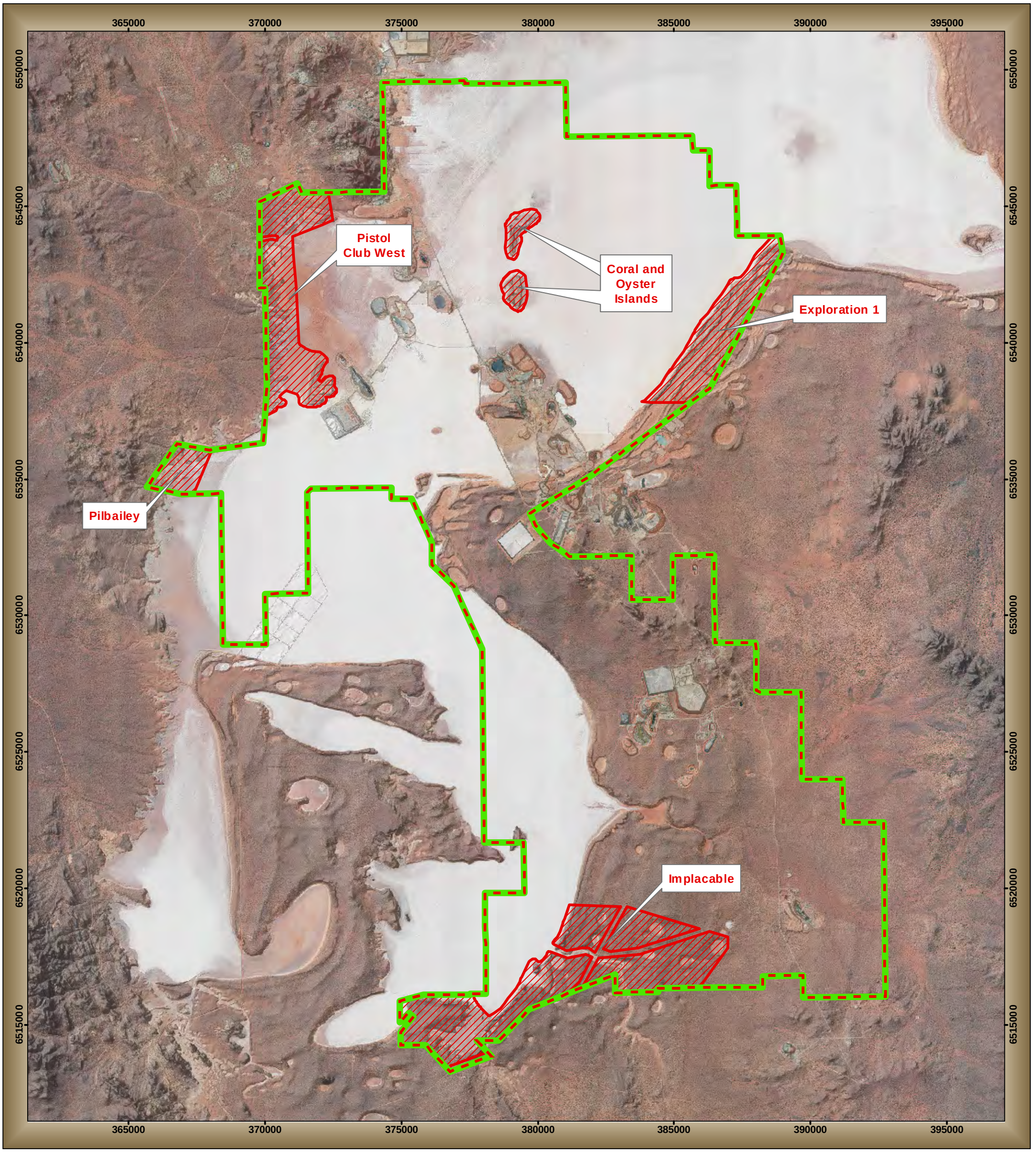
Locally significant vegetation types are represented in each exclusion zone. The criteria for their inclusion is outlined in Table 4-19. All locally significant vegetation types are well represented in exclusion zones (more than 50% of their extent in the Development Envelope) with the exception of C1, C2, S3 and R2. Of these, all are known to occur outside of the Development Envelope.

[7] The Implacable exclusion zone was originally a single area but has been divided into four segments to take account of existing disturbance (access roads and pipeline corridors). These disturbed areas plus a 100 m buffer either side of the road or pipeline corridor are now omitted from the exclusion zone. The buffer area has been included to take account of any indirect impacts, such as dust generation from light vehicle traffic, potential runoff from the corridors and minor disturbance associated with pipeline monitoring and management. No change to this infrastructure is proposed in the B2018 Project.

Table 4-19: Proposed exclusion zones – locally significant vegetation types protected

Exclusion Zone	Locally significant vegetation types	Criteria for significance
Exploration 1	R1	Habitat for *Tecticornia mellarium.*
	R2	Habitat for *Tecticornia mellarium.*
Coral and Oyster Islands	R1	Habitat for *Tecticornia mellarium.*
	R3	One of only two recorded locations for this vegetation type.
	W2	Habitat for *Tecticornia mellarium*.
Pistol Club West	S2	Habitat for *Calandrinia* sp. Widgiemooltha.
	S7	Restricted vegetation type. Exclusion zone contains all of this unit's representation in Development Envelope.
Pilbailey	C3	Exclusion zone contains the total mapped extent in Development Envelope. Has much higher representation outside Development Envelope. Habitat for *Calandrinia* sp. Widgiemooltha.
	S4	Very restricted vegetation type. Exclusion zone contains nearly all of S4 mapped within B2018.
Implacable	R1	Main habitat for *Ptilotus rigidus.*
	R2	Habitat for *Ptilotus rigidus.*
	R3	One of only two recorded locations for this vegetation type.
	S1	Highly restricted vegetation type, extent mostly in B2018.

Figure 4-10
Exclusion Areas



LEGEND

- Development Envelope
- Exclusion Areas

0 3 6 9 12

Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	26/07/2018

LOCALITY MAP

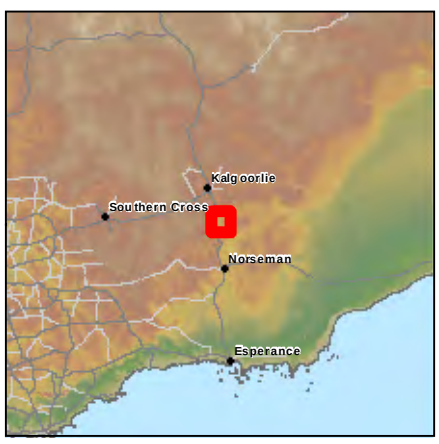


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Table 4-20 lists their known extent outside the Development Envelope based on survey data for the Beyond 2018 Project. Note that the regional survey covered SIGMC tenure only and large areas of vegetation along or adjacent to the shoreline of Lake Lefroy are under other tenure and have not been mapped. Therefore, while no vegetation type is restricted to the Development Envelope, there is a strong likelihood that further survey will increase the known extent of at least some vegetation types.

No threatened flora has been recorded within the Development Envelope. However, a number of species of Priority Flora and other species of conservation significance have been recorded, some of which are afforded protection within the exclusion zones (Table 4-21 and Table 4-22).

Table 4-20: Proposed exclusion zones – extent of protection and occurrence outside Development Envelope

Locally significant vegetation types	Total Area in Development Envelope (ha)	Area in Exclusion Zones (ha) (% of total area in Development Envelope)	Known Area Outside Development Envelope (ha)
R1	416.4	217.4 (52.2)	118.9
R2	261.3	122.7 (47)	232.8
R3	1.9	1.9 (100)	2.0
C1	286.5	39.8 (13.9)	659.1
C2	172.5	55.4 (32.1)	544.6
C3	9.8	9.8 (100)	194.9
S1	52.3	52.3 (100)	8.7
S2	181.4	166.1 (91.5)	935.3
S3	24.9	5.1 (20.5)	55.9
S4	2.8	2.8 (100)	8.1
S7	14.1	14.1 (100)	43.6

Table 4-21: Proposed exclusion zones – Priority and other species of conservation significance protected

Exclusion Zone	Priority Species
Exploration 1	*Tecticornia mellarium* (P1).
Coral and Oyster Islands	*Tecticornia mellarium* (P1).
Pistol Club West	*Calandrinia* sp. Widgiemooltha (P1).
Pilbailey	*Calandrinia* sp. Widgiemooltha (P1), *Tecticornia* SIGMq.
Implacable	*Ptilotus rigidus* (P1), *Tecticornia* SIGMb.

Table 4-22: Proposed exclusion zones – conservation significant flora protected

Conservation signficant flora	No. of plants in Development Envelope	No. of plants in Exclusion Zones (% of total numbers in Development Envelope)	Occurs outside Development Envelope?
Calandrinia sp. Widgiemooltha (P1)	2	2 (100)	Yes
Ptilotus rigidus (P1)	352	352 (100)	Yes
Tecticornia mellarium (P1)	2773	2155 (77.7)	Yes
Tecticornia SIGMb	No data	No data but only collections were made within the Implacable Exclusion Zone	No data
Tecticornia SIGMq	No data	No data but only collections were made within Pilbailey Exclusion Zone	No data

While the vegetation and flora occurring within the Development Envelope has been well characterised, further targeted surveys will be conducted during the course of the B2018 Project to extend the understanding of conservation significant vegetation types and flora beyond the Development Envelope. The surveys will concentrate on fringing vegetation on large areas of Lake Lefroy that are outside of the Development Envelope and which have not yet been the subject of intense survey.

All disturbed landforms will be rehabilitated in accordance with the Rehabilitation and Mine Closure Plan (Appendix H).

SIGMC proposes the mitigation measures as outlined in Table 4-23.

Table 4-23: Predicted Impacts and Mitigation Strategies for Flora and Vegetation

Predicted Impact from the B2018 Project	Mitigation Hierarchy	Mitigation
Clearing of native vegetation	Avoid	To protect flora and vegetation, establish five exclusion zones – Exploration 1, Oyster and Coral Islands, Pistol Club West, Pilbailey and Implacable - within the Development Envelope within which no mine-related activities may occur (Commitment 1).
Clearing of native vegetation	Avoid/ Minimise	The total clearing of native vegetation is limited to 3,000 ha on land for the duration of the B2018 Project (Commitment 2).
Clearing of native vegetation	Minimise	Further targeted surveys will be conducted outside the Development Envelope during the B2018 Project to build on the understanding of conservation significant vegetation types and flora (Commitment 3).
Clearing of native vegetation	Avoid/ Minimise	Ground disturbing activities at SIGMC are managed through the implementation of a Surface Disturbance Permit Procedure (SIG-ENV-PR049). These procedures are intended to prevent accidental disturbance of areas not scheduled for clearing and to advise field personnel on methodology for topsoil recovery and stockpiling, and related matters. These activities can be managed under the *Mining Act 1978*.
Clearing of native vegetation	Rehabilitate	SIGMC will undertake progressive rehabilitation in areas where mining operations have been completed. For land-based operations this will involve rehabilitation of disturbed areas and constructed landforms such as WRLs and TSFs. The rehabilitation will be undertaken in accordance with the RMCP (Appendix H) and site-wide MCP. The MCP will be updated every three years to reflect changes in operations and environmental baseline data. The overall aim of the rehabilitation and closure is that all disturbed areas are rehabilitated in accordance with the closure priorities of safe, non-polluting and stable at all locations, with self-sustaining ecological communities where possible. This activity can be managed under the *Mining Act 1978*.
Introduction or spread of weed species	Minimise	Weed control will be carried out to control weeds in accordance with the SIGMC Weed Management Plan (SIG-ENV-PL047), Weed Monitoring procedure (SIG-ENV-PR041) and Weed Control procedure (SIG-ENV-PR042). These activities can be managed under the *Mining Act 1978*.
Other potential impacts	Minimise	Dust associated with the operations will be managed in accordance with the SIGMC Dust Management Procedure (SIG-ENV-PR029). These activities can be managed under the *Mining Act 1978*.
Other potential impacts	Avoid	Procedures to minimise the risk of accidental fires are in place. This activity can be managed under the *Mine Safety and Inspection Act 1994*.

Predicted Impact from the B2018 Project	Mitigation Hierarchy	Mitigation
Other potential impacts	Avoid	Local drainage will be considered when constructing new haul roads and access tracks and maintaining existing road infrastructure. This activity can be managed under the *Mining Act 1978*.

SIGMC commits to the following:

Commitment 1: To protect flora and vegetation, establish five exclusion zones – Exploration 1, Oyster and Coral Islands, Pistol Club West, Pilbailey and Implacable - within the Development Envelope within which no mine-related activities may occur.

Commitment 2: The total clearing of native vegetation is limited to 3,000 ha on land for the duration of the B2018 Project.

Commitment 3: Further targeted surveys will be conducted outside the Development Envelope during the B2018 Project to build on the understanding of conservation significant vegetation types and flora.

4.2.7 Predicted Outcome

In consideration of the outcomes of the EIA and proposed management measures, SIGMC considers that EPA's objective for Flora and Vegetation to "*protect flora and vegetation so that biological diversity and ecological integrity are maintained"* can be achieved. The following outcomes are predicted:

- No loss of any Threatened Ecological Community or Priority Ecological Community;
- All vegetation types in which clearing will potentially occur are listed as Least Concern and have around 90% or more of their Pre-European extent intact;
- No loss of any regionally significant vegetation types;
- No loss of groundwater dependent ecosystems;
- Some potential loss in area of locally significant vegetation types, all of which are also known from outside the Development Envelope;
- No loss of any Threatened species;
- Some potential loss of one P1 flora species although most of the known numbers (78%) within the Development Envelope are protected within Exclusion Zones. Two other P1 flora species also occur within the Development Envelope but are fully (100%) protected within Exclusion Zones. All three species also occur outside of the Development Envelope; and
- No significant risk of an increase in weeds.

By implementing management measures detailed above and through the implementation of the Exclusion Zones, the residual impact is not significant and no offsets are considered to be required.

4.3 *Terrestrial Fauna*

4.3.1 EPA Objective

The EPA's environmental objective for the factor Terrestrial Fauna is:

To protect terrestrial fauna so that biological diversity and ecological integrity are maintained.

4.3.2 Policy and Guidance

The following policies and guidelines apply to Terrestrial Fauna:

- EPA Environmental Factor Guideline – Terrestrial Fauna (EPA 2016g);
- EPA Technical Guidance - Sampling methods for terrestrial vertebrate fauna (EPA 2016l);
- EPA Technical Guidance - Terrestrial fauna surveys (EPA 2016p);
- EPA Technical Guidance - Sampling of short range endemic invertebrate fauna(EPA 2016o);
- Interim guideline for preliminary surveys of night parrot (*Pezoporus occidentalis*) in Western Australia (DBCA 2017a);
- Survey guidelines for Australia's threatened birds (DEWHA 2010);
- WA Environmental Offsets Policy (Government of Western Australia 2011); and
- WA Environmental Offsets Guidelines (Government of Western Australia 2014).

4.3.3 Receiving Environment

4.3.3.1 Survey effort

Previous surveys

The Development Envelope has been extensively surveyed for fauna over several years and seasons. A total of 29 fauna surveys have been undertaken which are summarised in Table 4-24. Figure 4-11 depicts the area these surveys cover. Results from previous surveys were utilised in the most recent surveys undertaken by Phoenix (2017a, 2017c).

Table 4-24: Summary of Previous Fauna Surveys Relevant to the Project

Reference	Report Name	Location of Survey	Study Area Extent	Survey Date	Survey type	Survey Effort	Conservation Significance[8]
Hudson (1995)	Report on a Survey of the Terrestrial Invertebrate Fauna of Lake Lefroy, WA	Lake Lefroy and surrounds	Not provided in the report	Feb-Mar 1994	Terrestrial invertebrate fauna survey	20 collection sites	None recorded
Curtin University of Technology (1999)	Baseline Ecological Study of Lake Lefroy Lake Fringing Vegetation, Aquatic Flora, Aquatic Invertebrates and Terrestrial Invertebrates	Lake Lefroy and surrounds, Lake Zot, Lake Cowan	Not provided in the report	Feb-99	Baseline ecological study	26 sampling sites; 12 pitfall traps, 21 systematic collections and spotlighting, 10 nocturnal sampling, 8 hand collections, 5 burrow excavation, 4 debris collection	None recorded
Outback Ecology (2004)	Assessment of Biota at Lake Lefroy	Lake Lefroy and riparian zone	Not provided in the report	Oct-04	Assessment of biota	9 sampling sites; 4 pitfall traps, 4 bush beating; 4 hand collections, 4 systematic collections and spot lighting	None recorded
Outback Ecology (2005)	Re-assessment of Biota at Lake Lefroy	Lake Lefroy and riparian zone	Not provided in the report	May-05	Re-assessment of biota	3 sites; pitfall traps	None recorded
Western Wildlife (2006)	St Ives Gold Fauna Survey: Spring 2005	St Ives Operational areas, Lake Lefroy	Not provided in the report	Sep-05	Level 2 terrestrial vertebrate fauna survey	20 trapping grids each consisting 10 pitfall traps, 5-10 funnel traps, 10 Elliot traps, two cage traps, bat detectors, spotlighting	Rainbow Bee-eater (*Merops ornatus*) (formerly Migratory)

[8] A number of conservation significant species that are not listed anymore were identified during the surveys. These species are excluded from this table.

Reference	Report Name	Location of Survey	Study Area Extent	Survey Date	Survey type	Survey Effort	Conservation Significance[8]
ATA Environmental (2006)	Vertebrate Fauna Assessment St Ives Gold Mine	Lake Lefroy	Not provided in the report	Apr-06	Level 2 terrestrial vertebrate fauna survey	20 trapping grids each consisting 10 pitfall traps, 5-10 funnel traps, three cage traps, 10 Elliot traps, systematic bird survey, spotlighting, bat detectors	Rainbow Bee-eater (*Merops ornatus)* (formerly Mig)
Outback Ecology (2006)	Assessment of Aquatic Biota & Fringing Flora at Lake Lefroy	Lake Lefroy and riparian zone	Not provided in the report	Jun-06	Aquatic biota and fringing flora	3 sites; pitfall traps	None recorded
Outback Ecology (2007)	Assessment of Aquatic Biota & Fringing Flora at Lake Lefroy	Lake Lefroy and riparian zone	Not provided in the report	Jul-07	Aquatic biota and fringing flora	3 sites; pitfall traps	None recorded
Keith Lindbeck and Associates (2007)	Spring Fauna Survey St Ives Gold TSF 4	TSF 4	300 ha	Oct-Nov 2007	Level 2 terrestrial vertebrate fauna survey	8 trapping grids each consisting 20 buckets, 20 funnel traps, 16 Elliot traps, 4 cage traps, opportunistic sampling, spotlighting	Rainbow Bee-eater (*Merops ornatus*) (formerly Mig)
Keith Lindbeck and Associates (2008)	Level 1 Fauna Survey St Ives AAA Project	AAA Project	1,072 ha	Sep-08	Level 1 terrestrial vertebrate fauna survey	Traverse only	None recorded
Outback Ecology (2009a)	Assessment of Aquatic Biota & Fringing Vegetation at Lake Lefroy	Lake Lefroy and riparian zone	Not provided in the report	Jul-08	Aquatic biota and fringing flora	4 sites each consisting of 20 pitfall traps	None recorded
Harewood (2010c)	Level 1 Terrestrial Fauna Survey St Ives Pistol Club	Pistol Club	69 ha	Nov-09	Level 1 terrestrial vertebrate fauna survey	Opportunistic observations	Rainbow Bee-eater (*Merops ornatus*) (formerly Mig)

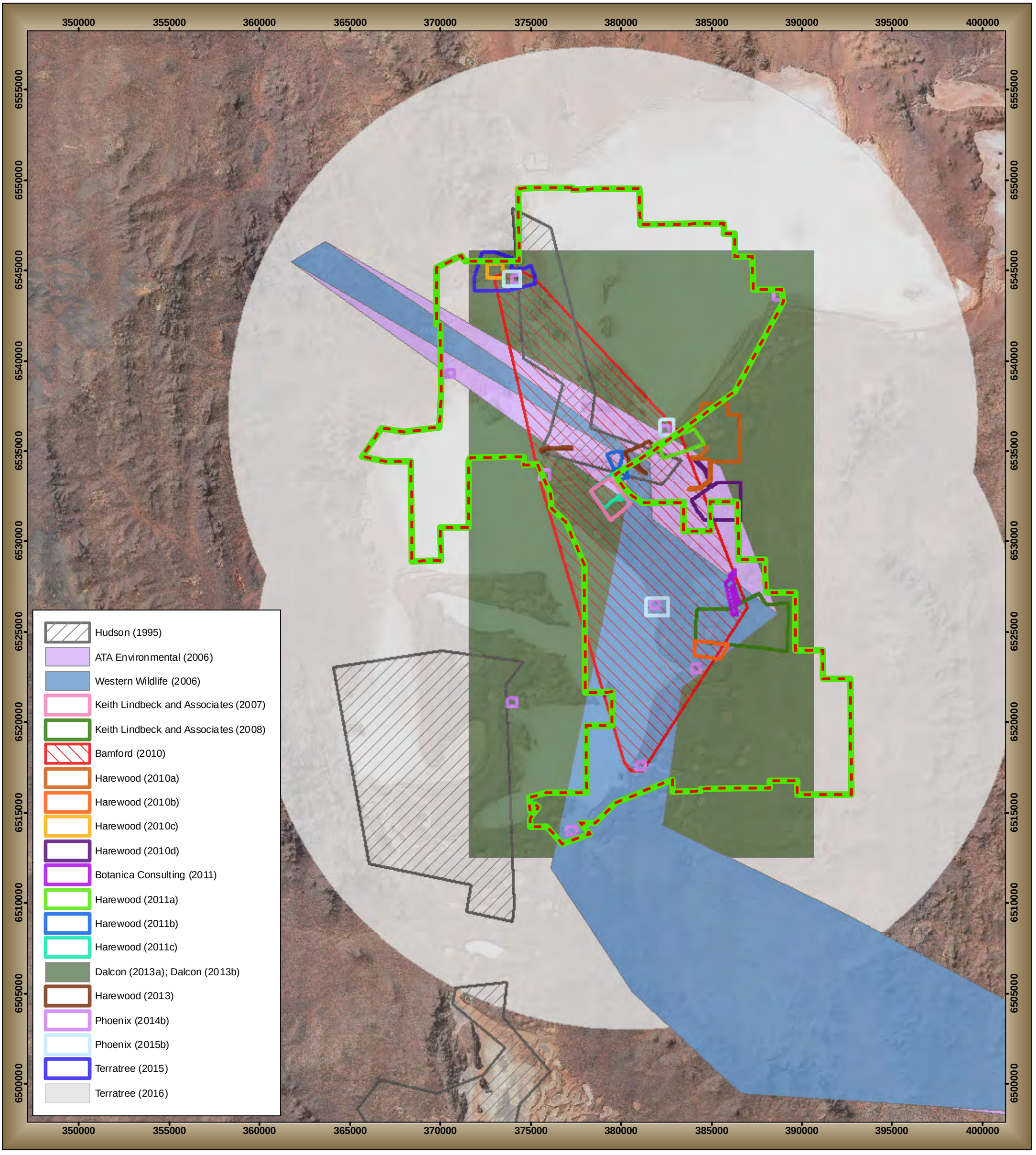
Reference	Report Name	Location of Survey	Study Area Extent	Survey Date	Survey type	Survey Effort	Conservation Significance[8]
(Harewood 2010b)	Terrestrial Fauna Survey (Level 1) of the proposed Diana Mine Area	Diana Mine Area	170 ha	Nov-09	Level 1 terrestrial vertebrate fauna survey	Opportunistic observations	None recorded
Bamford (2010)	Fauna Assessment: impacts of water discharge and general mining activity on vertebrate fauna	Beyond 2010 Project area, numerous locations	Not provided in the report	Nov-09	Level 2 terrestrial vertebrate fauna survey	9 sites each consisting of 10-30 pitfall traps, 5 funnel traps, 5 Elliott traps, systematic bird survey, opportunistic observations	Malleefowl (*Leipoa ocellata*) (VU); two inactive mounds Rainbow Bee -eater (*Merops ornatus*) (formerly Mig)
Harewood (2010d)	Terrestrial Fauna Survey (Level 1) of the proposed West Idough Mine Area St Ives - Kambalda	West Idough Mine Area	500 ha	Sep-09	Level 1 terrestrial vertebrate fauna survey	Opportunistic observations	Rainbow Bee -eater (*Merops ornatus*) (formerly Mig)
Dalcon (2010)	Environmental Survey of Lake Lefroy	Lake Lefroy and riparian zone	Not provided in the report	Sep-10	Environmental survey	7 sites each consisting of 10 or 15 pitfall traps; beats, sweeps, spotlighting, litter collections	None recorded
Harewood (2010a)	Terrestrial Fauna Survey (Level 1) of the proposed Bellerophon Mine Area St Ives - Kambalda	Bellerophon Mine Area	approx. 400ha	Sep-09	Level 1 terrestrial vertebrate fauna survey	Opportunistic observations	Rainbow Bee -eater (*Merops ornatus*) (formerly Mig)
Botanica Consulting (2011)	66KW extension power line fauna assessment	Powerline extension	12 ha	Feb-11	Desktop review, terrestrial fauna	Not relevant	Not relevant

Reference	Report Name	Location of Survey	Study Area Extent	Survey Date	Survey type	Survey Effort	Conservation Significance[8]
Harewood (2011a)	Terrestrial Fauna Survey (Level 1) of Thunderer Mine Area St Ives - Kambalda	Thunderer	223 ha	Sep-11	Level 1 terrestrial vertebrate fauna survey	Opportunistic observations	None recorded
Harewood (2011b)	Terrestrial Fauna Survey (Level 1) of Workshop Project Area St Ives - Kambalda	Workshop area	88 ha	Sep-11	Level 1 terrestrial vertebrate fauna survey	Opportunistic observations	None recorded
Harewood (2011c)	Wildlife sweep of TSF4 - area to be cleared	TSF 4	194 ha	Nov-11	Pre-clearance fauna survey	Closely spaced transects 30m apart	Malleefowl (*Leipoa ocellata*) (VU); one inactive mound, fresh set of malleefowl tracks
Dalcon (2013c)	Terrestrial Invertebrate Survey - Lake Lefroy (2010) Beyond 2010 project (Final)	Beyond 2010 - Lake Lefroy and riparian zone	Not provided in the report	Sept-Oct 2009 and 2010	Terrestrial invertebrate fauna monitoring 2011 and 2012	11 sites each consisting of 5-15 wet pitfall traps, beats, sweeps, light trapping, litter collections, foraging, incidental collections	No SREs identified during 2009 and 2010 surveys. Significant species recorded during the previous surveys were not recorded in 2009 and 2010 surveys.
Harewood (2013)	Fauna Assessment of Neptune Mine Area and Invincible Road, St Ives - Kambalda	A5 shoreline area, shoreline north west of TSF4	113 ha	Not relevant	Level 1 terrestrial vertebrate fauna survey	Not relevant	Not relevant
Dalcon (2013a)	Terrestrial Invertebrate Biodiversity Bio-monitoring Beyond 2010 Project Lake Lefroy 2011 & 2012 Surveys - Part A: Comparative Monitoring Report	Beyond 2010 - Lake Lefroy and riparian zone	Not provided in the report	Aug - Oct 2011 and Oct - Nov 2012	Terrestrial invertebrate fauna monitoring 2011 and 2012	12 sites each consisting of 10-15 wet pitfall traps, beats, sweeps, vegetation vacuuming, light trapping, litter collections, foraging, incidental collections	No SREs recorded.

Reference	Report Name	Location of Survey	Study Area Extent	Survey Date	Survey type	Survey Effort	Conservation Significance[8]
Dalcon (2013b)	Terrestrial Invertebrate Biodiversity Bio-monitoring Beyond 2010 Project Lake Lefroy 2011 & 2012 Surveys - Part B: Data Report	Beyond 2010 - Lake Lefroy and riparian zone	Not provided in the report	Aug - Oct 2011 and Oct - Nov 2012	Terrestrial invertebrate fauna monitoring 2011 and 2012	12 sites each consisting of 10-15 wet pitfall traps, beats, sweeps, vegetation vacuuming, light trapping, litter collections, foraging, incidental collections	No SREs recorded.
Phoenix (2013a)	Invertebrates from Lake Lefroy (Western Australia)	Identification of invertebrates for Dalcon (2013a, 2013b, 2013c)	Not provided in the report	Not relevant	Invertebrates from Lake Lefroy	Not relevant	Not relevant
Phoenix (2013b)	Review of the terrestrial invertebrate monitoring program for the St Ives Gold Mine at Lake Lefroy	Beyond 2010 - Lake Lefroy and riparian zone	Not provided in the report	Not relevant	Desktop review, terrestrial invertebrate monitoring program	Proposed changes to monitoring plan.	Not relevant
Phoenix (2014b)	Terrestrial invertebrate fauna monitoring for the St Ives Gold Mine - Annual survey 2013	Beyond 2010 - Lake Lefroy and riparian zone	Not provided in the report	Oct-Dec 2013	Terrestrial invertebrate fauna monitoring	10 sites each containing 10 pitfall traps, beats, sweeps, vegetation sifting, foraging. Proposed changes to monitoring plan; focussed on spiders, ants and bugs and allies.	One confirmed SRE species collected: *Tetralycosa* 'baudinetti' Eight potential SRE species collected.

Reference	Report Name	Location of Survey	Study Area Extent	Survey Date	Survey type	Survey Effort	Conservation Significance[8]
Phoenix (2015b)	Terrestrial invertebrate fauna monitoring for the St Ives Gold Mine - annual survey 2014. Final Report March 2015	Beyond 2010 - Lake Lefroy and riparian zone	Not provided in the report	Nov-14	Terrestrial invertebrate fauna monitoring	10 sites each containing 10 pitfall traps, beats, transects (2 x 100m), foraging Modified survey design, focussed on discharge sites. Only ants and spiders were targeted.	No confirmed or potential SREs collected but 8 new species of spider recorded for the location.
Terratree (2015)	Level 1 Flora, Fauna & Vegetation Assessment	Pistol club	526 ha	Oct-15	Level 1 flora, vegetation and fauna survey	8 vegetation communities	Malleefowl (*Leipoa ocellata*) (VU); two inactive mounds recorded Rainbow Bee-eater (*Merops ornatus*) (formerly Mig)
Terratree (2016)	Desktop Assessment of Environmental Constraints & Opportunities within Delta Island South & Incredible Project Areas	Delta Island and Incredible Project Areas	128 ha	Not relevant	Desktop review, ecological constraints	Not relevant	Not relevant

Figure 4-11
Coverage of Previous Fauna Surveys Undertaken over the Development Envelope



LEGEND

Development Envelope

0 4.5 9 13.5 18

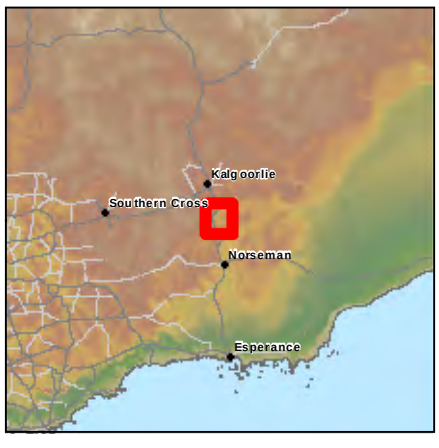
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	B
Date:	24/07/2018

LOCALITY MAP



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Two conservation significant species have previously been recorded in the Development Envelope: the Malleefowl and the Hooded Plover, the latter with an unspecified record in a recent desktop review (Terratree 2016). Malleefowl have previously been recorded three times from secondary evidence (tracks and an inactive mound), with two further inactive mounds located to the north (Bamford 2010, Harewood 2011c, Terratree 2015). The Hooded Plover has not been recorded outside of the record described above and is not considered further although it could be an occasional visitor.

ATA Environmental (2006) recorded the conservation significant (P4) bat species, *Nyctophilus major tor* (then known as *Nyctophilus timorensis*). The report lacks sufficient detail to determine the precise location of the record, although records are likely to be from within 5 km of the Development Envelope.

The desktop database review identified 50 short range endemic (SRE) taxa, of which 16 have been recorded in the Development Envelope. Ten of the species in the desktop database review area were unidentifiable based on morphology, i.e. female or juvenile spiders or snails ("sp. indet.") and may represent other species listed in the same genus.

Only one of the species from the Development Envelope, the playa specialist wolf spider *Tetralycosa baudinettei*, is considered a confirmed SRE (Framenau & Hudson 2017). Distribution patterns of other recorded invertebrate species from the Development Envelope are not well known and these are therefore considered potential SREs (Phoenix 2014b, 2015b) .

The desktop review recorded seven species are known only from the Development Envelope:

- *Aname* 'MYG223', *Aname* 'SIGM121 and *Aname* 'SIGM122' (trapdoor spiders);
- *Lychas* 'SIGM132', *Urodacus* 'SIGM131', *Urodacus* 'lefroy' (scorpions); and
- *Philosciidae* 'lefroy' (slater).

Recent surveys

Phoenix has undertaken Level 1 vertebrate fauna and Level 2 SRE assessments over the Development Envelope in October 2016 (Phoenix 2017c). The objective of the fauna survey was to define the fauna and fauna habitat values within the Development Envelope, in particular with respect to conservation significant species and SREs to inform planning and environmental impact assessment of the B2018 Project. Survey design, methodology and reporting adhered to relevant principles and guidelines, including:

- EPA Statement of environmental principles, factors and objectives (EPA 2016j);
- EPA Environmental Factor Guideline: Terrestrial fauna (EPA 2016g);
- EPA Technical Guidance: Terrestrial fauna surveys (EPA 2016p); and
- EPA Technical Guidance: Sampling of short-range endemic invertebrate fauna (EPA 2016o).

Commonwealth Government guidelines on surveys for threatened birds (DEWHA 2010) were not adopted but more recent survey guidelines for the Night Parrot (DBCA 2017) were used to inform the survey effort.

The following database searches were undertaken within a 40 km buffer around the Development Envelope:

- EPBC Act Protected Matters Search Tool (DoE 2016);
- DPaW Threatened Flora, Fauna and Ecological Communities database searches (DPaW 2016c);
- DPaW/WA Museum NatureMap database (DPaW 2016b); and
- Birdlife Australia Birdata database (Birdlife Australia 2016).

The SRE invertebrate fauna database search area was based on a rectangular search grid determined by the proposed maximum range of short-range endemism, 10,000 km^2, equivalent to approximately 100 km x 100 km (Harvey 2002). It included:

- WA Museum Arachnology and Myriapodology, Crustacea and Mollusca databases; and
- Phoenix invertebrate database.

A literature search was conducted for accessible reports of vertebrate and SRE invertebrate fauna surveys conducted within the vicinity of the Development Envelope to build on the potential species lists developed from the database searches. Reports for many of these surveys may not give detailed distribution data; however, distribution information for many of the vertebrates and invertebrates collected is available through the WA Museum database, which was accessed for this desktop review.

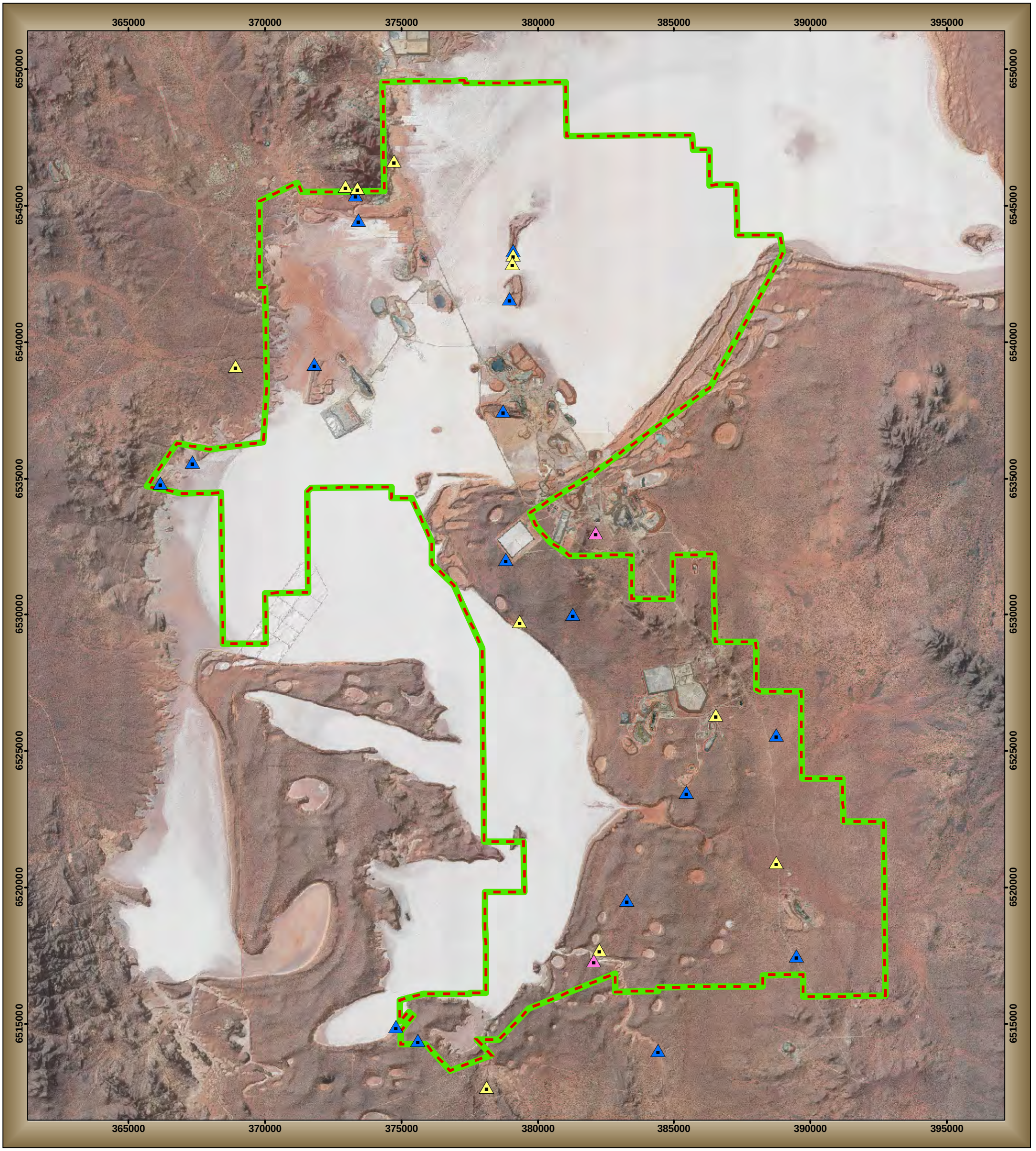
Level 1 vertebrate and Level 2 SRE surveys were undertaken from 19–22 October 2016 and comprised on-site habitat assessments, litter/soil sieving and active searches and foraging. A total of 18 sites (Figure 4-12) were surveyed totalling 36 person hours of active searches and foraging, and nine litter sieves. Two bat echolocation call recording devices (SongMeter SM2) were deployed at two sites for overnight recordings on 15–16 November 2016.

The Level 1 vertebrate fauna and Level 2 SRE assessment were further supplemented by a targeted survey for the Night Parrot (*Pezoporus occidentalis*) in July/August 2017.

Survey methods were consistent with the most recent edition of DBCA's survey guidelines for the Night Parrot (DBCA 2017a). They consisted of passive acoustic surveys with SongMeter SM2 recording devices at eight sites spread evenly throughout the Development Envelope in potential habitat for the species, i.e. open bushland with old-growth spinifex (*Triodia* spp.). SongMeters were installed to record for at least seven nights continuously. Potential roosting and nesting sites for Night Parrots were targeted. The recorded data were analysed by Mr. Bob Bullen, Bat Call WA.

Full terrestrial fauna reports are contained in Appendices H and I.

Figure 4-12
Vertebrate and SRE Fauna Survey Sites



LEGEND

- Development Envelope
- Systematic Sites
- Opportunistic Sites
- SongMeter Locations

0 3 6 9 12

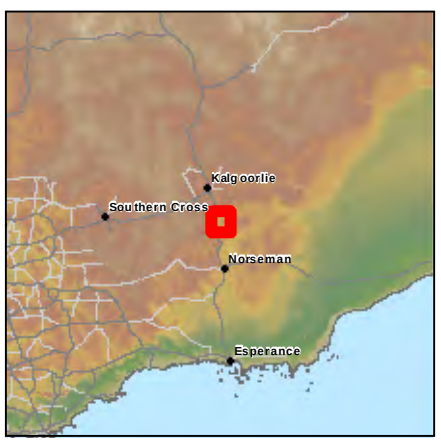
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	24/07/2018

LOCALITY MAP



Document Path: \\server\talis\SECTIONS\Environment\Projects\TE2016\TE16034 - SIGM B2018 EPA Process\10. GIS\Maps\ERD_Mapping\TE16034_ERD_4-12_FaunaSurveySites_RevA.mxd

4.3.3.2 Fauna Habitats

In addition to developed areas, the Development Envelope comprises three broad fauna habitats:

- Salt lake playa and riparian zone - salt lake habitat and associated fringing riparian zone;
- Woodland on plain - *Eucalyptus* species up to 15 m, over Acacia species to 3 m, over missed small to medium shrubs to 2 m and hummock and tussock grasses to 0.8 m;
- Riparian woodland - *Eucalyptus* species to 15 m and tall shrubs to 4 m over mixed small to medium shrubs (to 2 m) and hummock and tussock grasses (to 0.8 m) on sandy to clay-loam substrates along drainage lines;
- Shrubland on dune - patches of mixed small to medium shrubs to 2 m with scattered larger shrubs to 3 m, often dominated by Acacia species; and
- Open woodland on rocky hill - sparsely scattered *Eucalyptus* species to 10 m and Acacia species to 3 m over missed small to medium shrubs to 2 m and mixed hummock and tussock grasses on a stony or gravelly substrate.

The remainder of the Development Envelope is comprised of existing cleared and/or developed areas which do not provide suitable habitat for most terrestrial fauna species. Some conservation significant species may occur occasionally in these areas as transients from adjacent fauna habitats (e.g. Malleefowl and migratory bird species) or to nest where suitable structures are present (e.g. Peregrine Falcon). The extent of fauna habitats is summarised in Table 4-25.

Table 4-25: Fauna Habitats of the Development Envelope

Habitat	Area (ha)	Percentage
Salt lake playa and associated riparian zone	25,338.1	56.3
Shrubland on dune	1,887.3	4.2
Woodland on plain (including woodlands along drainage lines and those with scattered small rocky hills)	13,613.7	30.2
Disturbed/developed	4,174.4	9.3
Total:	**45,013.5**	**100.0**

All broad fauna habitats occurring within the Development Envelope are well represented in areas across the broader Coolgardie bioregion. The dominant habitats of the Development Envelope are the salt lake and its riparian zone, and open woodland habitats (critical for conservation significant vertebrates such as the Malleefowl). Both occur broadly across the Coolgardie bioregion and the Development Envelope is not considered to be critical to the survival of any species.

4.3.3.3 Vertebrate Fauna

A total of 252 vertebrate fauna species (three amphibians, 73 reptiles, 140 birds and 36 mammals – 28 native and eight introduced) have been identified from the desktop review as potentially occurring in the Development Envelope. Of these, 26 species were of conservation significance, including 11 listed under the EPBC Act and/or *Wildlife Conservation Act 1950* (WC Act) as threatened, conservation dependent or specially protected.

A total of 33 vertebrate species were recorded during the B2018 Project field survey representing approximately 13% of the species identified from the desktop review. Evidence of two vertebrate fauna species of conservation significance was recorded within the Development Envelope during the field survey:

- Malleefowl (*Leipoa ocellata*) (Vulnerable under the EPBC Act and WC Act); and
- Fork-tailed Swift (*Apus pacificus*) (Migratory and Marine under the EPBC Act and Migratory under the WC Act).

Fauna habitats, and desktop and survey record locations of these species are shown in Figure 4-13.

Three old inactive Malleefowl mounds were recorded during the survey, though only one of these was within the Development Envelope. Although not recorded directly during the current survey, several previous Malleefowl records exist within and near the Development Envelope, and suitable open woodland habitat is broadly present, indicating the species may utilise the Development Envelope. However, its occurrence may be restricted to less developed and disturbed areas, particularly the south-eastern part of the Development Envelope.

The Fork-tailed Swift was recorded from direct observation and calls (Phoenix 2017c).

Targeted Surveys for the Night Parrot (*Pezoporus occidentalis*) were undertaken over the Development Envelope using SongMeter SM2 devices. No evidence of Night Parrot calls were recorded (Phoenix 2017a).

There were no records on the conservation significant reptiles in samphire habitat. The Salt Lake Dragon (*Ctenophorus salinarum*) is the only samphire reptile returned by the desktop review for the B2018 Development Envelope. This species is not listed as conservation significant and is common around saline inland habitats in southern WA.

Profiles of the Malleefowl, Fork-tailed Swift and Night Parrot are presented in Table 4-26 through to Table 4-28. Other species of conservation interest that may occur within the Development Envelope are listed in Table 4-29.

Figure 4-13
Fauna Habitats and Recorded Conservation Significant Vertebrate Species

GOLD FIELDS
ST IVES GOLD MINE

365000 370000 375000 380000 385000 390000 395000

6550000 6545000 6540000 6535000 6530000 6525000 6520000 6515000

B2018 Field Survey
- Fork-tailed Swift
- Malleefowl
- Rainbow Bee-eater

Desktop Study
- Malleefowl
- Rainbow Bee-eater

Fauna Habitats
- Salt lake playa
- Shrubland on dune
- Woodland
- Disturbed/developed

0 3 6 9 12
kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	B Harvey
Reviewed:	N King
Checked:	G Barrett
Project No:	TE16034
Revision:	C
Date:	27/09/2018

LOCALITY MAP

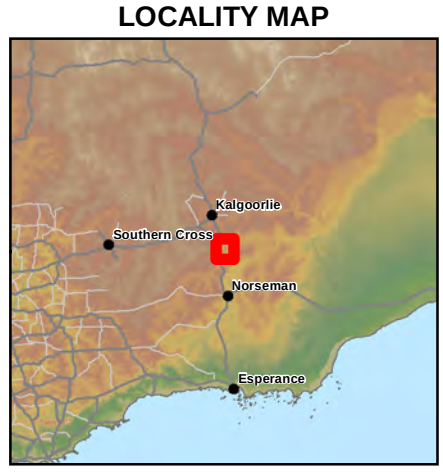


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*Table 4-26: Malleefowl (*Leipoa ocellata*)*

Feature	Details
Status	Vulnerable (EPBC Act), Vulnerable (WC Act)
Old malleefowl mound	 (Phoenix 2017c)
Distribution and ecology	The Malleefowl is found across the southern half of the Australian continent and is the only Megapodiidae in the South-west Region. In WA, the majority of the population is found south of a line from Shark Bay to the Nullarbor Plain. In the extreme south-west of WA, the species displays a patchy distribution. Recent work (Parsons et al. 2008) highlighted the substantial contraction of the Malleefowl distributional range in WA. The Malleefowl is a mound builder. Pairs are territorial. The eggs (on average 16) are laid in a chamber over which the male builds a mound from soil and leaf litter material. The combination of solar heat and composting organic material provides the heat required for egg incubation. Malleefowl are typically found in mallee woodlands but also in *Eucalyptus* woodlands and shrublands. The decline of the species is due to several factors: land clearing, habitat fragmentation, introduced predators, altered fire regime, competition for food with stock, road kill and the bio-accumulation of chemicals used in agriculture (Garnett et al. 2011). A National Recovery Plan was launched in 2007 in response to the dramatic decrease in Malleefowl numbers throughout Australia (Benshemesh 2007). In WA, a Strategic Action Plan was enacted for the 2005–2010 period (Western Australian Malleefowl Network 2006).
Records and likely distribution in the Development Envelope	The Malleefowl was recorded once from secondary evidence during the B2018 Project field survey. One inactive mound was recorded within 10 m of an access track in the south-east of the B2018 Development Envelope (see image above). The condition of the mound and vegetation growth occurring on the mound indicates the mound has remained unused for some time. The mound recorded during the B2018 Project field survey was previously recorded and identified as inactive in a previous survey within the Development Envelope (Bamford 2010). The potential occurrence of Malleefowl has previously been recorded three times from inactive mounds in the Development Envelope (two mounds from three records) (Bamford 2010; Harewood 2011c) and once from tracks (Harewood 2011c). Of the two mounds previously recorded,

Feature	Details
	one located centrally (Bamford 2010; Harewood 2011c) has since been removed during clearing for Tailings Storage Facility 4. Two additional inactive mounds belonging to the species have previously been recorded from approximately 100–200 m north of the northern boundary of the Development Envelope (Terratree 2015). Both mounds were examined during the B2018 Project field survey and both showed no sign of recent use. Given the location of previous Malleefowl records within and in the broader vicinity of the Development Envelope, and the presence of suitable habitat for the species throughout large areas of the Development Envelope, it is considered likely to occur in areas of open to dense shrubland and woodland (Table 4-29) (Phoenix 2017c). Notwithstanding the large area of suitable habitat outside of the Development Envelope, SIGMC remains committed to undertaking additional targeted searches or clearance surveys prior to disturbing any areas of suitable habitat that are yet to be surveyed.

*Table 4-27: Night Parrot (*Pezoporus occidentalis*)*

Feature	Details
Status	Endangered (EPBC Act), Critically Endangered (WC Act)
Night Parrot	 (Night Parrot Recovery Team 2018)
Distribution and ecology	The Night Parrot is the rarest Australian bird and possibly one the of rarest bird species in the world. The species was thought to be extinct until a single road killed specimen was collected in Queensland in October 1990 (Boles et al. 1994). Since then, another dead individual was found in Queensland (McDougall et al. 2009) and three individuals were sighted in WA, in the Pilbara region, in 2005 (Davis & Metcalf 2008). In 2013 a specimen was captured on video, photographed, calls were recorded and feathers were collected at an undisclosed location in Queensland proving the species was not extinct (Pyke & Ehrlich 2014). Little is known about the biology of the species. Most sightings occur at night, near water and it is assumed that the birds come to drink prior to feeding. Their nests are located in tunnelled dense vegetation and can contain three to six eggs (Garnett & Crowley 2000a). Its likely typical habitat types include chenopod grasslands, open bushland with old-growth spinifex (*Triodia* spp) and hummock grasslands in the proximity of salt lakes. The map of historical records in WA indicates the species can potentially occur across a wide range of common habitat (Davis & Metcalf 2008). Alteration of fire regime, predation by introduced species and over-grazing by cattle are the main threat to the species, resulting in poor habitat quality and direct mortality of individuals. Roosting and nesting sites of the Night Parrot are in clumps of dense vegetation, primarily old and large spinifex clumps (often > 50 years unburnt), especially hummocks that are ring-forming (DBCA 2017a). These may be in expanses or isolated patches, but sometimes associated with other vegetation types, such as dense chenopod shrubs. Spinifex hummocks that are collapsed (i.e. less than about 40-50 cm in height) are not likely to provide adequate shelter (DBCA 2017a).
Records and likely distribution in the Development Envelope	No evidence of Night Parrot calls were recorded during the targeted survey (Phoenix 2017a). The Development Envelope is located in the Coolgardie IBRA region, subregion COO3 “Eastern Goldfields” (Cowan 2001). Based on previous records of Night Parrots, this subregion is considered only of ‘moderate priority’ for Night Parrot surveys (DBCA 2017a). This is consistent with the survey not providing any evidence of the species.

Feature	Details
	However, when considering the likelihood of Night Parrots occurring in the Development Envelope, it is important to consider that no available survey technique can irrefutably demonstrate that the species is absent from a site (DBCA 2017a). Where habitat is suitable, even if the species was not confirmed to be being present, it might still frequent the area at other times. In such cases, an impact assessments should indicate the likelihood of occurrence based on the quality of the habitat at the site, the absence of threats, focus on the risk of a project to the species on the assumption that it is present, and assess any threatening processes that may occur as a result (e.g. reduction of the extent or quality of habitat, increase in numbers of feral predators, increase (or decrease) in grazing pressure, or changed fire regime) (DBCA 2017a). There is a record of the species approximately 286 km southeast of the Development Envelope; however, the record lacks information to determine its accuracy and validity (DPaW 2016b).

*Table 4-28: Fork-tailed Swift (*Apus pacificus*)*

Feature	Details
Status	Migratory, Marine (EPBC Act), Migratory (WC Act)
Description	 (Fork-tailed Swift 2018)
Distibution and ecology	The Fork-tailed Swift is a widespread migratory species that overwinters in Australia. It can be found across most of WA and is uncommon to moderately common in the north-west. They are mostly found over inland plains and along foothills, coastal areas and over settlements. They occur in a wide range of dry or open habitats, including riparian woodlands, tea-tree swamps, low scrub, heathland, saltmarsh, grassland and spinifex sandplains, open farmland and inland and coastal sand-dunes. Fork-tailed Swifts are often found in areas that experience updraughts around cliffs and normally forage several hundred metres above ground level (DoE 2015).
Records and likely distribution in the Development Envelope	The Fork-tailed Swift was recorded once during the field survey from a single individual flying overhead in riparian woodland habitat (Table 4-29). The species is likely to occur occasionally in the Development Envelope. The species can occur within a wide range of habitats, including those found in the Development Envelope and is likely to forage, though it is unlikely it will land or nest within the Development Envelope. The Fork-tailed Swift has previously been recorded approximately 105 km west of the Development Envelope at Victoria Rock (Birdlife Australia 2016). On the basis of the presence of suitable habitat and proximity of recent records, a further 16 species of conservation significance, primarily migratory water birds and shorebirds, may occur in the Development Envelope (see Figure 4-13). None of these species were recorded during the surveys. The potential occurrence of conservation significant species in the Development Envelope was assessed based on presence of suitable habitat, proximity of previous records and current distributions. It was noted that lack of records for many conservation significant species is likely due to the limited survey effort within the broader region (Phoenix 2017c). Results of this assessment are summarised in Section 4.3.3. Note that the species that are unlikely to be found within the area are not included in the summary.

Table 4-29: Other Vertebrate Species of Conservation Significance that May Occur within the Development Envelope

Scientific name	Common name	Conservation status			Likelihood of occurrence	Fauna habitat					Summary of records and occurrence	Nearest record to the Development Envelope (Birdlife Australia 2016, DPaW 2016b, 2016c)
		EPBC Act	WC Act	DBCA		Salt lake playa and riparian zone	Shrubland on dune	Open woodland on plain	Open woodland on rocky hill	Riparian woodland		
Birds												
Oxyura australis	Blue-billed Duck			P4	Possible	●					May occasionally occur in saltlake habitat following suitable rainfall events and flooding, particularly in areas with well vegetated banks.	~90 km south
Ardea modesta	Eastern Great Egret	Mig	Mig		Possible	●					May occasionally occur in saltlake habitat and drainage areas following suitable rainfall events and flooding of lakes.	~220 km south
Ardea ibis	Cattle Egret	Mig	Mig		Possible	●					May occasionally occur in saltlake habitat and drainage areas following suitable rainfall events and flooding of lakes.	~54 km north-northeast
Plegadis falcinellus	Glossy Ibis	Mig	Mig		Possible	●					May occasionally occur in saltlake habitat and drainage areas following suitable rainfall events and flooding of lakes.	~54 km north-northeast
Falco hypoleucos	Grey Falcon		VU		Likely		●	●	●	●	Likely to occasionally occur within the Development Envelope to forage, unlikely to nest within the Development Envelope though may utilise suitable nesting structures in the vicinity.	~47 km south

Scientific name	Common name	Conservation status			Likelihood of occurrence	Fauna habitat					Summary of records and occurrence	Nearest record to the Development Envelope (Birdlife Australia 2016, DPaW 2016b, 2016c)
		EPBC Act	WC Act	DBCA		Salt lake playa and riparian zone	Shrubland on dune	Open woodland on plain	Open woodland on rocky hill	Riparian woodland		
Falco peregrinus	Peregrine Falcon		SP		Likely		●	●	●	●	Likely to occasionally occur within the Development Envelope to forage, unlikely to nest within study area though may utilise suitable nesting structures in the vicinity.	~9.5 km west
Thinornis rubricollis	Hooded Plover			P4	Likely	●					Likely to occur on saltlakes and may occasionally nest on suitable shorelines surrounding saltlakes.	~70 km north
Tringa nebularia	Common Greenshank	Mig	Mig		Possible	●					May possibly occur in saltlake habitat and adjacent shorelines following suitable rainfall events when water is present.	~64 km north-northwest
Tringa glareola	Wood Sandpiper	Mig	Mig		Possible	●					May possibly occur in saltlake habitat and adjacent shorelines following suitable rainfall events when water is present.	~47 north-northwest
Calidris ruficollis	Red-necked Stint	Mig	Mig		Possible	●					May possibly occur in saltlake habitat and adjacent shorelines following suitable rainfall events when water is present.	~68 km north
Calidris acuminata	Sharp-tailed Sandpiper	Mig	Mig		Possible	●					May possibly occur in saltlake habitat and adjacent shorelines following suitable rainfall events when water is present.	~34 km north
Calidris ferruginea	Curlew Sandpiper	CR/ Mig	VU/ Mig		Possible	●					May possibly occur in saltlake habitat and adjacent shorelines following suitable rainfall events when water is present.	~68 km north

Scientific name	Common name	Conservation status			Likelihood of occurrence	Fauna habitat					Summary of records and occurrence	Nearest record to the Development Envelope (Birdlife Australia 2016, DPaW 2016b, 2016c)
		EPBC Act	WC Act	DBCA		Salt lake playa and riparian zone	Shrubland on dune	Open woodland on plain	Open woodland on rocky hill	Riparian woodland		
Platycercus icterotis xanthogenys	Western Rosella (inland ssp.)			P4	Possible			●	●	●	May occur in woodland habitat of the Development Envelope, nesting may also occur in woodland habitat where suitable hollows are present.	~45 km southwest
Mammals												
Phascogale calura	Red-tailed Phascogale	EN	CD		Possible			●		●	Development Envelope outside of species current known distribution and species considered regionally extinct in association with the Development Envelope (Burbidge 2004, Van Dyck and Strahan 2008); however, records of the species indicate it may possibly occur within the Development Envelope. An unconfirmed record exists ~21 km southeast of the Development Envelope and others further south from the 1980s suggesting the species may occur.	~21 km southeast (2005)
Nyctophilus major tor	South-western Long-eared Bat			P4	Likely			●	●	●	Species may occur within the Development Envelope to forage and may roost in woodland habitat where suitable hollows are present.	From within 5 km of the B2018 study area.

4.3.3.4 Short Range Endemic (SRE) Invertebrates

Two conservation significant terrestrial invertebrate species were returned in the desktop review:

- The Arid Bronze Azure Butterfly (*Ogyris subterrestris petrina*) (EPBC, WA Act – CR) has been recorded from around Kalgoorlie until the early 1990s (Field 1999), but is currently only known from Barbalin Nature Reserve in the northern Avon Wheatbelt (Gamblin et al. 2009); and
- The Inland Hairstreak (*Jalmenus aridus*) (DPaW – P1), originally described from Lake Douglas, ca. 12 km SW of Kalgoorlie (Graham & Moulds 1988). The larvae feed on the leaves and flowers of *Senna nemophila* and *Acacia tetragonophylla*. The caterpillars are attended by the ant species *Froggatella kirbii*. It is currently not known from the Development Envelope.

Based on habitat preferences, neither of these species is expected to occur within the Development Envelope and these two species are not considered further.

Only one of the species recorded from the Development Envelope, the playa specialist wolf spider *Tetralycosa baudinettei*, is a confirmed SRE (Framenau & Hudson 2017). This species has been recorded from other lakes in the region, including Lake Goongarrie, Lake Roe and Lake Yindarlgooda. Distribution patterns of all other invertebrate species from the Development Envelope are not well known and are therefore considered potential SREs.

Currently, seven invertebrate species are only known from the Development Envelope - three species of mygalomorph spiders, three scorpions and one slater respectively – while a further five species are known only from Lake Lefroy but have been recorded outside of the Development Envelope (Table 4-30; Figure 4-14). *Aname* 'SIGM122' and *Lychas* 'SIGM132' are considered as potential riparian specialists.

The species that are potentially endemic to Lake Lefroy include two species of spiders, two tiger beetles and a slater (Table 4-36). Three of these are playa specialists, a jumping spider and the two beetles, and one a likely riparian species, *Nemesiidae* 'SIGM104', the most commonly collected mygalomorph spider in the riparian zone. The single slater is considered an occasional visitor to the riparian zone from the surrounding woodland.

All other species recorded in the riparian zone are also considered occasional visitors from adjoining habitat and are likely to usually occur in the expansive woodlands around the lake, both within and external to the Development Envelope. These are unlikely to be affected by the B2018 Project.

Based on the faunal composition of the SREs identified from the Development Envelope and the potential Lake Lefroy endemics, the habitat type 'salt lake and associated riparian zone' has been assessed as having the greatest importance for potential range-restricted species, whereas the woodland habitats surrounding the lake represent regionally widespread habitat types which facilitate the broader distribution of species (Table 4-31).

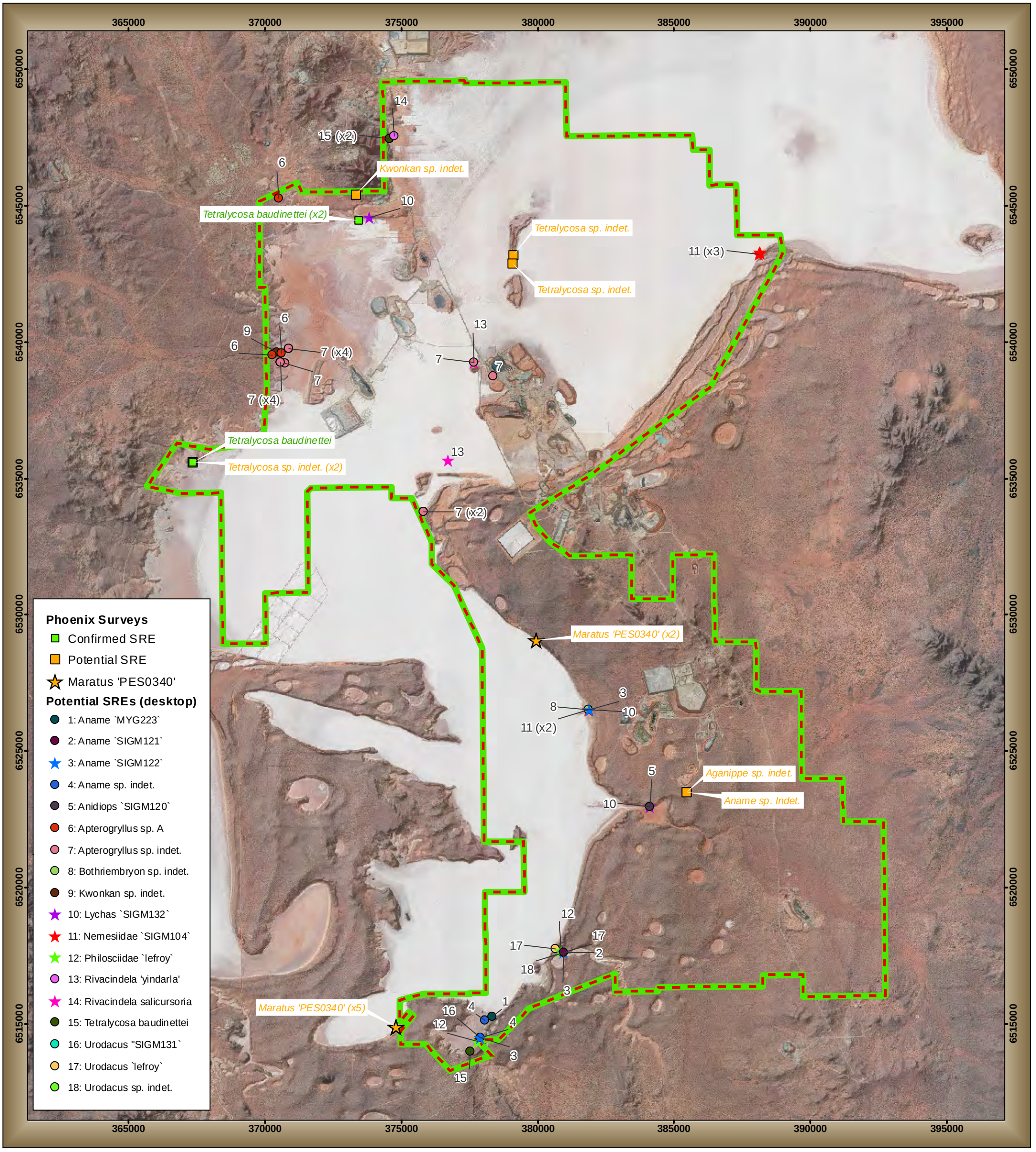
When considering the 'salt lake and its riparian zone' as a habitat, it is presumed that some of its inhabiting specialists may utilise the playa only, some the riparian zone, and others may be dependent on the presence of both. For example, the three tiger beetles are specialists of the salt lake playa with their burrowing larvae and foraging adults only found there, and the two mygalomorph spiders and a scorpion appear to be riparian specialists based on the frequency of their occurrence in the B2010 riparian monitoring program. In contrast, the jumping spider *Maratus* 'PES340' appears to primarily forage on the playa of the salt lake, but based on the knowledge of the reproductive behaviour of these spiders, they are likely to utilise structures in the riparian zone such as debris and vegetation to lay their eggs. These spiders require both the

playa and the riparian zone, supported by the fact that some of these spiders were collected in pitfall traps in previous surveys.

Table 4-30: Potential SREs Only Known from Lake Lefroy

Family	Genus and species	Original source	Habitat	Only known from the Development Envelope
Order Araneae (spiders)				
Infraorder Mygalomorphae (trapdoor spiders)				
Nemesiidae	*Aname* 'MYG223'	WA Museum, Dalcon (2013c)	Likely woodland species	✓
	Aname 'SIGM121'	Phoenix (2013a)	Likely woodland species	✓
	Aname 'SIGM122'	Phoenix (2013a)	Potentially a riparian specialist	✓
	Nemesiidae 'SIGM104'	WA Museum, Dalcon (2013c)	Potentially riparian around lake	
Infraorder Araneomorphae (modern spiders)				
Salticidae	*Maratus* 'PES0340'	WA Museum, Dalcon (2013c)	Salt lake playa specialist but likely to require riparian zone for laying eggs	
Order Scorpiones (scorpions)				
Buthidae	*Lychas* 'SIGM132'	Phoenix (2014b)	Potentially a riparian specialist	✓
Urodacidae	*Urodacus* 'SIGM131'	Dalcon (2013c)	Likely woodland species	✓
	Urodacus 'lefroy'	Phoenix (2014b)	Likely woodland species	✓
Order Coleoptera (beetles)				
Carabidae	*Cicindela salicursoria*	Hudson (1995)	Salt lake playa specialist with burrowing larvae	
	Cicindela necopinata	Sumlin (1997)	Salt lake playa specialist with burrowing larvae	
Isopoda (slaters)				
Philosciidae	Philosciidae 'lefroy'	Phoenix (2014b)	Possible riparian specialist	✓
	Cubaris 'lefroy'	Phoenix (2014b)	Likely woodland species	

Figure 4-14
Confirmed and Potential Short-range Endemic Invertebrates



LEGEND

Development Envelope

0 3 6 9 12

Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	24/07/2018

LOCALITY MAP

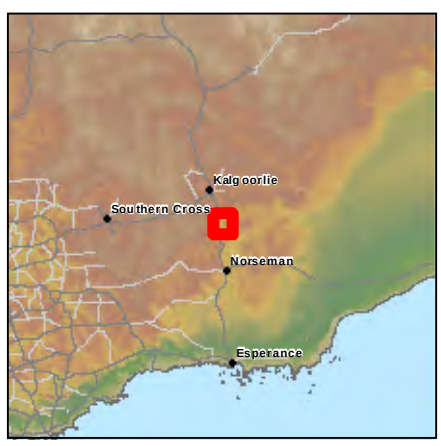


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Table 4-31: SRE Habitat Comparison

Habitat	Development Envelope endemics	Lake Lefroy endemics	Regional SREs
Salt lake playa and riparian zone	Unlikely *Aname* 'SIGM122', *Lychas* 'SIGM132' and Philosciidae 'lefroy' were found at a number of sites within the Development Envelope, which suggests occurrence outside the Development Envelope.	Likely *Aname* `SIGM122` *Lychas* `SIGM132` Philosciidae 'lefroy' *Nemesiidae* `SIGM104` *Maratus* `PES340` *Cicindela salicursoria* *C. necopinata*	Likely *Tetralycosa baudinettei*
Shrubland on sand dune	Unlikely	None	Unlikely
Open woodland	Unlikely	None	Likely *Aname* `MYG223' *Aname* `SIGM121` *Urodacus* `SIGM131` *Urodacus* `lefroy` *Cubaris* `lefroy`

The likelihood of SREs occurring in a particular habitat is summarised in Table 4-31. The three different levels of endemism, i.e. Development Envelope endemic, Lake Lefroy endemic and regional endemic are reviewed.

Of the SRE species currently only known from the Development Envelope, those that are habitat specialists of the riparian zone (*Aname* 'SIGM122', *Lychas* 'SIGM132 and *Philosciidae* 'lefroy') should receive most consideration, due to their limited habitat availability. All other species are currently only known from the Development Envelope are likely inhabitants of the expansive woodlands around the lake. In addition, those species currently endemic to Lake Lefroy (inside and outside of the Development Envelope) require further consideration, including two species of spider (*Maratus* 'PES340', *Nemesiidae* 'SIGM104') and two tiger beetles (*Cicindela salicursoria* and *C. necopinata*) (Phoenix 2017c).

4.3.3.5 Aquatic Invertebrate Fauna

Aquatic invertebrate fauna are discussed in Section 4.6.

4.3.4 Potential Impacts

4.3.4.1 Loss and fragmentation of fauna habitat

The single most widespread direct impact arising from the B2018 Project is the clearing of native vegetation and consequent loss and alteration of fauna habitat. Fauna habitat also extends to parts of the lake surface which may also form habitat for invertebrates, particularly the near shore sections of the lake surface.

Clearing for infrastructure such as roads, pipelines and power lines have the potential to fragment habitat. This can result in restricted movements of animals and has the potential to cause an impact on the fauna community that is greater than just the area cleared.

4.3.4.2 Mortality during land clearing

Direct mortality of fauna during clearing works may occur.

4.3.4.3 Other potential impacts

Other potential impacts relate to habitat degradation through:

- Dust on vegetation
- Invasive weeds
- Changed fire regimes
- Feral animals, and
- Noise and vibration associated with heavy vehicle operations, or blasting and drilling.

4.3.5 Assessment of Impacts

4.3.5.1 Overview of impacts

The Proposal is likely to have an impact on particular environmental values for terrestrial fauna as defined in the EPA's factor guideline for terrestrial fauna (EPA 2016g) and as outlined in the following table.

Table 4-32: Terrestrial fauna – relevant environmental values

Environmental value	Relevant to Proposal?	Comments
Threatened or priority species	✓	Two vertebrate species recorded under both the *Wildlife Conservation Act 1950* (WA) or the *Environment Protection and Biodiversity Act (1999)* (Commonwealth) with one listed as Vulnerable and the other as Migratory.
Species with a restricted distribution	✓	One confirmed and a number of potential short range endemic species (SREs) have been identified.
Degree of historical impact from threatening processes	×	Terrestrial ecosystems in the region are largely intact.
Providing an important function required to maintain the ecological integrity of a significant ecosystem	×	No known examples.

Compliance with survey guidelines for impact assessment (EPA 2016o, p; DBCA 2017a) is discussed in section 4.3.3.1.

4.3.5.2 Loss and fragmentation of fauna habitat

As with flora and vegetation, previous EPA assessments have been limited to Lake Lefroy and its riparian zone. However, the B2018 Project proposes further disturbance to additional areas on the surface of Lake Lefroy, in the riparian zone and the land beyond the riparian zone. Some of the existing land based disturbance has occurred via approval under other regulatory mechanisms. The current inferred extent of fauna habitat disturbance within the Development Envelope is summarised in Table 4-33 below. The reason the habitat is inferred is due to the lack of fauna habitat information under some of the existing disturbance due to its age.

In light of the above, the impact on fauna to date is considered to have been minimal in the context of the wider SIGMC tenements and regional setting.

The B2018 Project involves excavation of pits and the construction of infrastructure leading to a direct loss of habitat. In such circumstances, riparian specialists, such as certain SREs are particularly susceptible to these impacts as their habitat within the Development Envelope is relatively small being limited to a habitat strip around Lake Lefroy. In addition to direct habitat loss, fragmentation of the continuous riparian zone into smaller stretches without the ability for dispersal for the specialised fauna may compromise those smaller populations that remain in the less affected parts outside future developments (Ewers & Didham 2006; Hobbs 1993).

Table 4-33: Total Inferred Disturbance to Fauna Habitat to Date across the Development Envelope

Habitat type	Total disturbance to date (ha)	Total estimated area of habitat type in Development Envelope (pre-disturbance) (ha)	Percentage disturbed to date in Development Envelope
Salt lake playa and associated riparian zone	1,953.7	27,291.9	7.2
Shrubland on dune	69.8	1,957.1	3.6
Woodland on plain (including woodlands along drainage lines and those with scattered small rocky hills)	2,150.9	15,764.5	13.6
Total	**4,174.4**	**45,013.5**	**9.3**

An impact assessment on terrestrial invertebrates undertaken as part of the B2010 PER and its associated riparian monitoring program concentrated on the effects of increased flooding of the riparian zone. It has been argued that this impact is negligible (Phoenix 2013b, 2014b), mainly because coping with varying water levels is one of the main characteristics of true riparian fauna (Framenau et al. 2002; Manderbach & Framenau 2001). Species from the arid woodland matrix that only utilise the riparian zone opportunistically will not be affected.

The Development Envelope also provides habitat for other conservation significant species such as Malleefowl, Night Parrot, Grey Falcon, Peregrine Falcon, Western Rosella (inland ssp.), Red-tailed Phascogale and South-western Long-eared Bat. These species are typically found in Woodland or Shrubland on dune habitats. At a regional scale, however, these habitats are however known to be widely represented and expand beyond the Development Envelope boundary.

The salt lake playa and associated riparian habitat may also provide habitat for some migratory birds including the Blue-billed Duck, Eastern Great Egret, Cattle Egret, Glossy Ibis, Hooded Plover, Common Greenshank, Wood Sandpiper, Red-necked Stint, Sharp-tailed Sandpiper and Curlew Sandpiper. However, the lake does not appear to maintain a low salinity phase, even following large influxes of freshwater (Phoenix 2014a), which is considered to be less attractive to birds. Regionally this habitat type is widely represented.

The targeted survey undertaken for Night Parrot did not identify the species within the Development Envelope. Potential impacts from the B2018 Project are therefore considered low.

Overall, the cumulative impact on vertebrate fauna through direct habitat loss is not significant when considering the widespread occurrence of habitat at the regional level (Table 4-34).

With regard to short range endemic invertebrates (SREs), a number of the species recorded are likely to be restricted in distribution (Table 4-31), with the salt lake playa and riparian zone emerging as an important habitat for many of these fauna. SIGMC notes, however, that the Development Envelope contains less than one third of the shoreline of the lake.

Table 4-34: Potential impacts to Significant Terrestrial Fauna Habitat from B2018 Project

Habitat	Significant species utilising or potentially utilising the habitat	Extrapolated extent sub-IBRA (ha)	Residual impact
Open woodland on plain	Potential habitat for Malleefowl, Night Parrot, Grey Falcon, Peregrine Falcon, Western Rosella (inland ssp.), Red-tailed Phascogale, South-western Long-eared Bat	431,216.9	Low - loss within B2018 Development Envelope is low. Regionally negligible.
Salt lake playa and associated riparian zone	Potential habitat for Blue-billed Duck, Eastern Great Egret, Cattle Egret, Glossy Ibis, Hooded Plover, Common Greenshank, Wood Sandpiper, Red-necked Stint, Sharp-tailed Sandpiper, Curlew Sandpiper	300,445.9	Low - loss within B2018 Development Envelope is low. Regionally negligible.
Shrubland on dune	Potential habitat for Malleefowl, Grey Falcon, Peregrine Falcon.	134,059.6	Low to Moderate – a more restricted habitat than others. Negligible at regional scale.

4.3.5.3 Mortality during land clearing

Vegetation clearing is likely to lead to some mortality of terrestrial fauna. However, none of the conservation significant vertebrate fauna are burrowing animals so may be expected to disperse during the clearing process. Given the potential presence of Malleefowl, pre-clearing checks are appropriate to determine if active mounds are present.

4.3.5.4 Other potential impacts

Management of dust deposition, invasive weeds and changed fire regimes, all of which may degrade fauna habitat, is discussed in section 4.2.6.

Existing methods of managing feral animals – careful management of putrescible waste and trapping of feral cats – will continue.

Noise and vibration impacts and light spill will occur but are not likely to be so significant as to implement specific management measures.

Speed limits are applied, primarily for safety reasons, but they also help to reduce the potential for vehicle strike. Off road driving restrictions also apply. The site induction includes an environmental component.

4.3.6 Mitigation

As for flora and vegetation, SIGMC has identified some fauna habitats within the Development Envelope that are may support fauna of conservation significance. Some of the exclusion zones utilised for protection of flora and vegetation (see Section 4.2) can play a similar role for fauna. Three of the proposed exclusion zones – Exploration 1, Pilbailey and Implacable - contain habitat likely to support SRE fauna (Figure 4-15, Table 4-35).

There are, however, other SRE fauna that occur within the Development Envelope but not in exclusion zones, and have not been recorded outside the Development Envelope. These are listed in Table 4-36. As noted by the EPA (2016g), "the level of knowledge of invertebrate groups is often poor. There are still many gaps regarding taxonomy, habitat requirements, distribution and natural history. New species are regularly discovered during EIA surveys and provide a challenge when assessing impacts". To help address this issue, further survey work, not restricted to the Development Envelope, will be undertaken to establish the status of particular SRE fauna. With regard to the near shore environment, SIGMC notes that more than two thirds occurs outside of the Development Envelope, with more contained within exclusion zones within the Development Envelope.

Regarding malleefowl, SIGMC will manage potential impacts on malleefowl using pre-clearance surveys and associated measures. All active or potentially active malleefowl mounds recorded in pre-clearing surveys will be flagged with 100 m buffers and restricted access will apply. Signage will be erected and maintained. Where possible, all active or potentially active mounds will be avoided, leaving a 100 m buffer around the mound and maintaining connectivity to surrounding habitat.

Where clearing is unavoidable (e.g. mound occurs over the ore body), the following will apply:

- If the mound is active or potentially active, clearing will be delayed for a suitable period of time that allows monitoring of the mound;
- If the mound is found to be currently active, clearing will be delayed until chicks have fledged or the mound has been abandoned; or
- If the mound is not found to be currently active, clearing can proceed.

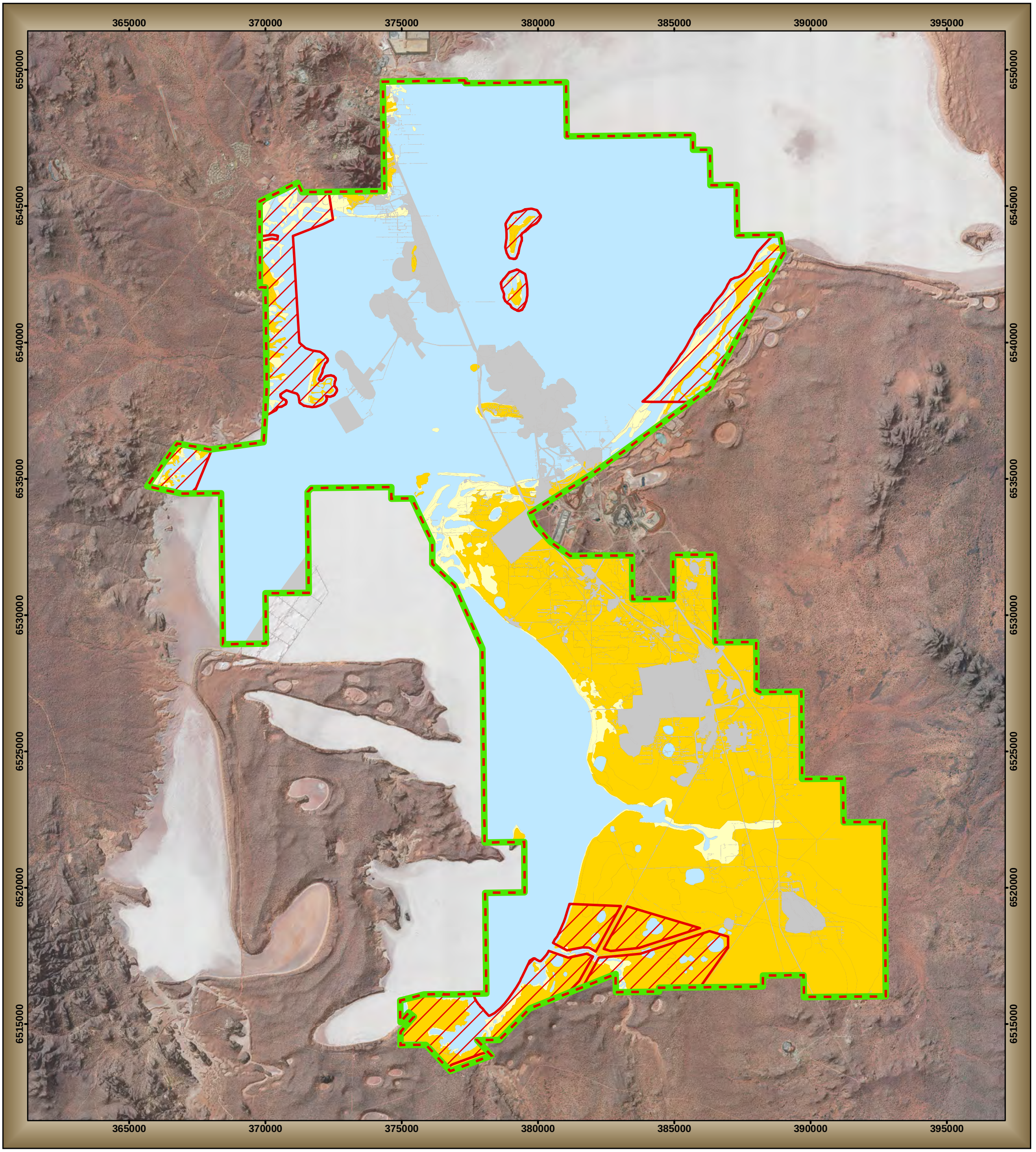
The following commitments are made:

Commitment 4: To protect terrestrial fauna, establish three exclusion zones – Exploration 1, Pilbailey and Implacable - within the Development Envelope within which no mine-related activities may occur.

Commitment 5: Undertake further SRE survey work prior to ground disturbing works to clarify the status of fauna only known from the Development Envelope.

These commitments, and other fauna management measures, are listed in Table 4-37.

Figure 4-15
Fauna Habitats and Proposed Exclusion Zones



Exclusion Areas

Fauna Habitats

- Salt lake playa
- Shrubland on dune
- Woodland
- Disturbed/developed

0 3 6 9 12

kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	B Harvey
Reviewed:	N King
Checked:	G Barrett
Project No:	TE16034
Revision:	B
Date:	27/09/2018

LOCALITY MAP

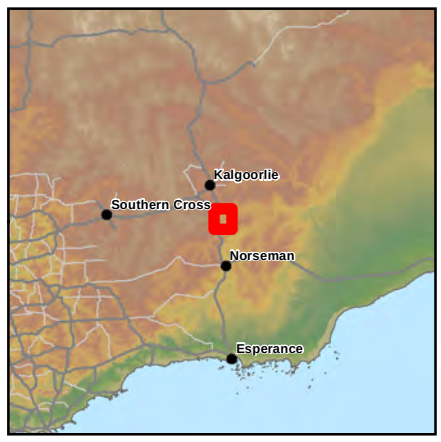


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Table 4-35: Proposed exclusion zones – confirmed or potential SREs protected

Exclusion Zone	SRE fauna	Status	Comments
Exploration 1	*Nemesiidae* 'SIGM 104'	Potential SRE	Likely riparian specialist and therefore potentially endemic to Lake Lefroy.
Pilbailey	*Tetralycosa baudinettei*	Confirmed SRE	Regional endemic with several records outside Lake Lefroy.
	Tetralycosa sp. indet.	Potential SRE	No *Tetralycosa* species are endemic to lake. Regional endemic if *T. baudinettei*, widespread if *T. alteripa.*
Implacable[9]	*Aname* 'MYG223'	Potential SRE	Location of only known record, unlikely riparian specialist and therefore possibly more widespread in woodlands surrounding lake.
	Aname 'SIGM121'	Potential SRE	Location of only known record, unlikely riparian specialist and therefore possibly more widespread in woodlands surrounding lake.
	Aname 'SIGM122'	Potential SRE	Likely riparian specialist due to multiple records around lake; potentially endemic to Lake Lefroy.
	Philoscidae 'lefroy'	Potential SRE	Location of only known records. Potentially riparian and endemic to Lake Lefroy
	Tetralycosa baudinettei	Confirmed SRE	Regional endemic with several records outside Lake Lefroy.
	Urodacus 'SIGM131'	Potential SRE	Location of only known record. Unlikely riparian specialist, but potentially endemic to woodlands around Lake Lefroy.
	Urodacus 'lefroy'	Potential SRE	Location of only known record. Unlikely riparian specialist, but potentially endemic to woodlands around Lake Lefroy.
	Urodacus sp. indet.	Potential SRE	Poor taxonomic resolution and therefore unknown habitat preferences. Potential SRE and rating based on its potential conspecificity with U. 'SIGM131' and U. 'lefroy'.

Table 4-36: SRE fauna only known from Development Envelope and outside of exclusion zones

SRE fauna	Status	Comments
Cicindela salicursoria	Potential SRE	Only known records are from within Development Envelope. Potential Lake Lefroy endemic.
Lychas `SIGM132`	Potential SRE	Only known records are from within Development Envelope. Possible riparian specialist.
Aganippe sp. indet.	Potential SRE	Poor taxonomic resolution but many *Aganippe* sp. indet. records outside Development Envelope (NB - all *Aganippe* now belong to the genus *Idiosoma*).

[9] Some taxa were recorded at a sample site immediately adjacent to this exclusion zone so it is assumed they occur within it.

Table 4-37: Predicted Impacts and Mitigation Strategies for Terrestrial Fauna

Predicted Impact from the B2018 Project	Mitigation Hierarchy	Mitigation
Loss and fragmentation of fauna habitat	Avoid	To protect terrestrial fauna, establish three exclusion zones – Exploration 1, Pilbailey and Implacable - within the Development Envelope within which no mine-related activities may occur (Commitment 4)
Loss and fragmentation of fauna habitat	Avoid/ Minimise	Undertake further SRE survey work prior to ground disturbing works to clarify the status of fauna only known from the Development Envelope (Commitment 5).
Loss and fragmentation of fauna habitat	Avoid/ Minimise	Ground disturbing activities at SIGMC are managed through the implementation of a Surface Disturbance Permit Procedure (SIG-ENV-PR049). These procedures are intended to prevent accidental disturbance of areas not scheduled for clearing and to advise field personnel on methodology for topsoil recovery and stockpiling, and related matters. These activities can be managed under the *Mining Act 1978*.
Loss and fragmentation of fauna habitat	Avoid/ Minimise	Incorporate checks for malleefowl mounds into the Surface Disturbance Permit Procedure. This activity can be managed under the *Mining Act 1978*.
Loss and fragmentation of fauna habitat	Rehabilitate	SIGMC will undertake progressive rehabilitation in areas where mining operations have been completed. This activity can be managed under the *Mining Act 1978*.
Other potential impacts (degradation of fauna habitat)	Minimise/ Avoid	Dust associated with the operations will be managed in accordance with the SIGMC Dust Management Procedure (SIG-ENV-PR029). Weed control will be carried out to control weeds in accordance with the SIGMC Weed Management Plan (SIG-ENV-PL047), Weed Monitoring Procedure (SIG-ENV-PR041) and Weed Control Procedure (SIG-ENV-PR042). Existing methods of managing feral animals – careful management of putrescible waste and trapping of feral cats – will continue. Vehicle speed limits apply, as do restrictions on off road driving. Procedures to minimise the risk of accidental fires are in place. These activities can be managed under the *Mining Act 1978* and the *Mine Safety and Inspection Act 1994*.

4.3.7 Predicted Outcome

In consideration of the outcomes of the EIA and proposed management measures, SIGMC considers that EPA's objective for Terrestrial Fauna to '*protect terrestrial fauna so that biological diversity and ecological integrity are maintained*' can be achieved. The following outcomes are predicted:

- No loss of any Threatened Ecological Community or Priority Ecological Community;
- No loss of important populations of conservation significant fauna;
- Loss of fauna habitat is negligible at the regional scale; and
- Retention of riparian habitat for SREs both outside of the Development Envelope and within Exclusion Zones within the Development Envelope.

By implementing management measures detailed above, the residual impact is not considered significant and no offsets are considered to be required.

4.4 *Subterranean Fauna*

4.4.1 EPA Objective

The EPA's environmental objective for the factor Subterranean Fauna is:

To protect subterranean fauna so that biological diversity and ecological integrity are maintained.

4.4.2 Policy and Guidance

The following policies and guidelines apply to Subterranean Fauna:

- EPA Environmental Factor Guideline - Subterranean Fauna (EPA 2016b)
- EPA Technical Guidance - Subterranean fauna survey (EPA 2016m) ; and
- EPA Technical Guidance - Sampling methods for subterranean fauna (EPA 2016k).

4.4.3 Receiving Environment

4.4.3.1 Survey effort

A total of five subterranean studies have been previously undertaken within the Development Envelope between 2009 and 2016. These studies are summarised in Table 4-38. Figure 4-16 depicts the area the studies cover.

To aid assessment of the B2018 Project, Phoenix undertook a Level 1 subterranean fauna assessment over the Development Envelope in October 2016 (Phoenix 2016b). The assessment consisted of a detailed desktop review of available technical reports, published scientific literature and database searches and a reconnaissance survey undertaken in 19–22 October 2016.

4.4.3.2 Subterranean habitats

Subterranean fauna live within air- or water-filled underground networks. They are predominantly invertebrates, although the subterranean fauna in WA also includes fish and reptiles (Larson et al. 2013; Rabosky et al. 2004). Organisms specialised for living in air-filled subterranean networks are referred to as troglofauna, while those inhabiting water-filled subterranean networks are referred to as stygofauna (Howarth 1983; Humphreys 2000).

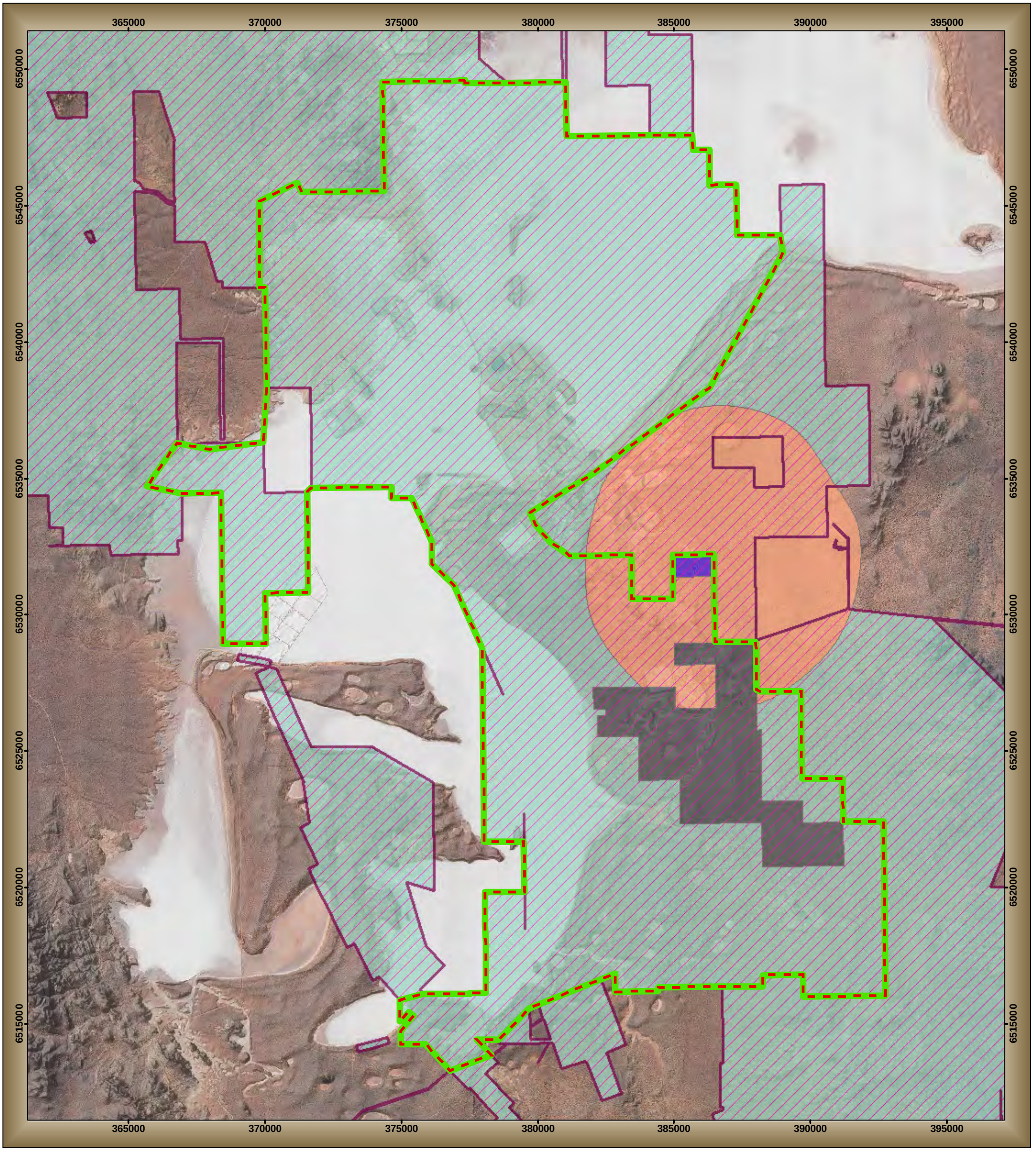
Subterranean habitats are perpetually dark, are constant in temperature and humidity (air-filled networks) and very low in nutrients and energy that are required to support organisms (Howarth 1993). Evolution under such conditions has resulted in much specialised organisms that are restricted to the void networks in which they have evolved (Harvey 2002; Holsinger 2000; Howarth 1993; Ponder & Colgan 2002). Such species are obligated to living in subterranean networks and cannot live in epigean (surface) environments.

Organisms specialised to live in subterranean networks are likely to represent narrow or short-range endemics (SREs) with limited capabilities of dispersal (Harvey 2002; Ponder & Colgan 2002; Volschenk & Prendini 2008). Short-range endemics are species with naturally small distributions; nominally less than 10,000 km^2 (Harvey 2002) although a lower threshold for subterranean species of 1,000 km^2 was subsequently proposed (Eberhard et al. 2009). It is these subterranean species that are considered to be of conservation significance because they are at greatest risk of extinction from development projects.

Table 4-38: Subterranean Fauna Studies Conducted within the Development Envelope

Reference	Report Name	Survey Type	Survey Level	Location of Survey	Survey Date	Survey Effort	Key findings and Recommendations
Outback Ecology (2009b)	Assessment of the potential impacts of mining on stygofauna communities in the Athena Complex Project Area	Stygofauna desktop review	Desktop	Athena project area	Not relevant	Not relevant	Lake Lefroy is hypersaline and acidic. The area has no significant value for stygofauna habitat, stygofauna occurrence is low to none. Stratigraphy of the area consists mainly of fine sand and silty clays. Lack of pore space for colonisation and habitat.
Subterranean Ecology (2010c)	Goldfields, St Ives Gold Mines Stygofauna Desktop Assessment	Stygofauna desktop review	Desktop	Beyond 2010 project area	Not relevant	Not relevant	High salinity to likely limit the occurrence of stygofauna in all areas. Well-developed calcrete aquifers absent.
Subterranean Ecology (2010b)	Goldfields, St Ives Gold Mines Troglofauna Desktop Assessment	Troglofauna desktop review	Desktop	Beyond 2010 project area	Not relevant	Not relevant	Unconsolidated sandy sediments do not provide prospective habitat for troglofauna. Calcrete deposits absent, limiting the occurrence of troglofauna. Islands and quaternary transported sediments listed as being possible to inhabit troglofauna.
Outback Ecology (2011b)	West Idough Deposit Subterranean Fauna Desktop Assessment	Subterranean desktop review	Desktop	West Idough	Not relevant	Not relevant	Probability of the area having significant stygofauna values is considered to be low. Project area is unlikely to support rich troglofauna communities. A pilot troglofauna survey recommended to investigate the prospectivity of calcrete geologies.
Outback Ecology (2011a)	Level 1 Pilot Troglofauna Assessment	Level 1 troglofauna survey	Level 1	West Idough	Sept -Nov 2011	15 litter traps, 60 scrape samples from 15 uncased holes	No troglofauna found. Local geologies in West Idough comprise predominantly of mafic and felsic volcanic rocks, which do not provide the vugs and voids considered to be prospective habitat.

Figure 4-16
Coverage of Previous Subterranean Fauna Surveys Undertaken over the Development Envelope



LEGEND

Development Envelope

Previous Subterrenean Fauna Surveys

- Gold Fields, St Ives Gold Mines, Stygofauna Desktop Assessment, 2010
- Assessment of potential impacts of mining on stygofauna communities in the Athena Complex Project Area, 2009
- Idough Geology, 2011
- West Idough Deposit Subterranean Fauna Desktop Assessment,
- Gold Fields, St Ives Gold Mines, Troglofauna Desktop Assessment, 2010

0 3 6 9 12

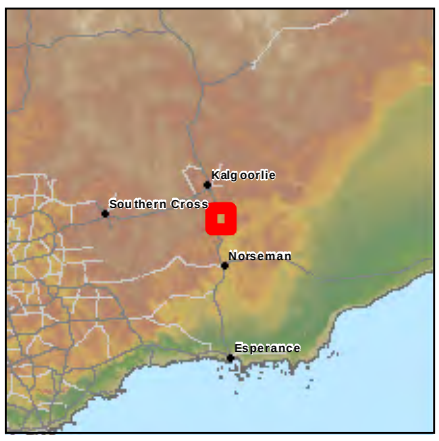
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	24/07/2018

LOCALITY MAP



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Two factors predominantly determine the presence of subterranean fauna, the vugginess of the geology and presence and quality (in particular salinity) of groundwater. Habitats likely to support troglofauna are karstic limestone, channel iron deposits (CIDs) (in particular pisolite in inverted landscape geomorphology), groundwater calcretes above the water table, alluvium/colluvium in valley-fill settings, BIFs and weathered and fractured sandstone. Stygofauna are likely where there are groundwater voids present, for example in karst limestone, calcretes, alluvial formations and fractured rock (EPA 2013).

4.4.3.3 Stygofauna

Stygofauna represent the fauna living within subterranean water bodies or aquifers (Humphreys 2000). They typically show similar traits to troglobites in their specialisation to subterranean life, including loss of body pigment, eyes and heightened mechano-sensory systems. Stygofauna are similarly termed to troglofauna:

- stygobites, that are restricted to subterranean habitats and usually perish on exposure to the surface environment
- stygophiles, which facultatively use subterranean habitats but are not reliant on them for survival (Humphreys 2008)
- stygoxenes, species inhabiting surface water which may also be able to freely move from surface to subterranean systems and back (Humphreys 2000).

Short-range endemic stygofauna are only represented by stygobitic species.

Data from the database searches and literature reviews showed no stygofauna records within approximately 100 km of the Development Envelope.

In WA, stygofauna invertebrates have mainly been recorded within the crustaceans and insects, in particular (but not limited to):

- crustaceans:
    - ostracods (Karanovic 2007; Reeves et al. 2007)
    - copepods (Karanovic et al. in press; Karanovic et al. 2013)
    - amphipods (Bradbury & Williams 1996a; Finston et al. 2007)
    - syncarids (Abrams et al. 2013)
    - isopods (Finston et al. 2009; Keable & Wilson 2006)
- insects:
    - beetles, in particular water beetles (Dytiscidae) (Cooper et al. 2002; Leys et al. 2003)
- oligochaetes (Pinder 2001)
- nematodes (i.e. Halse et al. 2014).

A number of factors contribute to the potential for stygofauna to occur, including sediment texture (chiefly related to hydraulic conductivity and correlated with size of pore spaces suitable for biota), hydraulic conductivity (controlling food and oxygen supply), depth from surface, water regime (timing, frequency, duration, extent and depth, and variability), energy (food) flow (in form of dissolved organic matter (DOM)), salinity (accepted upper tolerance approximately 70,000 mg/L TDS), dissolved oxygen (DO) and redox status of the groundwater (Subterranean Ecology 2010c).

Independent of all other factors, salinity appears to be the main limiting factor for the occurrence of stygofauna in the aquifers of the Development Envelope. The majority of non-marine stygofauna are intolerant to salinity. Most are found in freshwater (<3,000 mg/L TDS) but some will tolerate water with salinities above this level. Stygofauna have been collected in saline waters (3,000-70,000 mg/L TDS) in calcrete formations in the Yilgarn and Nullarbor regions of WA (Ecologia 2006; Humphreys 2008; Humphreys et al. 2004; Outback Ecology 2011c). The

EPA accepts that stygofauna in the Pilbara should be considered in salinities up to 60,000 mg/L TDS (EPA 2007). Please refer to Appendix K on further information on hydrogeology and potential for stygofauna habitat.

With groundwater salinities generally well over 70,000 mg/L throughout much of the Development Envelope (although lower salinities have been measured locally), it is extremely unlikely that stygofauna are present. This confirms previous assessments of an extremely low likelihood of stygofauna to occur in the Development Envelope (Outback Ecology 2009b; Outback Ecology 2011b; Subterranean Ecology 2010c).

4.4.3.4 Troglofauna

Troglofauna are typically divided into three categories of specialisation to subterranean life:

- troglobites, that are restricted to subterranean habitats and usually perish on exposure to the surface environment (Barr 1968; Howarth 1983; Humphreys 2000)
- troglophiles, which facultatively use subterranean habitats but are not reliant on them for survival (Barr 1968; Howarth 1983; Humphreys 2000)
- trogloxenes, which use subterranean systems for specific purposes, such as roosts for reproduction (bats and swiftlets).

Both troglobites and troglophiles may be SREs and are therefore potentially conservation significant.

In WA, troglofauna invertebrates have been recorded from several taxonomic groups, in particular:

- arachnids:
    - spiders (Araneae) (Baehr et al. 2012; Burger et al. 2010; Harvey 2001b; Platnick 2008)
    - short-tailed whipscorpions (Schizomida) (Abrams & Harvey 2015; Harvey 2001a; Harvey et al. 2008)
    - pseudoscorpions (Pseudoscorpiones) (Edward & Harvey 2008; Harms & Harvey 2013)
    - scorpions (Scorpiones, (Volschenk & Prendini 2008)
- palpigrades (Barranco & Harvey 2008)
- myriapods:
    - millipedes (Diplopoda): (Humphreys & Shear 1993; Shear & Humphreys 1996)
    - centipedes (i.e. Scolopendromorpha) (Edgecombe 2005)
- crustaceans:
    - isopods (Javidkar et al. 2016)
- insects:
    - cockroaches (Roth 1991)
    - beetles (Tian et al. 2016)
    - bugs (Hoch 1993).

A single potential troglofauna centipede was returned by the WA Museum database from just east of City of Kalgoorlie-Boulder; however, the poor condition of the specimen did not unambiguously confirm it as obligatory subterranean.

The Development Envelope lies within the Eastern Goldfields Province of the Yilgarn Craton, which essentially consists of a granite-greenstone terrane of Archaean age with linear, north-northwest trending belts of supracrustal volcanic and metasedimentary rocks and granite intrusions. The bedrock is overlaid by a variety of early Tertiary sedimentary rocks, extensively deposited in the Palaeodrainage system (now defined by Lake Lefroy), in which lacustrine and fluvial sedimentary rocks are overlain by marine deposits, which include bioclastic calcarenite and spongolitic siltstone (dated to Upper Eocene based on Foraminifera).

Troglofauna cannot survive in areas of permanently saturated aquifers, such as those in the palaeodrainage channels and neighbouring salt lakes and salt pans. With groundwater levels of possibly 30 m bgl, and lower in land-based parts of the Development Envelope (i.e. as shown at West Idough, but also at Mt Morgan borefield outside the Development Envelope), troglofauna may potentially occur above the permanently saturated aquifers within the bedrock, lower saprolite/saprock and possible Quaternary deposits if these are deep enough. The likelihood of occurrence of troglofauna here shifts to an assessment of the porosity and stability of the regolith, i.e. the outcropping Archaean bedrock, saprolite and saprock and Quaternary alluvial and colluvial sediments (e.g. Lawrance 2009).

Subterranean Ecology (Subterranean Ecology 2010c) provided an in-depth analysis of the potential of troglofauna occurring in the SIGMC tenements based on geology and hydrology. They concluded that troglofauna may only occur in the land-based Quaternary alluvial deposits, such as those represented in the south-east of the Development Envelope and the Quaternary deposits of the Lake Lefroy islands (Oyster and Coral). The findings from the investigations associated with the B2018 Project align with this land-based assessment except that the Lake Lefroy islands generally consist of unconsolidated quartz sand and gypsum, forming stable sand dunes of compacted substrate of little or no vugginess. Furthermore, these islands are generally centrally compressed containing clay pans that appear to be temporarily fully saturated. It is therefore unlikely that troglofauna can persist on these islands due to lack or limited extend of suitable geology and groundwater saturation. Please refer to Appendix K for further information on site geology and potential troglofauna habitat.

In summary, suitable habitat and troglofauna species may occur in the Quaternary alluvial deposits that reach into the south-east of the Development Envelope, and continue to a much larger extent beyond (Figure 4-17). Quaternary alluvials also occur, in very small pockets, in the north-west of the study area south of Kambalda (Figure 4-17); however, these deposits are likely to be too small to support viable populations of troglofauna and are therefore not considered to have a significant implication for the B2018 project.

4.4.4 Potential Impacts

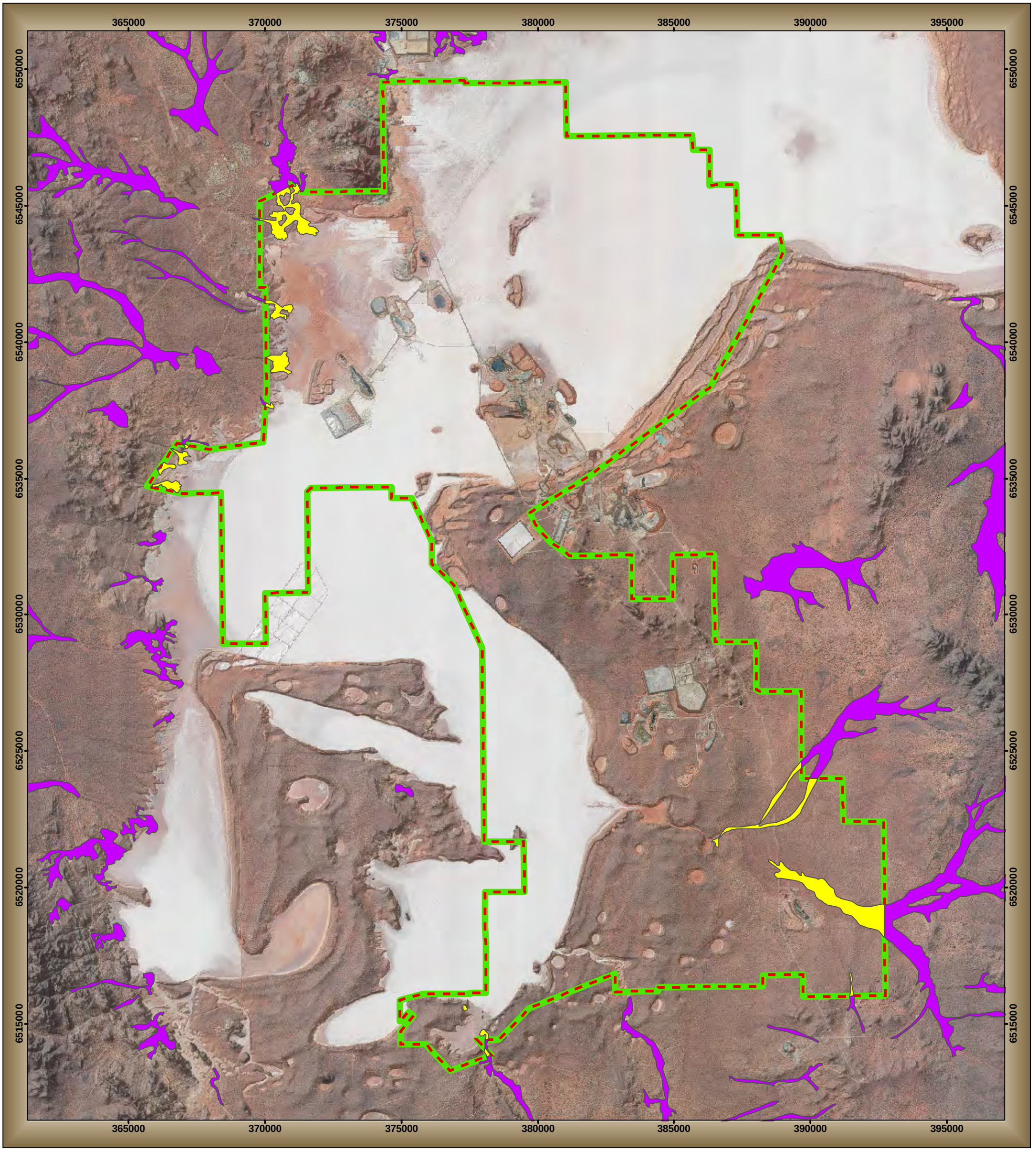
Subterranean fauna may be impacted as a result of loss of suitable habitat. There are commonly two key threatening processes from mining activities that impact subterranean fauna through the direct loss of habitat:

- Development of mine pits – the most obvious primary impact to subterranean habitats occurs as a result of their physical removal during mining. Troglofauna require air-filled void networks and most of this habitat exists in the overburden, which is typically destroyed during pit construction/excavation. Similarly, direct loss of stygofauna habitat may be caused by the removal of geological formations if any aquifers are associated with these formations; and
- Depletion of an aquifer leading to loss of stygofauna habitat – depletion of an aquifer that is identified as suitable for stygofauna represents a direct loss of stygofauna habitat. The significance of the impact is dependent on the depth of drawdown, the size and extent of the aquifer and the connectivity of the aquifer with adjacent habitat for stygofauna.

As identified by the surveys undertaken, the Development Envelope does not support stygofauna species as the groundwater is hypersaline throughout the area.

Troglofauna may occur in the Quaternary alluvial deposits that reach into the south-west of the Development Envelope, and to a lesser degree in the north-east of the Development Envelope (Figure 4-17). Removal of these sections may therefore result in some loss of potential habitat for troglofauna.

Figure 4-17
Potential Troglofauna Habitat



LEGEND

Development Envelope

Potential Troglofauna Habitat

Quaternary Alluvials (inside Development Envelope)

Quaternary Alluvials (outside Development Envelope)

0 3 6 9 12

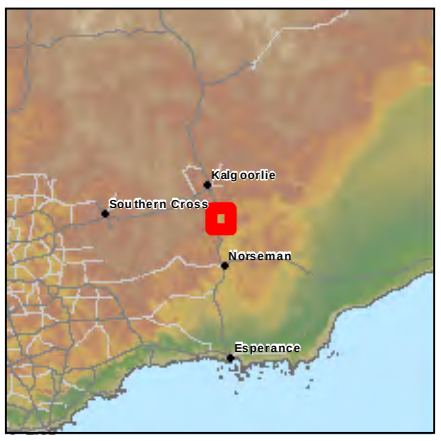
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	24/07/2018

LOCALITY MAP



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Other than loss of habitat through direct disturbance, the physicochemical properties of subterranean habitats may be indirectly affected. The nature of these changes can be difficult to measure and there is limited empirical evidence to support or refute these putative impacts. There are four secondary impacts that may potentially result in indirect impacts to troglofauna and stygofauna which are relevant to the Project:

- Depletion of an aquifer leading to altered relative humidity – Troglofauna are dependent on high relative humidity (Barr 1968; Humphreys 1991; Humphreys 2000). Dewatering may impact troglofauna habitat in unsaturated strata above the water table by lowering relative humidity.
- Nutrient starvation – surface vegetation is the primary source of nutrients entering subterranean systems. Large-scale clearing of vegetation may result in the localised nutrient starvation of underlying subterranean habitat. Smothering of these nutrient sources on which subterranean systems depend, in the form of waste and overburden stockpiles and tailings ponds, may reduce inflow of nutrients to subterranean systems and lead to nutrient deficient habitats (Howarth 1993; Humphreys 2000; Poulson & Lavoie 2000).
- Vibration – shock waves through subterranean strata from blasting or heavy vehicle traffic may result in the collapse of less-consolidated void spaces and also impact physically on subterranean fauna. There is little data to challenge or corroborate these observations and impacts may generally be localised rather than critically threatening.
- Contamination: contamination of subterranean habitats from spills, such as diesel fuel, AMD or from seepage from infrastructure (such as TSFs) may degrade the quality of subterranean habitats. Such impacts would generally be highly localised and minor in scale; however, major contamination of subterranean habitats may have significant impacts.

4.4.5 Assessment of Impacts

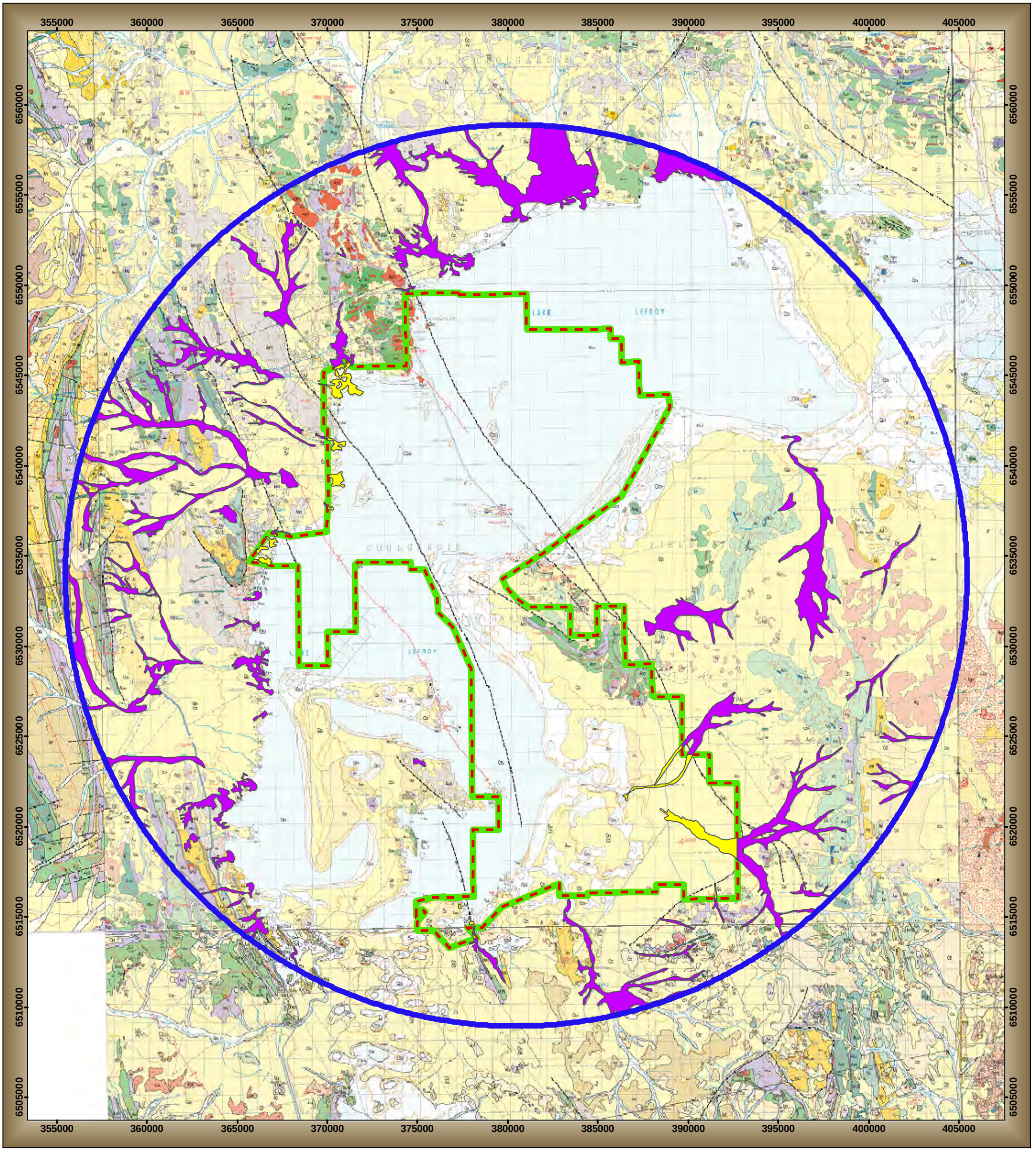
The Proposal is not likely to have an impact on particular environmental values of subterranean fauna as defined in the EPA's factor guideline for subterranean fauna (EPA 2016b). This is because the habitats that are prospective for subterranean fauna, as outlined in EPA (2013), are either absent from the Development Envelope or have a very restricted extent relative to habitat outside of the Development Envelope.

Based on the subterranean survey undertaken for the B2018 Project, it was concluded that no stygofauna habitat is present within the Development Envelope due to the hypersaline nature of the groundwater (Phoenix 2016b). Therefore, the B2018 Project is expected to have no impact on stygofauna.

Potential troglofauna habitat was further defined to exclude the Lake Lefroy islands but to include parts of the Development Envelope where Quaternary alluvial deposits are present (Phoenix 2016b). While the Development Envelope has been extensively mined over the years, to date only a small part of the Quaternary alluvial deposits (less than 20 ha) has been disturbed as a result of the St Ives operations. This disturbance has predominantly been for exploration activities or the development of transport or infrastructure corridors and as such is not considered to have had an impact on potential troglofauna habitat. As such, potential impacts on troglofauna to date are considered to be negligible.

SIGMC assessed the extent of Quaternary alluvial deposits within the Development Envelope compared with a 25 km radius of the Project (Figure 4-18). Given the relatively small portion of Quaternary alluvial deposits in the Development Envelope (632 ha or 5.7%) when compared to the broader area (11,146 ha within the 25 km radius), the predicted impacts to troglofauna from the Project are considered negligible.

Figure 4-18
Extent of Potential Troglofauna Habitat Within a 25km Radius of the Lefroy Mill



LEGEND

Development Envelope

Potential Troglofauna Habitat

Quaternary Alluvials (inside Development Envelope)

Quaternary Alluvials (outside Development Envelope)

0 4.5 9 13.5 18

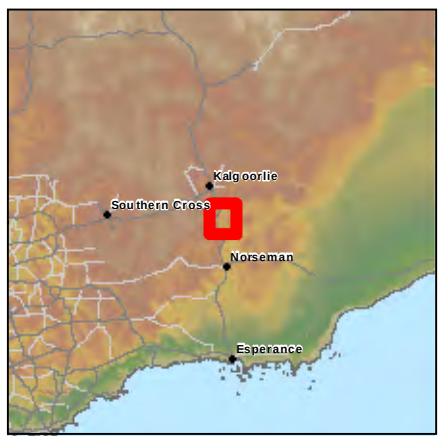
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	24/07/2018

LOCALITY MAP



Document Path: \\server\talis\SECTIONS\Environment\Projects\TE2016\TE16034 - SIGM B2018 EPA Process\10. GIS\Maps\ERD_Mapping\TE16034_ERD_4-18_TroglofaunaHabitatOverview_RevA.mxd

In considering cumulative impacts, given the widespread occurrence of Quaternary alluvial deposits in the region and the relatively small footprint from other mining activities in the region, any cumulative impacts on troglofauna are also considered negligible.

4.4.6 Mitigation

No specific mitigation measures are proposed.

4.4.7 Predicted Outcome

SIGMC considers that EPA's objective for Subterranean Fauna to '*protect subterranean fauna so that biological diversity and ecological integrity are maintained.*' can be readily achieved. The following outcomes are predicted:

- No known populations of stygofauna within the Development Envelope and no known potential habitat; and
- No known populations of troglofauna within the Development Envelope. Very limited occurrence of one potential troglofauna habitat within the Development Envelope but the habitat is widespread outside the Development Envelope.

The residual impact is not considered significant and no offsets are considered to be required.

4.5 Hydrological Processes

4.5.1 EPA Objective

The EPA's environmental objective for the factor Hydrological Processes is:

To maintain the hydrological regimes of groundwater and surface water so that environmental values are protected.

4.5.2 Policy and Guidance

The following policies and guidelines apply to Hydrological Processes:

- EPA Environmental Factor Guideline - Hydrological Processes (EPA 2016a);
- DoW - Operational policy no. 1.02 - Policy on water conservation/efficiency plans (DoW 2009a);
- DoW - Operational policy no. 5.12 - Hydrogeological reporting associated with a groundwater well licence (DoW 2009b);
- DoW - Western Australian water in mining guidelines (DoW 2013); and
- Australian Groundwater Modelling Guidelines (Australian Government National Water Commission 2012).

4.5.3 Receiving Environment

4.5.3.1 Hydrology of Lake Lefroy

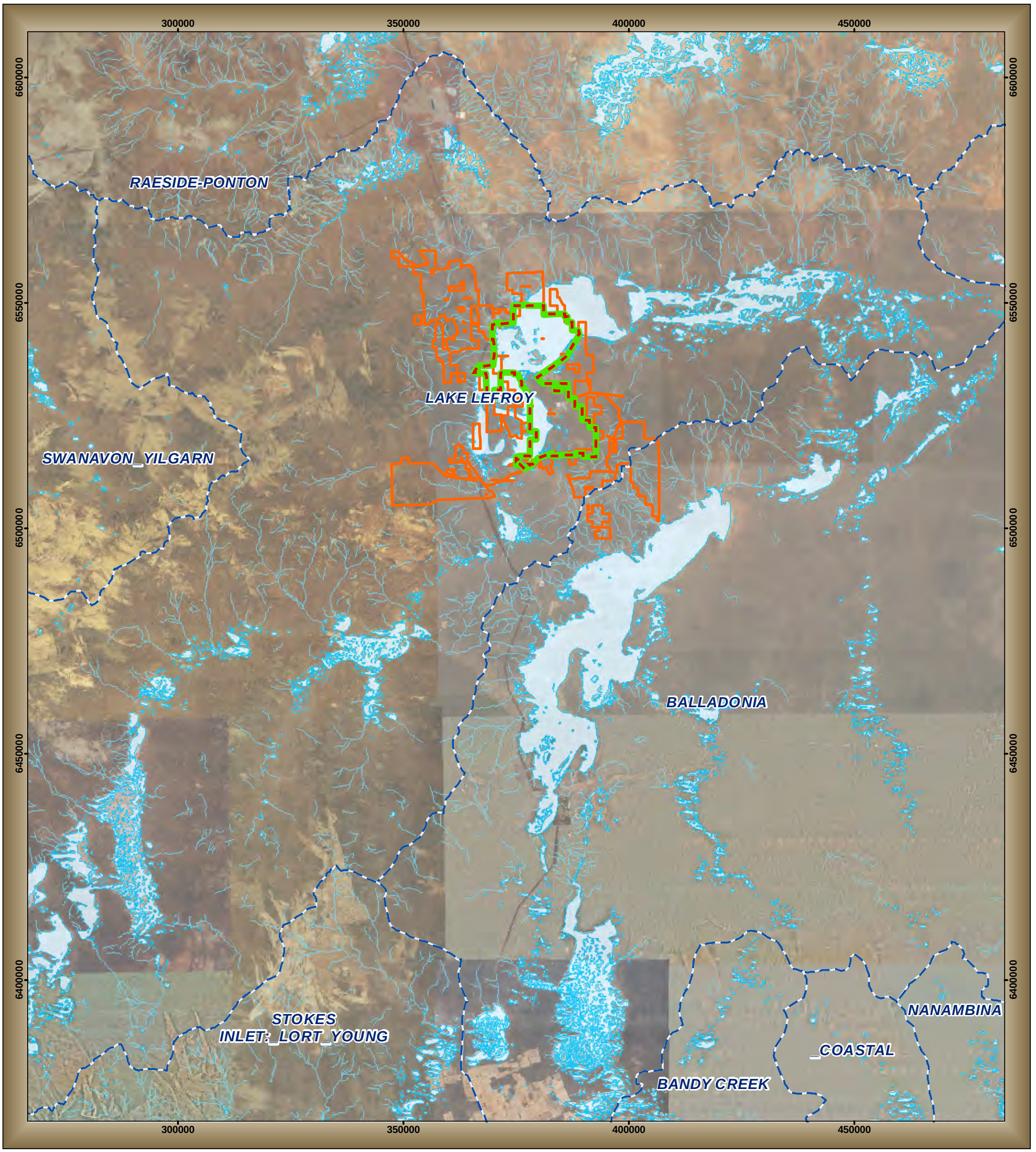
Lake Lefroy is a playa lake which has developed within the Roe palaeodrainage system and is located within the Lake Lefroy catchment (Figure 4-19), which is approximately 3,950 km^2 in size (Clarke 1991). The lake is the main receptor in the region and covers an estimated area of 554 km^2. The lake appears to be a system in transition between an ephemeral lake and a salt pan, with increased build-up of salts occurring via natural processes (Clarke 1994a), as well as salts from groundwater discharged onto the lake surface.

The regional topography is low to gently undulating, with plains rising from around 286 m AHD at Lake Lefroy to in excess of 410 m AHD at the catchment divide surrounding the lake. The surrounding catchments drain via ephemeral gullies and drainage lines, trending towards Lake Lefroy. Channels are generally poorly defined, with runoff largely occurring as sheet flow. Surface runoff is only generated in response to significant rainfall.

While the surface of Lake Lefroy varies in bathymetry over a large area, the playa is generally of low relief, at approximately 286 m AHD. There are two shallow-water accumulation areas in the northeast and central southern areas. The northern half of the lake has slightly higher elevations compared to the southern half. Rainfall typically generates minimal lake surface flows, with runoff tending to infiltrate terrestrial soils, prior to entering the playa (Handley 1991, MWH 2016b). The high infiltration capacity of the lake sediments, coupled with high evaporation rates, also generally contributes to the limited residency time of surface waters (URS 2010b).

Lake Lefroy is the major surface waterbody within the SIGMC operational area, and is surrounded by numerous ephemeral drainage channels and creeklines (Figure 4-19). The hydrology of the lake has been substantially altered through the construction of the primary causeway, built in the late 1960s (SIGM 2010). The causeway bisects the centre of the lake and is used for access, mining and exploration. The construction of the causeway has caused substantial hydrological changes to the lake, particularly to the flow regime during major flood events.

Figure 4-19
Lake Lefroy Regional Hydrology



LEGEND

- Development Envelope
- St Ives Tenements
- Catchment Divide
- Major Watercourse
- Lakes

0 10 20 30 40

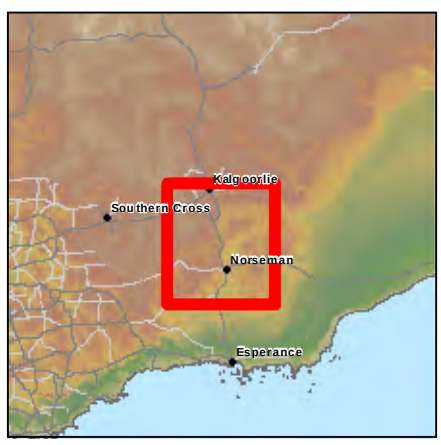
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	24/07/2018

LOCALITY MAP



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Due to its large size Lake Lefroy can accommodate major inflows and, while rare, is subject to major flooding events, often attributed to ex-tropical cyclones causing heavy rainfall during summer. In these instances, flooding occurs rapidly, and surface waters may remain in the lake for long periods (CSIRO Land and Water 2003). This was demonstrated after ex-tropical cyclones Vance in March 1999 and Steve in February and March 2000, which led to the persistence of surface waters in the lake for approximately nine months (MWH 2016b). Resultant from local storm activity, the last significant flooding of Lake Lefroy occurred in 2014 when more than 150 mm of rain was received over a three day period in late January (BOM 2015a).

During flooding, the lake exhibits substantial fluctuations in water depth and movement, due to its shallow nature and the action of prevailing winds (Clarke 1994b). In addition, due to substantial spatial variability in rainfall, the bathymetry of the playa, and the location of existing mining infrastructure, the lake does not necessarily fill in its entirety (Clarke 1991; CSIRO Land and Water 2003). There is also no evidence that delayed drainage to Lake Lefroy occurs from the surrounding catchment for a prolonged period after large rainfall events (CSIRO Land and Water 2003).

4.5.3.2 Hydrogeology of Lake Lefroy and surrounds

Fractured rock aquifers occupy the greater part of the Kalgoorlie area, generally containing only minor groundwater supplies, which can be difficult to locate. Fresh groundwater does not occur in the region, but some brackish groundwater exists in the upper reaches of some catchments. The regional water table ranges from less than 1 m bgl, beneath and adjacent to Lake Lefroy, to more than 50 m bgl in elevated areas. External recharge is restricted, occurring only during heavy rainfall, in areas containing outcrops of bedrock (Kern 1995). Recharge from the playa into underlying lacustrine sediments occurs, some of which is assumed to enter the palaeodrainage aquifer; however, regional hydraulic gradients are low within the palaeodrainage. Natural groundwater discharge occurs from the playa via evaporation (Kern 1995).

Groundwater quality in the vicinity of Lake Lefroy ranges between 274,000 and 423,000 mg/L TDS. Metal concentrations in groundwater are reflective of the mineralogy in the region. Groundwater typically occurs in limited quantities at a depth between 15-30 m bgl (URS 2010a), with the natural groundwater flow being towards the Lefroy Palaeodrainage. Aquifer types identified within the local region include:

- superficial playa lake deposits;
- palaeochannel sediments (Tertiary alluvial channel sand sequence); and
- weathered and/or fractured bedrock.

Superficial playa lake deposits are encountered in all lake-based mining pits within the uppermost 2 m. They have been described informally by Clarke (1993) as the Roysalt Formation comprising evaporative sediments with bedded gypsiferous sands and silts capped with an ephemeral halite crust on the lake floor.

This unit is responsible for groundwater inflows and seepages near the rims of the pits, usually leaving streaks of gypsum on the walls. The groundwater from all sites near Lake Lefroy is saturated with gypsum, with encrustations of this mineral evident wherever it is released from pipelines or seeps from pit walls.

Palaeochannel sediments are confined to channels. Typically, this unit comprises bedded fine to very coarse (sometimes gravelly) quartz sand that is rarely lithified and is often free-flowing in drillholes intersecting it.

The remaining aquifer type - weathered and fractured bedrock - is the most varied with respect to hydraulic properties. These properties are dependent on structural integrity, degree of weathering, depth, and lithology. Groundwater in this zone is present in sub-vertical, disconnected fractured rock aquifers resulting from structural movements along the many faults in the area; and the intrusion and damming action of porphyry and doleritic dykes.

All of the mining pits have intersected groundwater within the bedrock, generally in sheared and fractured rock zones associated with local and regional faults as well as the fractured intervals often well-developed in the weathered horizon. The long-term yields from this aquifer are strongly dependent on local variations of the key attributes described above and interconnection with recharge sources such as regional shears, weathered zones and overlying palaeochannel aquifers.

Simplified geological sections through the Project Area are presented in Figure 4-20 (Figure 3-3 from Appendix M). From the sections it is apparent that mining is centred on the Archaean bedrock which is partly or entirely overlain by Cenozoic sediments.

Groundwater recharge mechanisms vary from direct rainfall infiltration to enhanced creek (or drainage) line infiltration. Regional values of recharge rates typical for this region do not exceed more than 1 to 3% of annual rainfall. Presence of clays in the saprolite-weathering zone in area where Archaean basement is close to the surface may locally prevent or delay infiltration of rainfall to the underlying fractured bedrock.

Groundwater abstraction on site is regulated by DWER via the two groundwater well licences (GWL) GWL No. 171060(2) and GWL No. 62505(9). The average annual abstraction during the 2010 to 2016 period was 9.3 GL/yr. The majority of the water is drawn from palaeochannel aquifers which intersect some of the high water-yielding mining pits. There are no other downstream licensed users of groundwater.

Virtually all abstracted groundwater is discharged onto Lake Lefroy. A small part of dewatering discharge (less than 1%) is used for dust suppression. Saline groundwater has been discharged to Lake Lefroy since 1965, prior to the establishment of SIGMC (SIGM 2010). Dewatering discharge from SIGMC to the lake is believed to have commenced between 1980 and 1981, during initial development of the Victory-Leviathan gold deposits by WMC Resources.

Dewatering is undertaken through sumps; either within open pits, or from key points within underground operations. The sumps are used to allow settlement of sediments. SIGMC has approval to discharge from up to 18 lake-based points (Table 4-39) with a number of other discharge points proposed. Discharge occurs via a turkey nest lined with geotextile to remove any sediments remaining after the initial settlement phase (Plate 4-1; also see Figure 2-1). The dewatering regime is dynamic, and the discharge location varies dependent on operational requirements.

Plate 4-1: Example of a turkey nest on Lake Lefroy used for removal of sediments

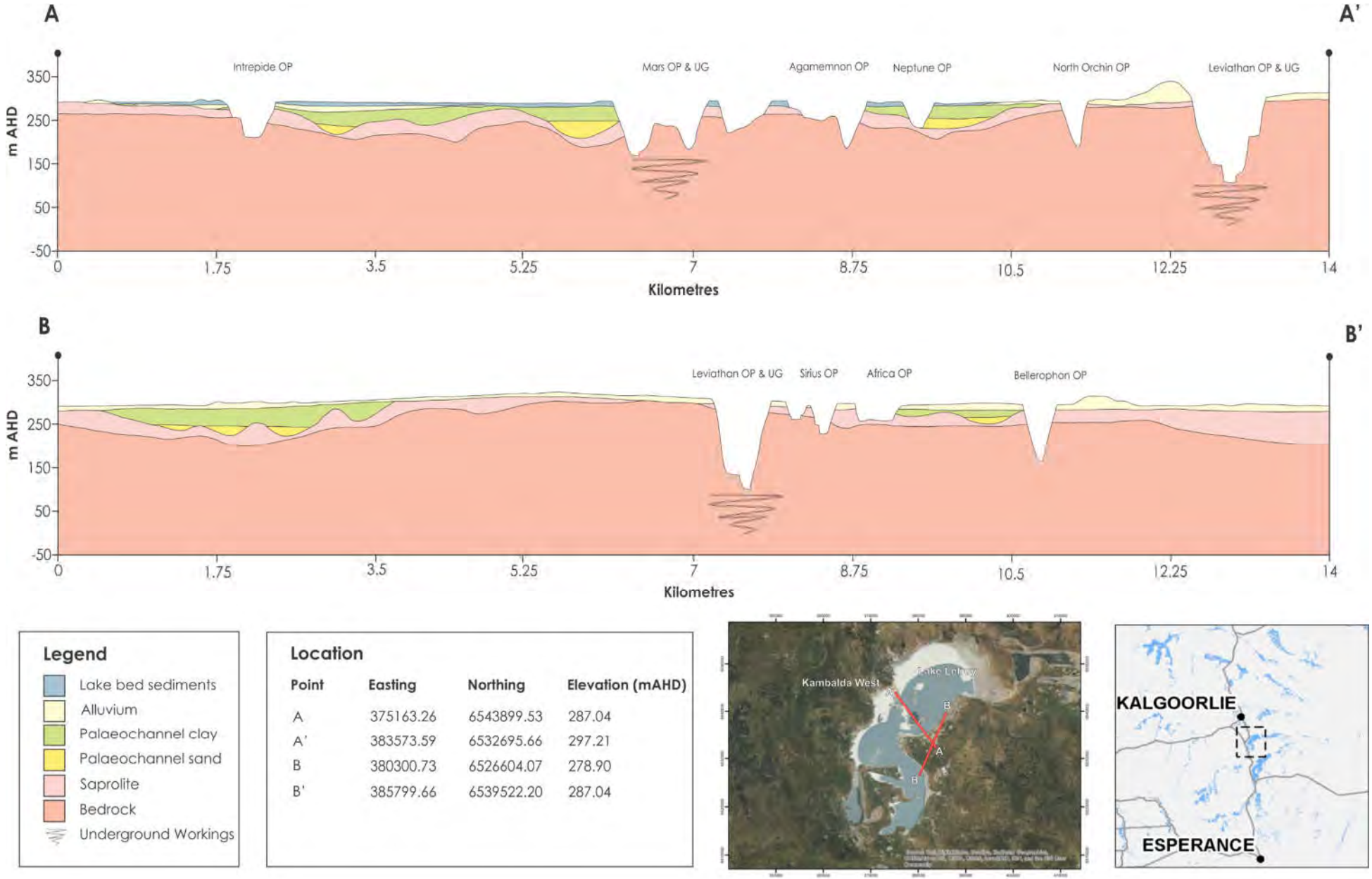


Figure 4-20: Lake Lefroy – simplified cross section of key hydrogeological units

Table 4-39: List of DWER-Approved and Historic Dewatering Discharge Point Locations and their SIGMC Operational Status (as at November 2017)

Dewatering Discharge Point	Approved by DWER	Discharge Infrastructure	Discharge Point Location Code	SIGMC Operational Status	Easting	Northing	Last Discharge Activity
Apollo Pit	Yes	In-pit	n/a	Active	384258	6526172	(current)
Cave Rocks	Yes	Turkeys Nest	W1	Active	370383	6543862	(current)
Revenge (GRA)	Yes	Turkeys Nest	W4	Active	380760	6537685	(current)
Leviathan (new)	Yes	Turkeys Nest	W5 (new location)	Active	382365	6536401	(current)
Invincible (a)	Yes	Turkeys Nest	W10	Active	375186	6539910	(current)
Temeraire Pit	Yes	In-pit	W12	Active	375462	6544150	(current)
Argo Pit	Yes	In-pit	n/a	Inactive	383769	6525727	TBA
Belleisle	Yes	Turkeys Nest	W3	Inactive	379695	6539462	Jul-14
Thunderer	Yes	Turkeys Nest	W6	Inactive	381387	6535703	Sep-10
Africa Pit	Yes	In-pit	W7	Inactive	383731	6534676	Dec-12
Argo Hydroslide	Yes	Turkeys Nest	W8	Inactive	381865	6526528	Apr-14
Santa Ana	Yes	Turkeys Nest	W9	Inactive	374766	6540530	Sep-15
Bahama-Santa Ana	Yes	Turkeys Nest	W11	Inactive	375273	6539964	Jun-15
Revenge (b)	Yes	Turkeys Nest	W16	Inactive	380860	6537626	TBA
Revenge Pit	Yes	In-pit	n/a	Inactive	379895	6529076	TBA
Intrepide Pit	Yes	In-pit	n/a	Inactive	376250	6541585	TBA
Leviathan (old)	No	Lake via channels	W5 (old location)	Inactive	382360	6536194	TBA ~mid 2000's
Foster (historic)	No	Lake	n/a	Inactive (historic)	379895	6529076	1990s
GRA	Yes	Turkeys Nest	W20	Inactive (historic)	378927	6539780	TBA
Junction	Yes	Creekline	W21	Inactive (historic)	381779	6517712	Late 1990s
Intrepide A	Yes	Turkeys Nest	W2	TBC	376311	6541171	Planned
Invincible (b)	Yes	Turkeys Nest	W18	TBC	374347	6538618	Planned
Foster (new)	Yes	Lake	W14	TBC	379352	6529491	Planned
Intrepide B	Yes	TBD	W13	TBC	376553	6542656	Planned

Dewatering Discharge Point	Approved by DWER	Discharge Infrastructure	Discharge Point Location Code	SIGMC Operational Status	Easting	Northing	Last Discharge Activity
Pistol Club	Yes	TBD	W15	TBC	373801	6543615	Planned
Grinder	Yes	TBD	W17	TBC	381330	6537054	Planned
Incredible	Yes	TBD	W19	TBC	380116	6523988	Planned

TBC = to be constructed

4.5.3.3 Overview of Hydrological and Hydrogeological Assessments

A comparatively extensive body of literature on hydrological and hydrogeological aspects of Lake Lefroy is available. In a regional context, Lake Lefroy is by far the most well documented hydrological case study of a salt lake system.

Earlier hydrological and hydrogeological assessments undertaken between 1991 and 2016 over the Development Envelope and reviewed as part of the B2018 Project are contained in Table 4-40.

The following sections detail the surface and groundwater modelling undertaken to inform the EIA for the B2018 Project. Both models were run over an indicative mining plan which considers proposed operations in the context of a maximum proposed disturbance of up to 2,000 ha on lake and up to 3,000 ha on land and utilises the 'template' design of selected current operations as an example for proposed operations (see Figure 4-21). The mine layout shown in this figure is for modelling purposes only – the precise location of mines in the B2018 Project is yet to be determined.

4.5.3.4 Surface Water Modelling

Stantec undertook surface water modelling to assess the surface water impacts from the B2018 project (Stantec 2017b). The primary objective of the surface water assessment was to simulate the potential impact to the Lake Lefroy riparian vegetation due to the proposed B2018 dewatering discharge by comparing water levels and vegetation inundation depths under different rainfall and discharge scenarios.

The modelling was undertaken using a 2-dimensional TUFLOW model (WBM 2016). Precipitation events of 20-year and 100-year average recurrence interval (ARI) with 72-hour duration were introduced into the hydraulic model as direct rainfall. Previous hydraulic models developed by URS in 2010 and 2013 were compiled and selected runs were tested to confirm prior results with updated versions of the TUFLOW model.

For the purposes of this assessment, the present day discharge volume scenario was assumed to be 6.8 GL/year based on the current discharge volumes. Sensitivity analysis included a no-dewatering scenario, as well as a maximum dewatering discharge of 60 GL/year, a discharge volume which was considered to potentially have an impact on the riparian section of the lake. The maximum discharge scenario was also used to assess potential impacts on modelled water levels east and west of the causeway, by introducing a number of culverts to allow east to west flow connection. A summary of the modelled scenarios is provided in Table 4-41.

4.5.3.5 Salt Balance Model

The surface water modelling report (Appendix L) also addresses the lake's salt balance. A spreadsheet-based monthly water and salt balance model was developed by Stantec (2017b) in order to qualitatively assess potential impacts of dewatering discharge and causeways on the salt balance of Lake Lefroy. The focus of the model is on potential change over time, providing a means for comparing potential impacts, rather than absolute values.

The calculations were based on water quality, salt loads and salinity assumptions. Lake Lefroy was divided into 10 discrete segments based on the indicative B2018 footprints and causeways. The inputs for each segment of the lake included:

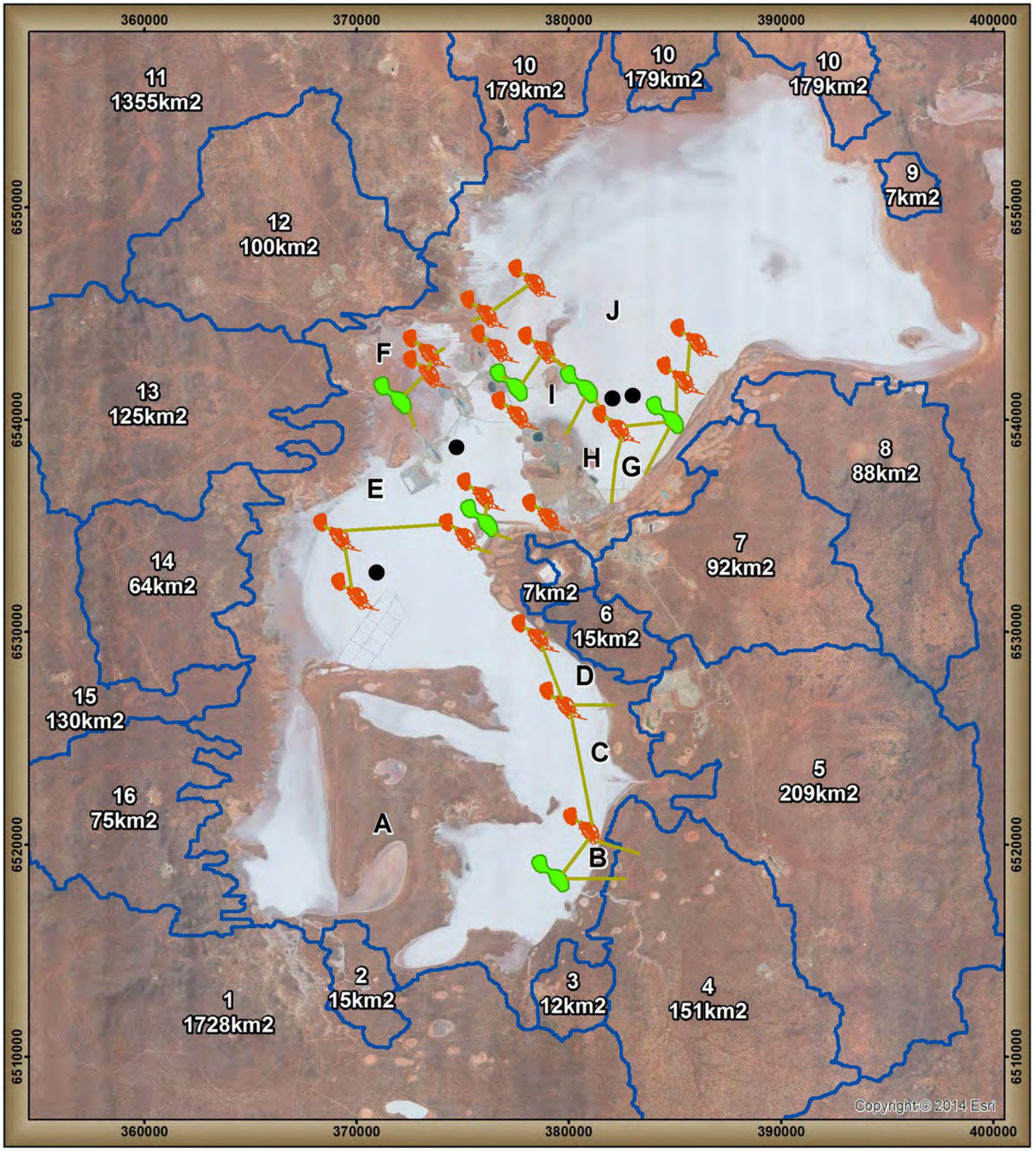
- Direct rainfall and assumed salinity concentration;
- Surface water runoff from external catchment draining into each segment and assumed salinity concentrations;
- Dewatering discharge and assumed concentration; and
- Evaporation losses.

Table 4-40: Hydrological and Hydrogeological Assessments Undertaken over the Development Envelope to 2016

Reference	Report Name	Assessment Type	Discharge Outfalls / Survey Sites	Sampling Components
Clarke (1991)	The hydrology, stratigraphy and history of Lake Lefroy	Hydrology / Hydrogeology / Bathymetry	Lake Lefroy	A summary of information relative to Lake Lefroy including climate, ecology. Physiography, hydrology, stratigraphy, evolution and economic significance.
CSIRO Land and Water (1999)	Lake Lefroy Hydrology Study - Literature Review	Hydrology	Lake Lefroy	Desktop review on literature available on the hydrology of Lake Lefroy.
CSIRO Land and Water (2001)	The Hydrology of Lake Lefroy. An interim report on progress to WMC St Ives Gold	Hydrology	Lake Lefroy	A progress report detailing the activities and outcomes of the study of Lake Lefroy between May 1999 and June 2000. Involves modelling of void water quantity and quality.
CSIRO Land and Water (2003)	Extension of Lake Lefroy Hydrological Program: A consultancy report to St Ives Gold Mining Company Pty Limited	Hydrology	Moorebar Creek, Railway, Lake Lefroy, Kalgoorlie-Boulder, Kalgoorlie-Bulong, Lefroy Causeway, Moorebar Dam, Revenge Pit, Orchin Pit	A summary of information related to Lake Lefroy lake levels, surface flows, catchment analysis and modelling of mine voids.
actis Environmental Services (2004)	Lake Lefroy Discharge Evaluation 2004	Hydrology	GRA, Gate House, South West, Junction	Desktop assessment to determine the likelihood that the proposed increases for dewatering, including current discharge volumes, would have a significant effect on the ecological function of Lake Lefroy.
Aquaterra (2008)	Proposed Tailings Storage Facility 4. Hydrogeological and hydrological Assessment Report	Hydrology / Hydrogeology	TSF4	Surface hydrology and hydrogeology assessment of the proposed TSF4 site.
URS Australia Pty Ltd (2010a)	Hydrogeological Assessment for Beyond 2010 Project	Hydrogeology	Beta Hunt, Temeraire, Intrepid/Santa Ana/Bahama, GRA, Thunderer, North Orchin/Pinnace, Leviathan/Victory, Argo, Junction	Hydrogeological assessment of the impacts of mine dewatering activities (including expansion) to support an application to increase the annual dewatering allocation to 30 GL/annum.

Reference	Report Name	Assessment Type	Discharge Outfalls / Survey Sites	Sampling Components
Palaris (2014b)	Lake Modelling Verification	Hydrology	Location K, Argo, Northwest Dune, Widji, Invincible	Verification of the existing flood model with raw field data following the January 2014 flood event. During 1:20 year ARI event, 5 crest gauges collect automated water level and salinity data. 312 riparian observation points are also established on the lake periphery. Qualitative analysis including photographs of crest gauge locations and photographs of the riparian zone to assess high water level marks.
URS Australia Pty Ltd (2010b)	Lake Lefroy Surface Water Impact Study	Hydrology	Argo, Belleisle, Beta Hunt, Leviathan, Revenge, Thunderer, Santa Ana	Desktop assessment and field study of potential impact of proposed mining activities on surface water levels and salinity levels of Lake Lefroy, as well as identifying areas where potential impacts on riparian vegetation zones may occur.
URS Australia Pty Ltd (2013b)	Invincible Mine Change Assessment on Lake Lefroy Hydrology	Hydrology	Invincible	An impact study of the Invincible mine on the Lake Lefroy hydrology including predicted change to lake water levels and water salinity.
URS Australia Pty Ltd (2014)	Invincible Dewatering Assessment, prepared for St Ives Gold Mining Company Pty Ltd, January 2014	Hydrogeology	Invincible	Quantification of the potential groundwater inflows to the proposed open pit, and subsequent dewatering requirements for the Project area.
Thorpe Groundwater and Environmental Services (2015)	St Ives Gold Mining Company 2014-2015 Groundwater Monitoring and Aquifer Review for Gold Fields Australia Limited	Hydrogeology	Groundwater licence management area	An annual monitoring and aquifer review for the period 1 July 2014 to 30 June 2015 to meet the groundwater licence requirements.
AQ2 (2016)	SIGM Expansion of Lake Based Operations – Surface Water Desktop Assessment	Hydrology	Delta Island South, Neptune Pit Expansion, Pistol Club, Pistol Club South, Trinidad, Invincible South and Incredible	Desktop surface water assessment on planned expansion on the lake based operation.

Figure 4-21
Lake Lefroy discretised segments based on indicative B2018 Project operations



Lake-Based Pit
Lake-Based Operations
External Catchments
Beyond 2018 Dewatering Locations
A Lake Segment

N

0 2.5 5
km

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Date: 5/10/2017
Compiled: Clare Thatcher
Drawn: rfeng
Name: SIGM_A4_SW_Sub_Catchments

SIGM LEASE LOCALITY MAP

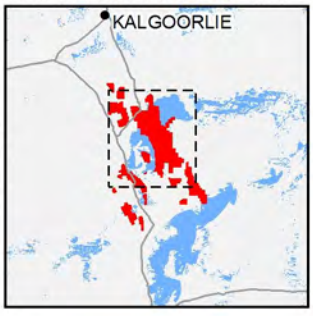


Table 4-41: Surface Water Modelling - Summary of Modelled Scenarios

Scenario Number	Description	Discharge Volume (GL/year)	Causeway	Design Rainfall event	Season	Evaporation (mm/hr)	Initial water level		Causeway Culverts
							East	West	
1	Present day	6.8	North-south only	100 yr	Summer	0.315	Dry	Dry	No
2				20 yr	Summer	0.315	Dry	Dry	No
3				100 yr	Winter	0.065	287.55	288.55	No
4				20 yr	Winter	0.065	287.55	288.55	No
5				100 yr	Winter	0.065	287.7	287.8	No
6	Maximum sensitivity	60	North-south only	20 yr	Winter	0.065	287.7	287.8	No
7				100 yr	Winter	0.065	287.55	288.55	No
8				20 yr	Winter	0.065	287.55	288.55	No
9				100 yr	Winter	0.065	287.7	287.8	No
10				20 yr	Winter	0.065	287.7	287.8	No
11				100 yr	Summer	0.315	Dry	Dry	No
12				20 yr	Summer	0.315	Dry	Dry	No
13				100 yr	Summer	0.315	Dry	Dry	Yes
14				100 yr	Winter	0.065	287.7	287.8	Yes
15	B2018	12.8	North-south + B2018	100 yr	Summer	0.315	Dry	Dry	No
16				20 yr	Summer	0.315	Dry	Dry	No
17				100 yr	Winter	0.065	287.7	287.8	No
18				20 yr	Winter	0.065	287.7	287.8	No
19				20 yr	Summer	0.315	Dry	Dry	Yes
20				100 yr	Winter	0.065	287.7	287.8	Yes (main causeway only)
21	No dewater	0	North-south only	100 yr	Winter	0.065	287.7	287.8	Yes, main causeway and proposed B2018 causeways
22				100 yr	Winter	0.065	Dry	Dry	No
23				20 yr	Summer	0.315	287.7	287.8	No
24	No dewater	0	North-south only	100 yr	Summer	0.315	Dry	Dry	No

The following assumptions were factored into the model:

- Indicative starting water levels of 0.1 m in all lake segments in order to set initial salt loads;
- Causeways contained no culverts to allow surface water flow between segments, i.e. both runoff and dewatering discharge volumes would be contained within the respective segments;
- A numerical groundwater model (Stantec 2017b) was developed to estimate potential volumes of discharge for the B2018 development period of 2017 to 2028. Historical monthly rainfall for the period 2004 to 2015 was used as proxy for the future rainfall. Rainfall from the same period was used for the balance calculations;
- The groundwater model was used to predict dewatering discharge volumes associated with the B2018 project and discharged onto the lake. These monthly volumes were used in the balance calculations;
- Dewatering discharge locations were assumed to be in the larger lake segments (segments A, E and J in Figure 4-21). Final discharge locations are yet to be determined and will be based on the mine footprint;
- The loss of salt due to aeolian transportation, as well as infiltration / leakage of surface water to the underlying aquifers, is minimal;
- The loss of water and salt to the subsurface is minimal or negligible due to the limited available storage (the groundwater level is close to the ground surface in the lake area);
- Change in salt load and concentration will be evenly spread throughout the various lake segments, i.e. results are averaged over the segment area and not limited to the extent of likely diffusion around the dewatering discharge location; and
- Depth of the salt crust varies throughout the lake. Limited information is available on the distribution of salt crust depths across the lake. This assessment focussed on potential increase in salt crust as a result of B2018 dewatering discharge volumes.

Salt load calculations were based on standard non-dynamic mass balance formulas.

4.5.3.6 Groundwater Modelling

Stantec undertook groundwater flow modelling to assess the various groundwater management impacts from the B2018 mining campaigns (Stantec 2017a). The objectives of the groundwater numerical modelling were to:

- Develop an operation-wide tool to simulate groundwater flow across the entire operational area incorporating the principal hydrogeological and mining features such as open pits;
- Ensure that the tool may be spatially refined in areas of interest in the future, to allow for evaluation of more detailed site-specific problems within the context of a sub-regional model;
- Simulate the potential impacts of dewatering (from mining) on groundwater flow and allow for understanding of key surface water groundwater interactions;
- Simulate the potential dewatering volumes that would be discharged onto Lake Lefroy and inform the surface water model of Lake Lefroy; and
- In combination with surface water model outputs, undertake a qualitative assessment of potential long term salinity impacts due to ongoing dewatering discharge to the lake.

The model was developed in accordance with the Australian modelling guideline (Barnett et al, 2012). The latest version of Modflow-USG v1.3 was used to construct the model, calibrate it and generate predictions scenarios for the current understanding of the B2018 working schedule.

The following key assumptions were incorporated into the model:

- The initial hydraulic parameters was based on the existing data, reports and experience with hydrogeological properties of the region; and
- As the geological structure for the model domain is fairly complex and heterogeneous in nature, for modelling purposes the lithology was simplified to inform parameter zone distribution.

Calibration of the model was performed using SIGMC data from 2011 to 2016; the period for which the most comprehensive monitoring data was available.

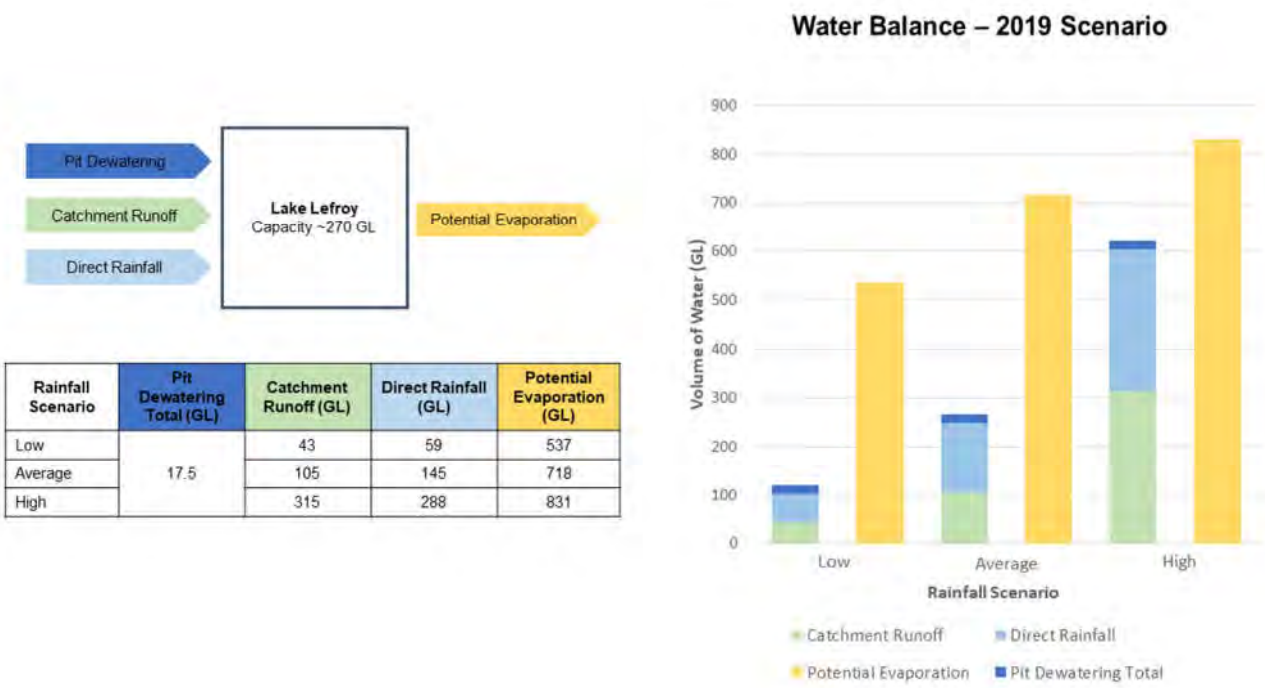
A sensitivity assessment was conducted to confirm key sensitive parameters. The assessment measured the magnitude of the sensitivity of all observations (water level monitoring data) to changes in particular model parameters such a hydraulic conductivity, storativity and recharge. Sensitivity runs suggest that hydraulic conductivity of the bedrock was the most sensitive parameter which is consistent with the fact that most of the mining pits and underground operations are situated in the Archaean bedrock lithology.

Predictive simulations were generated on the calibrated model for the proposed mining development and groundwater abstraction schedule. Estimates of dewatering rates were extracted from the predictive simulations and indicate that during 2019 to 2028 simulation period approximately 113 GL of groundwater will be extracted to support the dewatering regime of the current development scenario.

4.5.3.7 Site water balance

A water balance framework for the Project was compiled (Appendix N; Figure 4-22). The water balance compared the expected dewatering discharge in 2019 against a range of rainfall scenarios (low, average and high).

Figure 4-22: Site water balance under different rainfall scenarios



Rainfall Scenario	Pit Dewatering Total (GL)	Catchment Runoff (GL)	Direct Rainfall (GL)	Potential Evaporation (GL)
Low	17.5	43	59	537
Average		105	145	718
High		315	288	831

Under each rainfall scenario, the dewatering discharge was a relatively small component of the inputs to Lake Lefroy, and the proportional contribution decreased as rainfall increased. Under all three scenarios, evaporation was greater than inputs to the lake, more so under a low rainfall scenario. Potential pan evaporation was used, with a factor of 0.5 applied, to account for the effect of evaporation losses from the lake surface. For the lake to achieve a true water balance where inputs equal outputs, it is likely field evaporation values are lower still. Recharge to

groundwater may also be a factor but was not considered significant in the context of a basic water balance.

4.5.4 Potential Impacts

4.5.4.1 Dewatering discharge to Lake Lefroy – hydrology and water balance

Dewatering will be required to keep the mining voids and UG workings dry and safe. The mining operations associated with the B2018 Project will extract large volumes of water, mainly from bedrock and palaeochannel aquifers. The dewatered groundwater will necessitate an ongoing discharge onto the surface of Lake Lefroy through a number of discharge outfall points, the location of which will vary depending on operational circumstances. As a result, the water depth, lake hydroperiod and extent of inundation across the lake may increase when:

- Accompanied by a large rainfall event, and
- Additional haul roads and causeways constructed for the B2018 Project isolate parts of the lake surface and create smaller catchments.

While some plant species in the riparian zone are adapted to periodic inundation, an increase in the extent or duration of inundation has the potential to adversely affect riparian vegetation and other biota utilising this area. These species may include aquatic biota such as different algae, macrophytes and aquatic invertebrates and some SRE species that are known to burrow into lake sediments.

4.5.4.2 Dewatering discharge to Lake Lefroy – salt load and salt crust formation

Lake Lefroy has a naturally-occurring saline crust due to the action of evaporative forces over a long period of time. Discharge of saline groundwater in the past has increased the salt load on the surface of the lake and the discharge proposed in the B2018 Project will further increase the salt load. While the lake surface is devoid of vegetation, a significant expansion of the salt crust may:

- Adversely impact fauna that utilise the lake surface as habitat,
- Increase the salinity of lake water more rapidly following inundation from a rainfall event, potentially reducing the water quality during temporary inundation of riparian vegetation, and
- Increase the propensity for wind-blown salts to affect landforms surrounding the lake surface.

4.5.4.3 Groundwater drawdown or mounding

The operations have the potential to produce localised and temporary decline in groundwater levels around the dewatered voids and underground workings. While vegetation will not utilise the groundwater due to its high salinity, a reduction of groundwater levels may reduce availability to other potential users, should any occur.

Conversely, some of the mine's operations (e.g. TSF4, heap leach) have resulted in groundwater mounding (Stantec 2017a) originating from seepage from these facilities (although these facilities are not currently active). Groundwater mounding has the potential to enter the root zone of vegetation where it is likely to cause a decline in vegetation condition, although there is no evidence that this has occurred.

4.5.5 Assessment of Impacts

4.5.5.1 Overview of assessment

The Proposal is not likely to have an impact on significant environmental values supported by hydrological processes, as defined in the EPA's factor guideline for hydrological processes (EPA 2016a). However, impacts have been assessed on the basis that changes to Lake Lefroy resulting from discharge of the hypersaline product of pit dewatering have some potential to affect other environmental values e.g. riparian vegetation. The assessment has included groundwater impacts arising from the same activity and guidelines on modelling and reporting (Australian Government National Water Commission, 2012; Department of Water 2009b) have been utilised.

4.5.5.2 Dewatering discharge to Lake Lefroy – hydrology and water balance

Discharge of hypersaline water to Lake Lefroy has been occurring since 1965. Stantec (2017b) undertook surface water assessment for the B2018 Project to assess the likely outcome of a dewatering discharge as proposed in the B2018 Project under a range of rainfall scenarios.

Table 4-42 summarises the findings of the key modelling scenarios. The scenarios include various discharge strategies co-occurring with rainfall events of 20-year and 100-year ARI 72-hour duration. Rainfall events occurring in both winter, with low evaporation and some water already on the lake, and summer (high evaporation, dry lake surface) were also considered.

The model assessed whether inundation associated with particular rainfall events and discharge scenarios would reach certain 'vegetation points' around the lake edge. The vegetation points occur both east and west of the central causeway. This is significant as the causeway prevents movement of water from one side to the other.

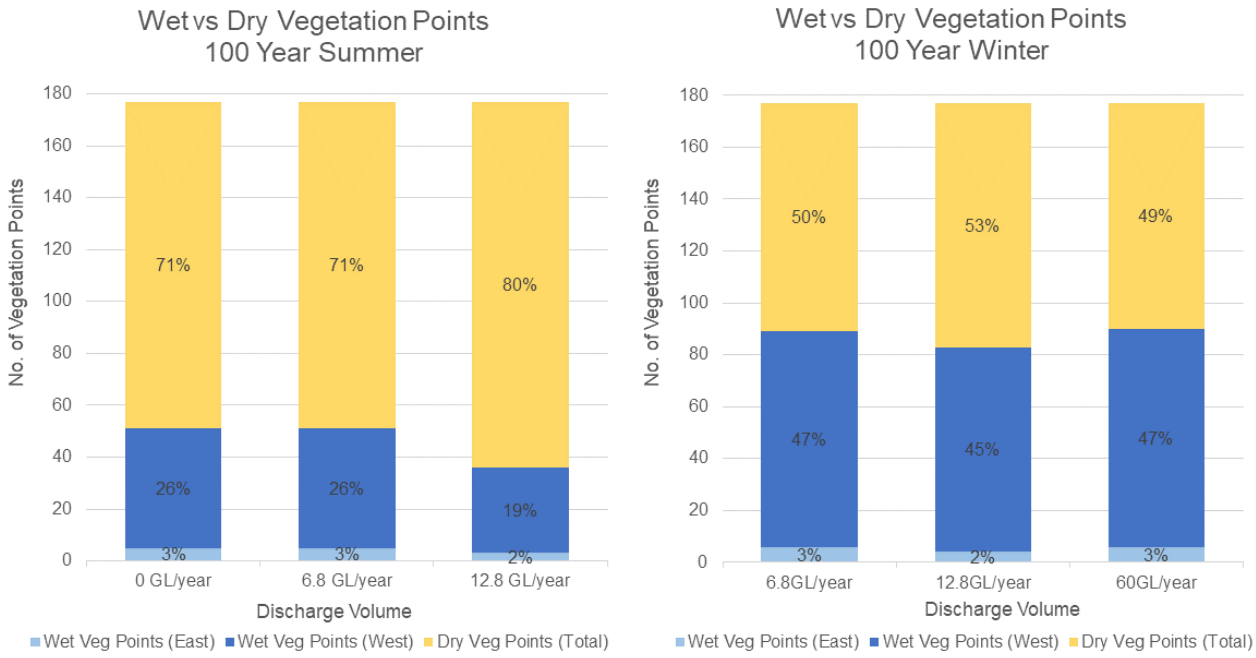
The graphs shown in Figure 4-23, based on the data in Table 4-42, highlight the main findings. The extent of lake inundation following a rainfall event is shown in:

- Figure 4-24: 100 year winter 72-hour ARI, 60 GL/year dewatering discharge
- Figure 4-25: 100 year winter 72-hour ARI, 12.8 GL/year dewatering discharge
- Figure 4-26: Comparison of flood extents for different events.

Table 4-42: Summary of Surface Model Results

Scenario Number	Description	Discharge Volume (GL/year)	Causeway	Design Rainfall event	Season	Causeway culverts	Initial water level		Wet Points	
							East	West	East	West
1	Present Day	6.8	North-south only	100 year	Summer	No	Dry	Dry	5	46
2				20 year	Summer	No	Dry	Dry	0	15
5				100 year	Winter	No	287.55	288.55	6	83
9	Maximum sensitivity	60	North-south only	100 year	Winter	No	287.7	287.8	6	84
10				20 year	Winter	No	287.7	287.8	0	23
14				100 year	Winter	Yes	287.7	287.8	5	124
15	B2018 maximum scenario	12.8	North-south +B2018	100 year	Summer	No	Dry	Dry	3	33
16				20 year	Summer	No	Dry	Dry	0	12
17				100 year	Winter	No	287.7	287.8	4	79
18				20 year	Winter	No	287.7	287.8	1	22
20				100 year	Winter	Yes	287.7	287.8	6	82
21				100 year	Winter	Yes	287.7	287.8	6	87
22				100 year	Winter	No	Dry	Dry	4	55
23				20year	Summer	No	287.7	287.8	0	17
24	No Dewater	0	North-south only	100 year	Summer	No	Dry	Dry	5	46

Figure 4-23: Key findings of surface water modelling



From Figure 4-23, when considering a summer 100 year 72-hour ARI rainfall event, there is little difference in the number of wet points either east or west of the causeway. It is noticeable that the number of wet vegetation points decreases slightly under the 12.8 GL/year scenario as a result of the new causeways constructed for the B2018 Project containing more direct rainfall and runoff around the mining areas. In considering a winter 100 year 72-hour ARI rainfall event, many more vegetation points are wet, compared with the summer equivalent. For this scenario the model assumed that some water would already be on the lake. However, there is little difference in the number of wet vegetation points across a range of discharge scenarios.

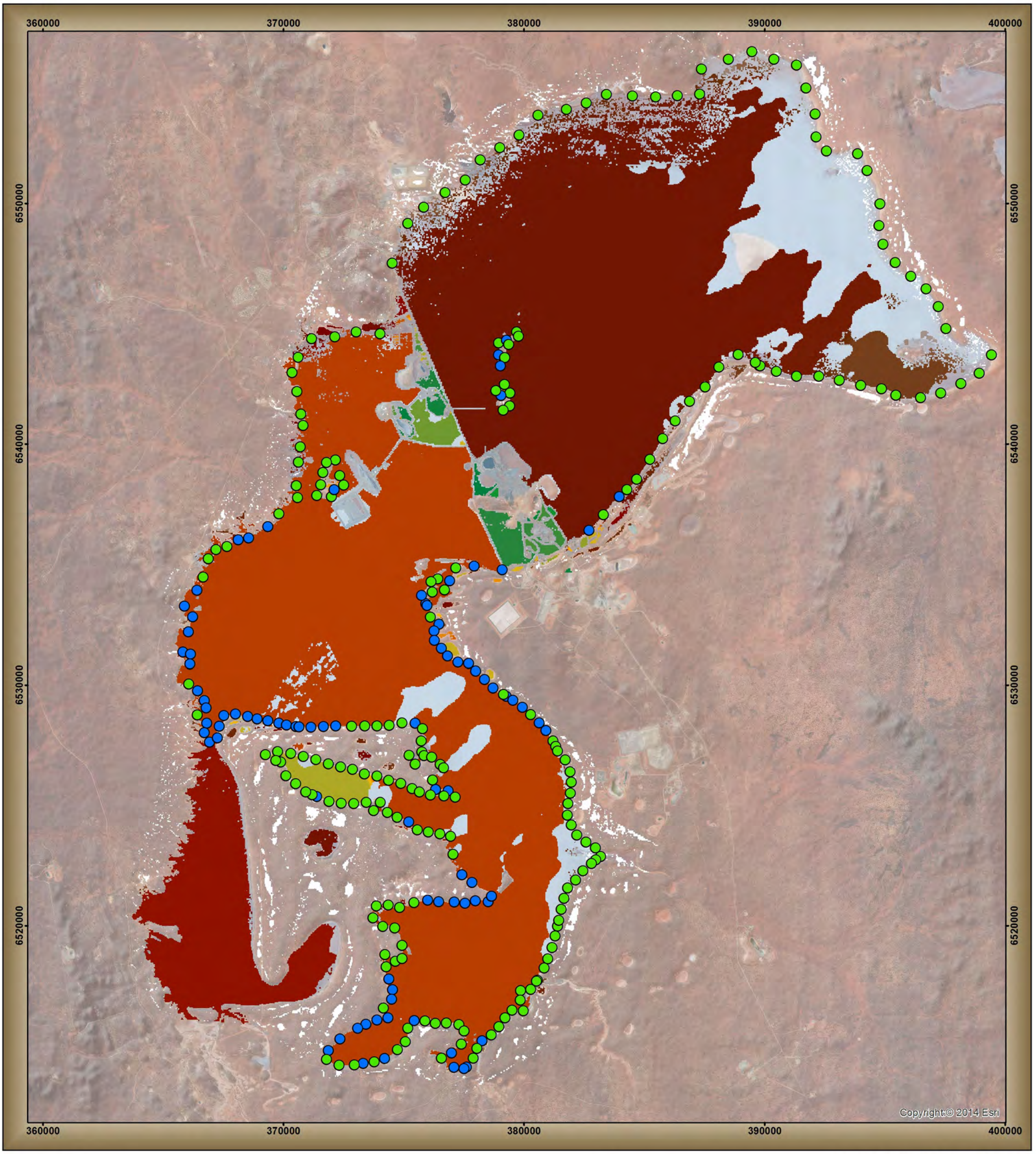
Figure 4-26 compares two different rainfall scenarios, highlighting the areas of the lake where water preferentially ponds – noticeably a single large area east of the causeway and a number of large areas of lower elevation on the western part of the lake.

The baseline hydroperiod of Lake Lefroy was previously estimated by URS (2010b) which reported a mean summer (74 days) and mean winter (265 days). Indicative present day hydroperiod estimates, based on the current model and a number of selected points east and west of the main causeway, were in the order of 100 days for summer and 270 days for winter, which are reasonably similar to the B2010 results (URS 2010b; Appendix L).

It can be concluded from the modelling that the dewatering discharge will have little impact on the extent of inundation of Lake Lefroy which is largely an effect of rainfall events. Previous lake bathymetry studies and flood inundation modelling undertaken by Clarke (1991) and URS (2010b) align with these findings.

With regard to water quality, the available data suggests that the salinity of water on the main body on Lake Lefroy does not go below 100,000 mg/L TDS, even when a significant rainfall event occurs (URS 2010b). Water quality in peripheral wetlands around the lake may be of lower salinity – see discussion in section 4.6.

Figure 4-24
100 year winter 72-hour ARI, 60 GL/year dewatering discharge



Vegetation Points
- Dry
- Wet

Flood Innundation Depth (m)
Value
High : 290
Low : 287

N

0 2.5 5
km

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Date: 19/10/2017
Compiled: Clare Thatcher
Drawn: rfeng
Name: SIGM_A3_SW_100yrWint

SIGM LEASE LOCALITY MAP

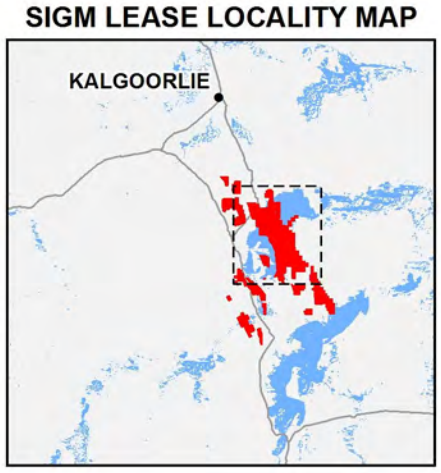
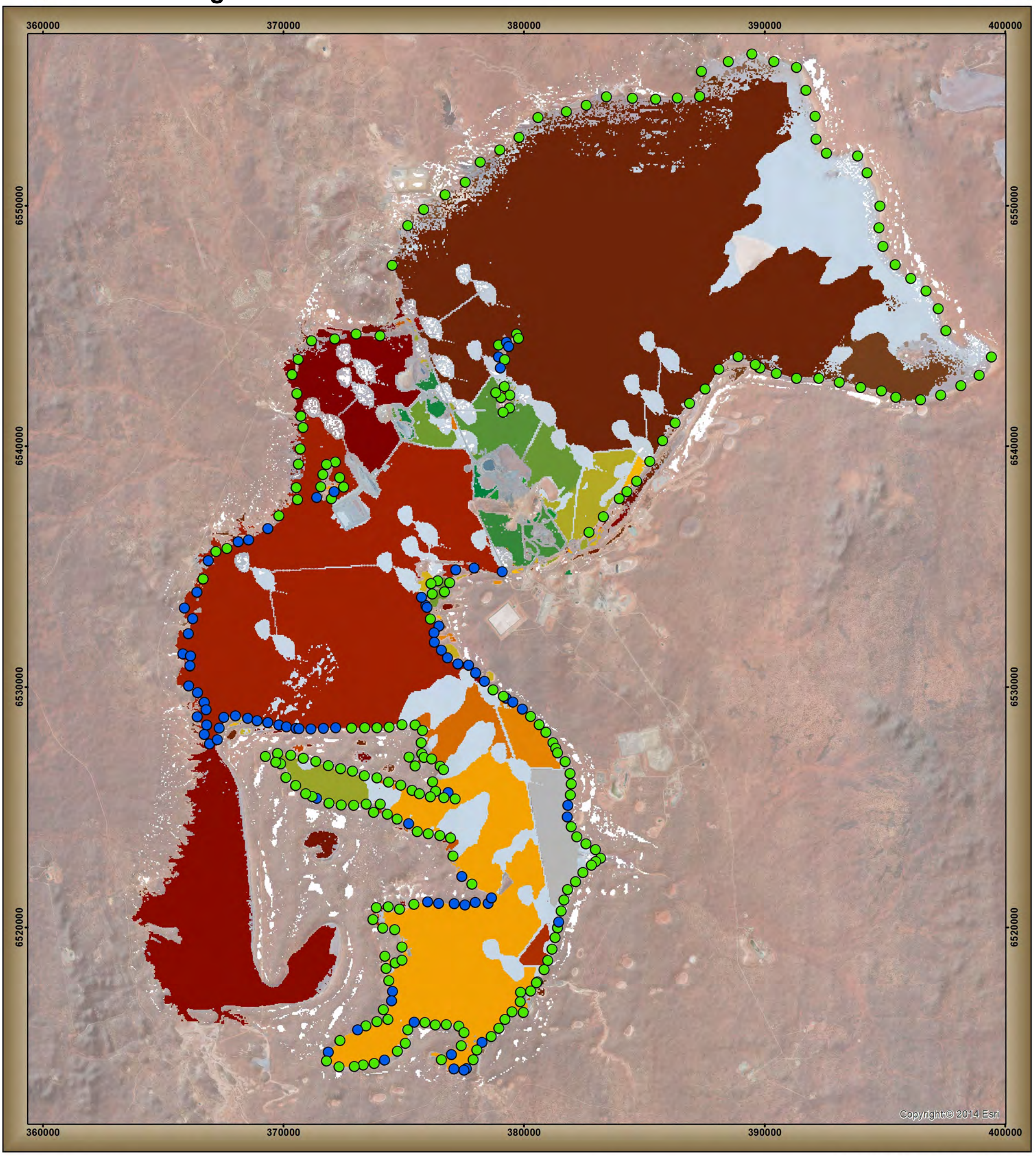


Figure 4-25
100 year winter event 72-hour ARI, 12.8 GL/year dewatering discharge



Vegetation Points
- Dry
- Wet

Flood Innundation Depth (m)
Value
High : 290
Low : 287

N

0 2.5 5
km

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Date: 23/10/2017
Compiled: Clare Thatcher
Drawn: rfeng
Name: SIGM_A3_SW_100yrWint_B2018

SIGM LEASE LOCALITY MAP

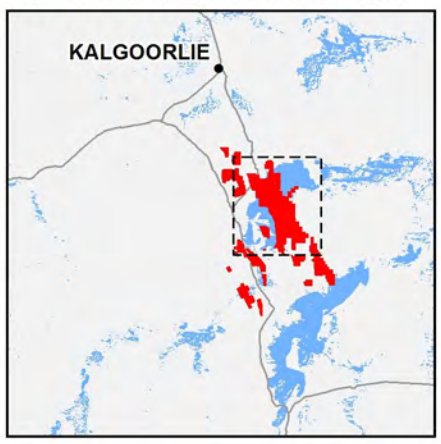
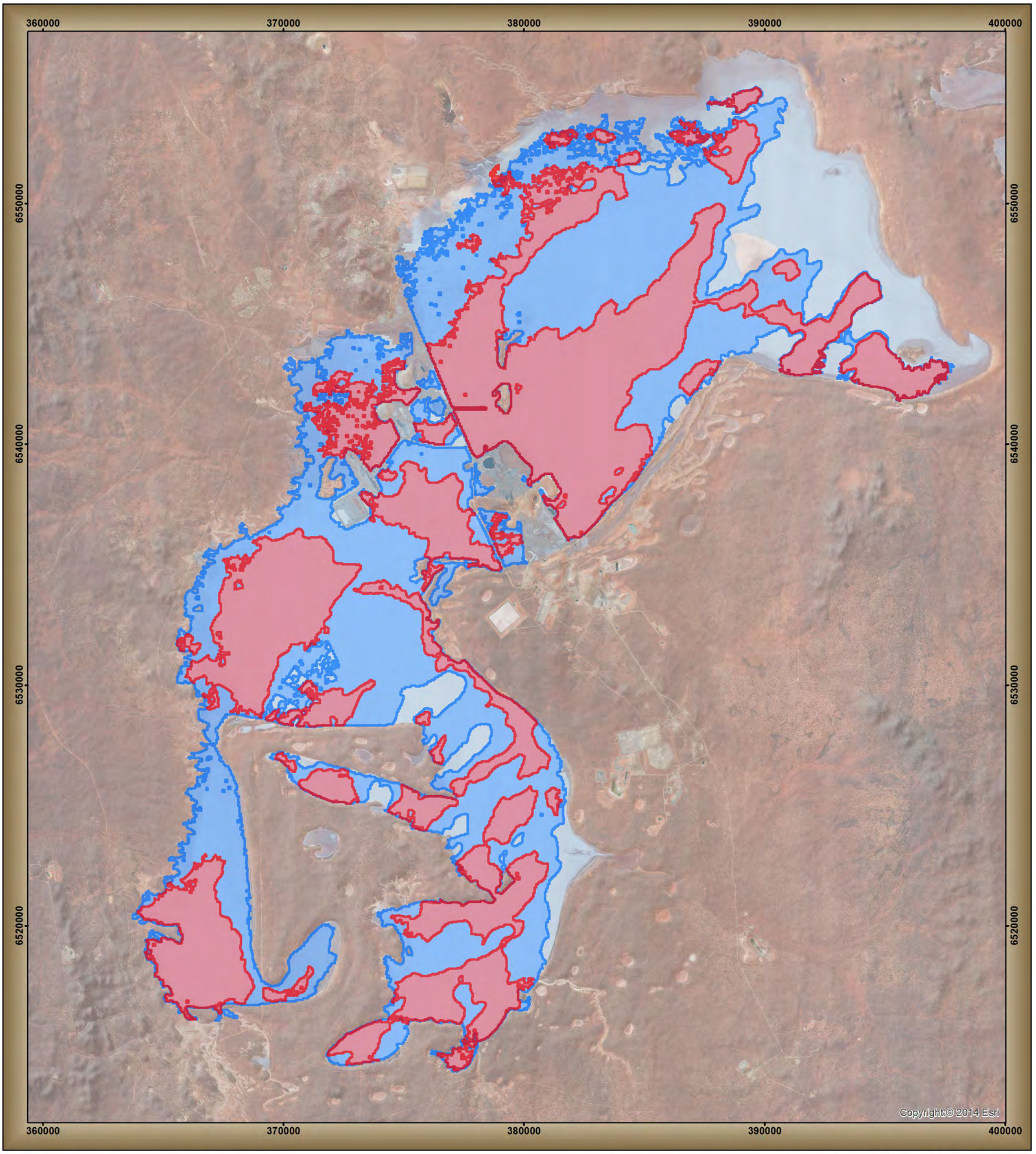


Figure 4-26
20 Year Summer and 100 Year Winter Flood Extents Comparison



20 Year Summer Flood Extent

100 Year Winter Flood Extent

N

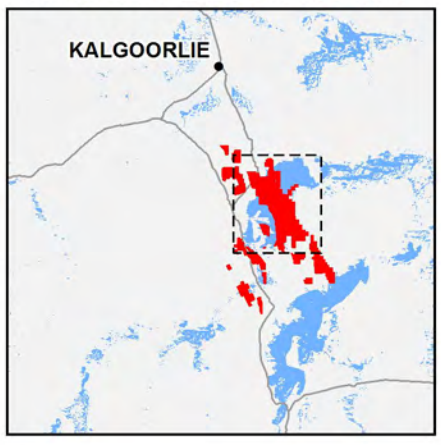
0 2.5 5

km

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Date: 19/10/2017
Compiled: Clare Thatcher
Drawn: rfeng
Name: SIGM_A3_SW_20yr_100yr_comparison

SIGM LEASE LOCALITY MAP



With regard to land-based activities, based on the proposed disturbance areas, the total impacted area will be approximately 230 km^2 which includes the upstream catchments. The impacted catchment results in a relative disturbance within the Lake Lefroy western extent catchment area of approximately 8.7%, or 5% of the total catchment area. The small percentage of disturbance within the regional catchment infers that any alteration to the surface water regime will likely be insignificant on the Lake Lefroy surface water regime (Stantec 2017b). The actual impact, is however likely to be significantly less than 8.7% given surface water management measures such as flow diversion will be implemented during the operations. While flow diversion measures may attenuate flood peaks, it is expected that most of the runoff volume will still reach Lake Lefroy, therefore reducing the potential impacts on the surface water of Lake Lefroy.

4.5.5.3 Dewatering discharge to Lake Lefroy – salt load and salt crust formation

In the early 1990s, the thickness of the salt crust has been estimated to range from 1-2 cm in areas remote to the discharge locations, increasing to up to 10 cm in areas closer to discharge locations (Clarke 1994a). Recent measurements and estimates indicate that the thickness of the salt crust has increased to around 50 – 60 cm in areas closer to the main north-south causeway, while reducing in the northern and southern extremities (MWH 2017, Stantec 2017b).

Based on the outcome of the salt balance model (Appendix L), lake infrastructure will divide the lake surface into segments (see Figure 4-21). When the discharge is considered from individual discharge points, the salt load received by the lake surface will depend on the receiving segment (Figure 4-27) with segments A, E and J receiving the large majority of the salt load. The cumulative B2018 discharge is estimated to be in the order of 31 Mt over the 12 year period, with an average annual load of 2.6 Mt/year. This average is based on a discharge TDS concentration of 260,000 mg/L.

The change in salt crust thickness associated with the predicted B2018 dewatering discharge was estimated based on an assumed salt crust density of 2,500 kg/m^3. Across the simulated period, it has been estimated that the salt crust will increase by less than 20 mm for the larger lake segments, increasing to approximately 160 mm for areas contained by the operations associated with the Pilbailey resource (the westernmost operations in segment E) and north-south causeway (Figure 4-28). These averages assume that causeways are in place without the culverts and the salt crust is spread evenly across the respective segments, whereas in reality, the crust thickness is likely to increase in the deeper (central) portions of the lake and close to discharge locations, compared to lake shorelines. Changes in the concentration and volume of the dewatering discharge, as well as location of discharge will also impact the cumulative changes in the salt crust thickness over time (Stantec 2017b).

The mass balance calculations do not take into account other potential losses such as limited infiltration of lake water to the subsurface or transport of salts from the lake surface by wind. These are considered to be minor compared to dewatering discharge and occasional surface runoff.

Based on this information, it can be concluded that some further accumulation of salt on the surface of Lake Lefroy can be expected as a result of dewatering for the B2018 Project. The large majority of this accumulation will occur in the central and westernmost parts of the lake with the remainder receiving relatively minor quantities. The accumulation is likely to be at its greatest close to discharge points.

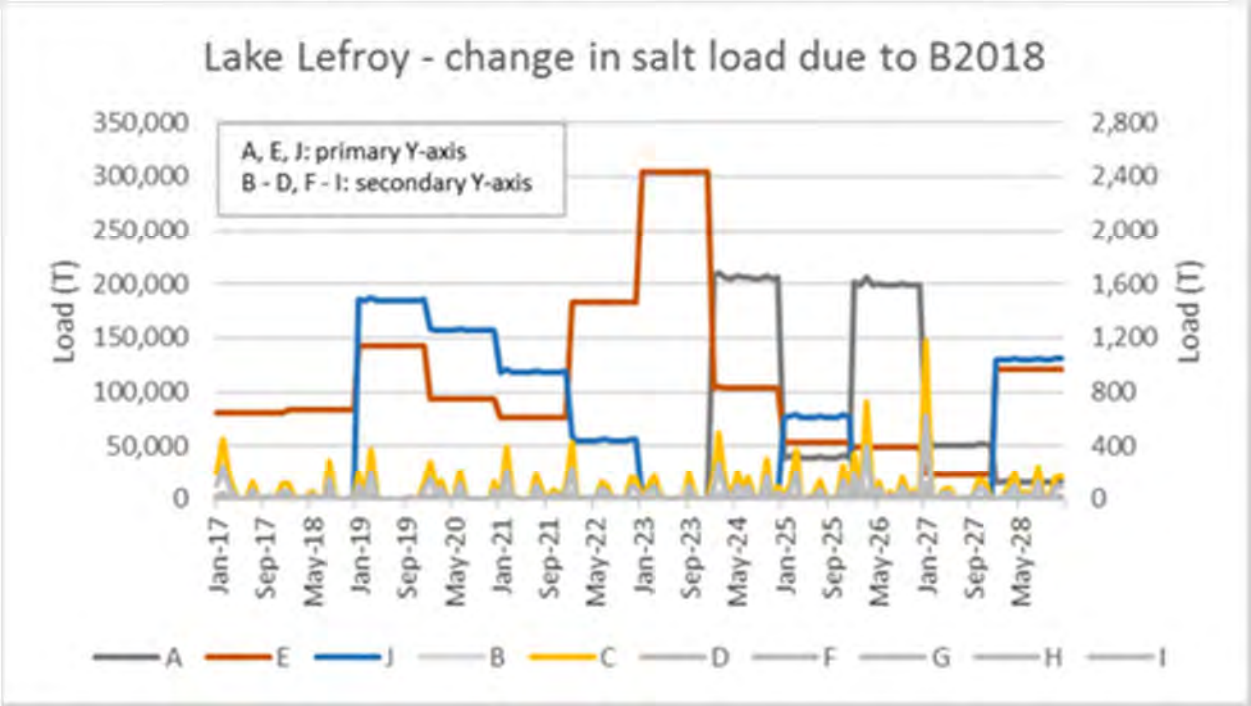


Figure 4-27: Change in Salt Load within Lake Lefroy Segments

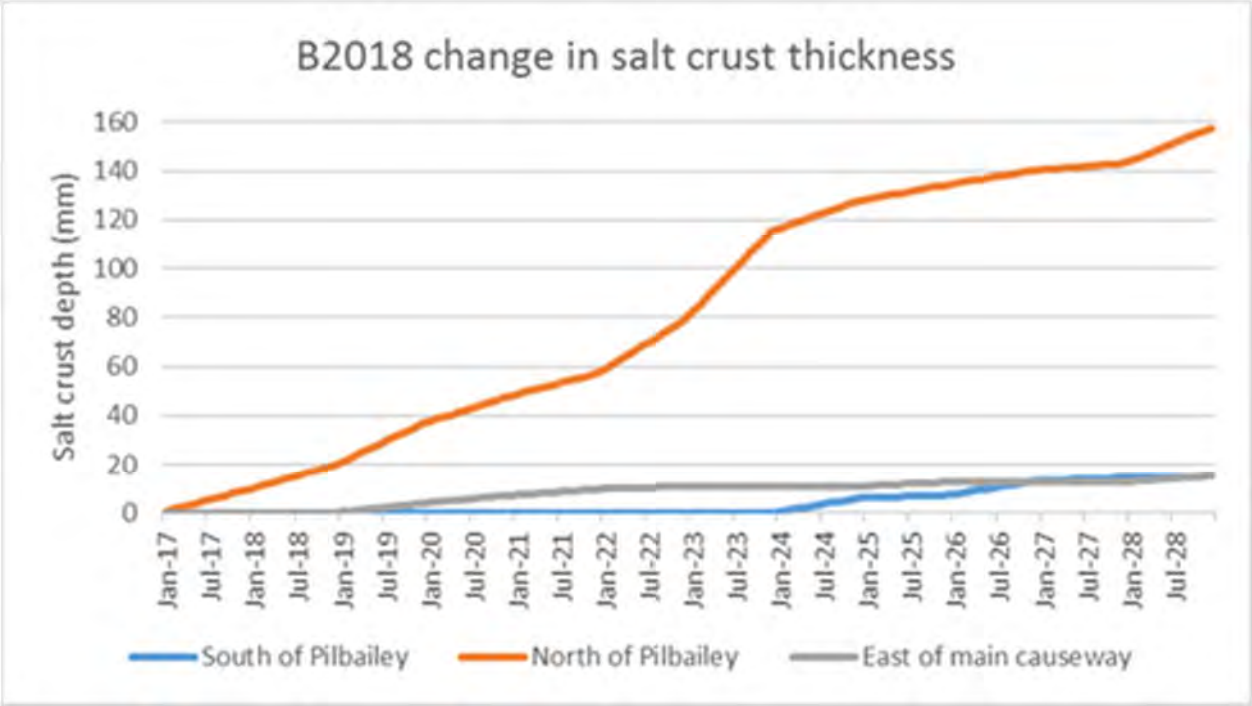


Figure 4-28: Change in Salt Crust Thickness

SIGMC notes that some SRE fauna utilise shoreline environments, including in the segments primarily likely to be affected by discharge associated with the B2018 Project. However, the data suggests that the bathymetry of the lake surface means that an accumulation of a salt crust at or close to the lake shoreline is unlikely, provided the discharge point is located away from these areas. Equally, the salinity of lake water in these lake segments may increase more rapidly following inundation from a rainfall event due to partial dissolution of the increased salt crust. Again, any impact on shoreline vegetation is not likely to be great as it takes a very large event for shoreline vegetation to be inundated and, due to the effects of evaporation and the lake bathymetry, flood waters quickly retreat from the shoreline environment.

Finally, with the added saline discharge, there may be some potential for an increase in wind-blown salts. Wind-blown salts originating from the lake surface are rarely observed (A. Langley, SIGMC, pers. comm., January 2018). This is likely to be attributable to residual moisture in the salt crust and the propensity for gypsum and halite encrustations to precipitate around the discharge points (URS 2010b). Gypsum and halite encrustations are not readily mobilised by wind. However, some dissolution of halite may occur during flooding events, resulting in some remobilisation around the lake surface.

4.5.5.4 Groundwater drawdown or mounding

Groundwater drawdown associated with dewatering for the B2018 Project was modelled (Appendix M). The regional extent of drawdown is relatively limited with the 1 m drawdown contour not extending far beyond the SIGMC tenement boundary. Deeper drawdowns in terms of tens of metres are limited to the immediate vicinity of the mining operations operated at the particular point in time. Consequently, other groundwater users in adjoining tenements are unlikely to be experience any significant change in groundwater levels.

There is some potential for groundwater mounding associated with any new above-ground TSFs required for the B2018 Project. While environmental impacts have not been recorded in the operations to date, the potential for mounding has been demonstrated.

4.5.6 Mitigation

SIGMC proposes the mitigation measures as outlined in Table 4-43.

Table 4-43: Predicted Impacts and Mitigation Strategies for Hydrological Processes

Predicted Impact from the B2018 Project	**Mitigation Hierarchy**	**Mitigation**
Dewatering discharge to Lake Lefroy – hydrology and water balance; salt load and salt crust formation.	Minimise	A dewatering discharge strategy will be developed for each new open pit operation on the lake, prior to its commencement. The strategy will consider: • Existing dewatering practices elsewhere and impacts, if any; • Likely discharge volumes; • Potential for localised flooding; • Likely extent and location of salt crust formation; and • Potential for impact to the riparian zone and, where necessary, measures for protection of the riparian zone. (Commitment 6).

Predicted Impact from the B2018 Project	Mitigation Hierarchy	Mitigation
Dewatering discharge to Lake Lefroy – salt load and salt crust formation.	Avoid/ Minimise	SIGMC will commence routine monitoring of salt crust formation around lake discharge points (Commitment 7). Monitoring will include salt crust levels and their chemical constituents, with reference points located away from discharge points to provide comparative or baseline information.
Groundwater drawdown and mounding	Avoid/ Minimise	Construction of tailings storage facilities will be informed by detailed hydrogeological and hydrological assessments and designed to minimise seepage. Groundwater monitoring with trigger levels to indicate if further action is required will be ongoing. Should groundwater mounding occur, a groundwater recovery system will be installed and operated. These measures can be managed under Part V of the *Environmental Protection Act (1986)* and the *Mining Act (1978)*.
Dewatering discharge to Lake Lefroy – salt load and salt crust formation.	Rehabilitate	SIGMC will consider closure options for dewatering discharge points and their associated salt crust formations. The options will consider how significant salt crusts can be removed, encapsulated or otherwise prevented from dispersal or partial dispersal across the lake surface following mine closure. This measure can be managed under the *Mining Act (1978)*.

Existing monitoring programs for groundwater and surface water will be maintained and extended as the project develops. The environmental outcome sought will be to maintain water quality on Lake Lefroy and in local groundwater at current levels – that is, the B2018 Project should not have an adverse impact beyond current levels. Trigger criteria are currently used in surface water monitoring and reported annually to the regulators. Threshold criteria can comprise three consecutive instances where the trigger criteria are exceeded. Contingency actions will be dependent on the cause(s) identified but could include a change in dewatering discharge practices (e.g. from lake to pit void).

The following commitments are made with respect to Hydrological Processes.

Commitment 6: A dewatering discharge strategy will be developed for each new open pit operation on the lake, prior to its commencement. The strategy will consider:

- **Existing dewatering practices elsewhere and impacts, if any;**
- **Likely discharge volumes;**
- **Potential for localised flooding;**
- **Likely extent and location of salt crust formation; and**
- **Potential for impact to the riparian zone and, where necessary, measures for protection of the riparian zone.**

Commitment 7: SIGMC will commence routine monitoring of salt crust formation around lake discharge points.

4.5.7 Predicted Outcome

SIGMC considers that EPA's objective for Hydrological Processes to '*maintain the hydrological regimes of groundwater and surface water so that environmental values are protected*' can be achieved. The following outcomes are predicted:

- Dewatering discharge onto the surface of Lake Lefroy will not significantly alter the extent or duration of flooding occurring after significant rainfall events;
- Dewatering discharge onto the surface of Lake Lefroy will not result in a significant change in the water quality regime i.e. dissolution of naturally-occurring surface salts after a rainfall event already results in a hypersaline water body on the lake; and
- Groundwater drawdown due to pit dewatering is very unlikely to adversely impact water availability to other groundwater users.

By implementing management measures detailed above, the residual impact is not considered significant and no offsets are considered to be required.

4.6 *Inland Waters Environmental Quality*

4.6.1 EPA Objective

The EPA's environmental objective for the factor Inland Waters Environmental Quality is:

To maintain the quality of the groundwater and surface water so that environmental values are protected.

4.6.2 Policy and Guidance

The following policies and guidelines apply to Inland Waters Environmental Quality:

- EPA Environmental Factor Guideline – Inland Water Environmental Quality (EPA 2016e);
- DER - Identification and investigation of acid sulfate soils and acidic landscapes (DER 2015), Revised June 2015;
- Preventing acid and metalliferous drainage – Leading practice sustainable development program for the mining industry (Commonwealth Department of Industry Innovation and Science 2016);
- DoW - Western Australian water in mining guideline, Report No 12, (DoW 2013a);
- DoW - WQPN 15: Extractive industries near sensitive water resources (DoW 2013b);
- DoW - WQPN 44: Roads near sensitive water resources (DoW 2006);
- DoW - WQPN 51: Industrial wastewater management and disposal (DoW 2009);
- DoW - WQPN 52: Stormwater management at industrial sites (DoW 2010);
- DoW - WQPN 81: Tracks and trails near sensitive water resources (DoW 2015); and
- DoW - WQPN 83: Infrastructure corridors near sensitive water resources (DoW 2007).

4.6.3 Receiving Environment

4.6.3.1 Survey effort

For the B2018 Project, Stantec (2018a) completed an ecological assessment of Lake Lefroy and its peripheral wetlands (Appendix O), summarised in sections 4.6.3.1 to 4.6.3.6. There have been more than 50 lake-based ecological studies, which have aimed to address knowledge gaps and comply with regulatory conditions. Table 4-44 summarises the key studies reviewed in the preparation of this ERD, with Figure 4-29 indicating aquatic ecology sampling sites over time. Many of the studies completed have attempted to quantify potential impacts associated with dewatering discharge to the lake (comparing discharge and reference sites). While baseline information on the historic lake condition is limited due to a lack of comprehensive study work completed prior to mining activities occurring on the lake in the 1960s, a significant amount of assessment and monitoring that has been conducted since mining commenced, particularly in recent years.

Initial baseline studies on the lake were undertaken in 1999 during flooding, to determine the diversity of aquatic biota (Curtin University of Technology 1999a; b). Then in 2004, an annual environmental monitoring program was established to assess the lake's ecology and potential dewatering discharge impacts, which continued until 2008 (Outback Ecology 2004b; 2005; 2006; 2007; 2009a). Additional monitoring has also been completed as required, to ensure compliance and meet approvals requirements over time (Clarke 1991; CSIRO Land and Water 2003; Jim's Weeds 2006; Western Wildlife 2006).

Table 4-44: Studies Undertaken on Lake Lefroy and Peripheral Wetlands

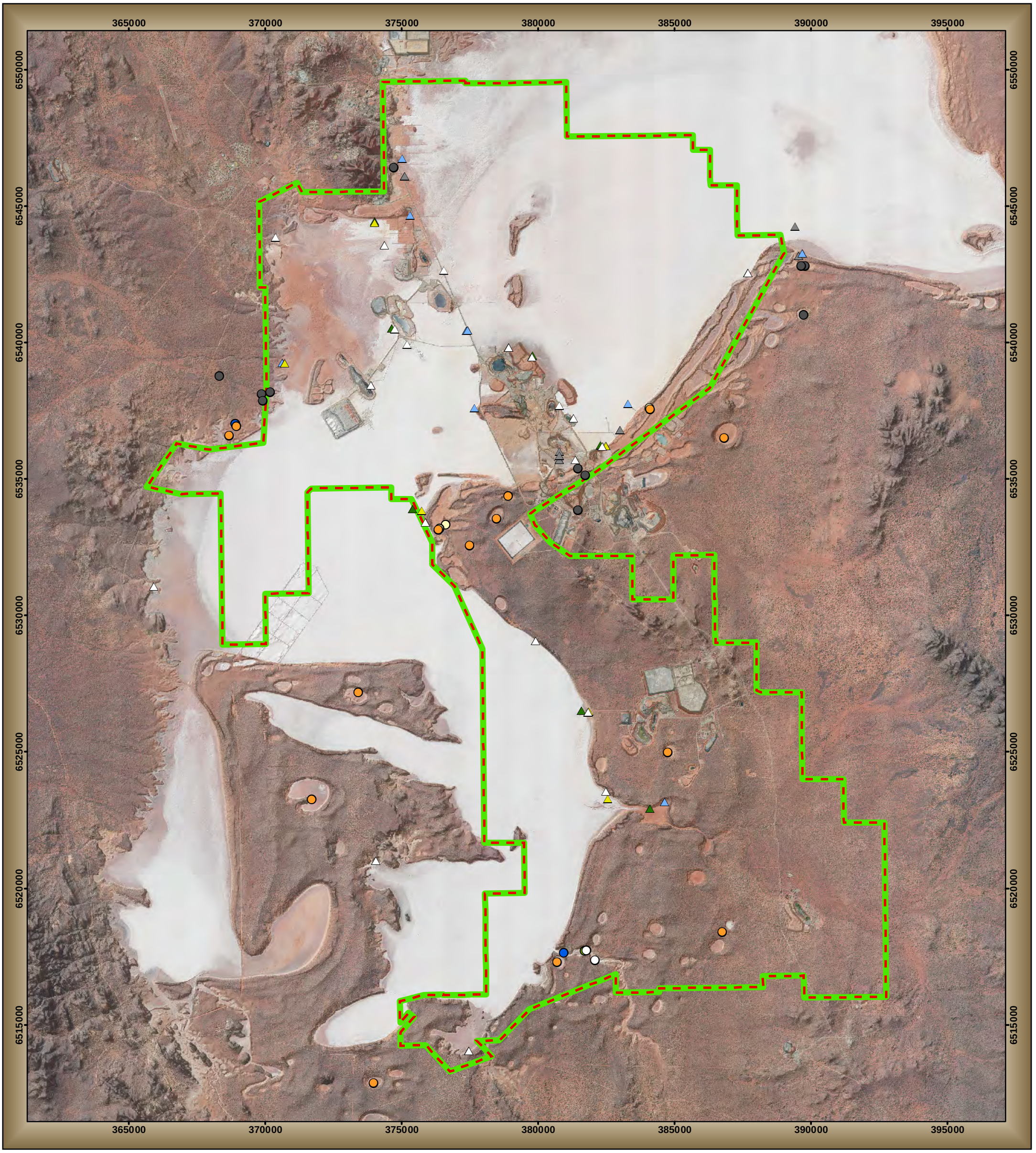
Reference	Report Name	Assessment Type	Sampling Sites or Wetlands	Ecological Components	Survey Timing
Curtin University of Technology (1999a)	Baseline Ecological Study of Lake Lefroy	Aquatic Ecology	North East, South West, Causeway North, EPC, Victory Gold Mine, Lake Zot	Riparian vegetation, aquatic flora, aquatic invertebrates, terrestrial invertebrates, rewetting trials	February 2015
Curtin University of Technology (1999b)	Biology and Water Chemistry of Lakes in the Semi-arid Lefroy-Cowan Region of Western Australia	Aquatic Ecology	Lake Lefroy, Lake Zot, Lake Cowan	Water chemistry, microalgae and aquatic invertebrates were sampled from several lakes in the region following flooding induced by typical cyclone activity (March 1999; Elaine, Vance)	April to June 1999
Outback Ecology (2004)	Assessment of Biota at Lake Lefroy	Aquatic Ecology	North East, South West, KFS5, KFS1, Site 4, Site 12, Site 13, Site 15, Site 16	Water quality, sediment quality, diatoms, resting stages, terrestrial invertebrates, avifauna	October 2004
Outback Ecology (2005)	Re-assessment of Biota at Lake Lefroy	Aquatic Ecology	North East, South West, Delta Island, Site 4, Site 12, Site 13, Site 15, Site 16, WP49/J	Water quality, sediment quality, diatoms, resting stages, terrestrial invertebrates	May 2005
Outback Ecology (2006)	Assessment of Aquatic Biota and Fringing Flora at Lake Lefroy	Aquatic Ecology	North East, South West, Delta Island, Site 4, Site 12, Site 13, Site 15, Site 16, WP49J, Temeraire	Water quality, sediment quality, diatoms, resting stages, terrestrial invertebrates, riparian vegetation	June 2006
Outback Ecology (2007)	Assessment of Aquatic Biota and Fringing Flora at Lake Lefroy	Aquatic Ecology	Site 4, Site 12, Site 13, WP49/J, Delta Island, Site 15, North East, South West, Site 16, East	Water quality, sediment quality, diatoms, resting stages, terrestrial invertebrates, riparian vegetation	July 2007
Outback Ecology (2009a)	Assessment of Aquatic Biota and Fringing Vegetation at Lake Lefroy	Aquatic Ecology	Site 4, Site 12, Site 13, Junction South (WP49/J), Argo Hydroslide, Delta Island, Site 15, North East, North, South West, East	Water quality, sediment quality, diatoms, resting stages, terrestrial invertebrates, riparian vegetation	July 2008

Reference	Report Name	Assessment Type	Sampling Sites or Wetlands	Ecological Components	Survey Timing
Dalcon Environmental (2010a)	Environmental Survey of Lake Lefroy	Aquatic Ecology	Junction, North East Dune, West Dune, Junction South (WP49/J), Argo Hydroslide, Belleisle, Beta Hunt, GRA, Leviathan/Thunderer, Santa Ana	Water chemistry, sediment chemistry, algae and cyanobacteria, diatoms, resting stages, aquatic invertebrates	Spring 2009
Dalcon Environmental (2010b)	Lake Lefroy Sediment Chemistry Survey	Sediment Quality	74 reference, 16 recovery (Junction) and 151 discharge sites	Sediment samples collected from 74 reference sites, 16 recovery sites and 151 discharge sites for analysis of a suite of parameters including pH, salinity and metal concentrations to establish a baseline set of data to be used to develop site-specific criteria	May 2010
URS Australia Pty Ltd (2013b)	St Ives Gold Mine Management Plan for Exceedances in Sediment and Surface Water	Sediment Quality	Argo Hydroslide, Beta Hunt	Sediment management plan for trigger exceedances	n/a
Palaris (2014a)	Annual Sediment Monitoring Report	Sediment Quality	Argo Hydroslide, Beta Hunt, GRA, Belleisle, Revenge, Leviathan, Junction, Cave Rocks	Annual sediment monitoring	December 2013 January 2014
Palaris (2014b)	Sediment Management Plan Implementation	Sediment Quality	Argo Hydroslide, Beta Hunt, GRA, Belleisle, Revenge, Leviathan, Junction, Cave Rocks	Sediment management plan for trigger exceedances	n/a
Phoenix (2014a)	Aquatic biota survey of the St Ives Gold Mine following a 1 in 20 year ARI rainfall event in January 2014	Aquatic Ecology	Invincible, Leviathan, West Dune, Claypan 1, Claypan 2, Claypan 3	A 3 phase biological sampling program conducted during a 1:20 year ARI event including water quality sampling (1 discharge, 2 reference and 3 claypan sites)	January 2014

Reference	Report Name	Assessment Type	Sampling Sites or Wetlands	Ecological Components	Survey Timing
MWH (2015a)	Surface Water Monitoring Report 2014 - St Ives Gold Mine	Water Quality	LL1 to LL7, Beta Hunt, Revenge	Seven opportunistic water samples were collected in February 2014 (after a 1:20 year ARI rainfall event), and two discharge site samples were collected in December 2014 at Beta Hunt and Revenge	February 2014 December 2014
MWH (2015b)	Sediment Monitoring Report 2014 - St Ives Gold Mine.	Sediment Quality	Argo Hydroslide, Belleisle, Beta Hunt, Cave Rock, GRA, Junction, Leviathan, Revenge	Sediment sampling of eight discharge areas was undertaken along a defined boundary of the zone of influence	October 2014
Phoenix (2015a)	Sediment monitoring of aquatic biota resting stages for the St Ives Gold Mine	Aquatic Ecology	Argo Hydroslide, Beta Hunt, Leviathan	Sediment scrapes for the identification of the resting stages of aquatic macrophytes and invertebrates	November 2014
MWH (2016b)	Annual Environmental Monitoring, Lake Lefroy, 2015	Aquatic Ecology	Argo Hydroslide, Belleisle, Cave Rocks, GRA, Invincible, Leviathan, Revenge (GRA), Santa Ana, Foster, Junction South (WP49/J), Junction Reference, Location 170a, Location K, West, North, North East, West Dune, North West	Water quality, sediment quality, diatoms, resting stages, aquatic invertebrates, riparian vegetation, avifauna	October 2015
MWH (2017)	Annual Environmental Program, Lake Lefroy, 2016	Aquatic Ecology	Argo Hydroslide, Belleisle, Cave Rocks, GRA, Invincible, Leviathan, Revenge (GRA), Santa Ana, Foster, Junction South (WP49/J), Junction Reference, Location 170a, Location K, West, North, North East, West Dune, North West	Water quality, sediment quality, diatoms, resting stages, aquatic invertebrates, riparian vegetation, avifauna	October 2016

Reference	Report Name	Assessment Type	Sampling Sites or Wetlands	Ecological Components	Survey Timing
Stantec (2018a)	B2018 Project: Ecological Assessment Of Lake Lefroy And Peripheral Wetlands	Aquatic Ecology	Overview of all Lake Lefroy and peripheral wetlands sampled to date, and additional sampling and rewetting trials for peripheral wetlands	Water quality, sediment quality, algae, diatoms, macrophytes, resting stages, aquatic invertebrates, riparian vegetation, avifauna	n/a
Stantec (2018b)	Annual Environmental Program, Lake Lefroy, 2017	Aquatic Ecology	Argo Hydroslide, Belleisle, Cave Rocks, Foster, Grinder, Incredible, Intrepide B, Invincible (W10), Invincible (W18), Junction South (WP49/J), Junction Reference, Leviathan, Location 170, Location K, North, North East, North West 2, Pistol Club South, Thunderer, West, West Dune	Water quality, sediment quality, diatoms, resting stages, aquatic invertebrates, riparian vegetation, terrestrial invertebrates, avifauna	October 2017
Stantec (2018c)	Revision of Water and Sediment Trigger Values for Lake Lefroy	Water and Sediment Quality	Review of all available water and sediment data for Lake Lefroy	Review of all available water and sediment data for Lake Lefroy	n/a

Figure 4-29
Aquatic Ecology Sampling Sites on Lake Lefroy and Peripheral Wetlands



LEGEND

Aquatic Survey Site 1999 to 2018

Curtin (1999a)
- Creek/Pool/Wetland
- Playa

Outback (2007 and 2009)
- Creek/Pool/Wetland
- Playa

Dalcon (2010)
- Creek/Pool/Wetland
- Playa

Phoenix (2014)
- Creek/Pool/Wetland
- Playa

Stantec (2018a)
- Creek/Pool/Wetland

Stantec (2018b)
- Creek/Pool/Wetland
- Playa

0 3 6 9 12

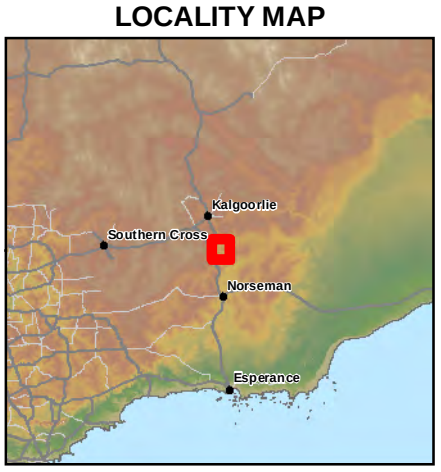
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	G Barrett
Project No:	TE16034
Revision:	A
Date:	24/07/2018

LOCALITY MAP



Document Path: \\server\talis\SECTIONS\Environment\Projects\TE2016\TE16034 - SIGM B2018 EPA Process\10. GIS\Maps\ERD_Mapping\TE16034_ERD_4-29_AquaticEcolSampSites_RevA.mxd

In 2010, a number of broad-scale, comprehensive studies were commissioned by St Ives' on the hydrology and ecology of Lake Lefroy, to support the submission (and ultimate approval) of the Beyond 2010 Project proposal (St Ives Gold Mining Company Pty Limited 2010). These studies investigated aquatic biota (Dalcon Environmental 2010a), and included sampling the lake during a major flood event in 2014 (Phoenix 2014a). Annual monitoring also continues to assess mining impacts related to the dewatering discharge (MWH 201b; 2017; Stantec 2018b), and ensure regulatory compliance (MS 879 and L8485/2010/2).

Stantec's (2018a) ecological assessment of Lake Lefroy and the peripheral wetlands (Appendix O) consolidated the previous work conducted on the lake, including database searches, a desktop assessment to review all available literature (primarily internal reports) and monitoring data. An analysis of the following ecological components was also undertaken; water and sediment quality, aquatic biota and riparian vegetation (Appendix O), summaries of which are provided in subsequent sections of this ERD.

In addition to the desktop assessment, opportunistic sampling and laboratory re-wetting trials were carried out in the latter half of 2017 to determine the ecological value of the peripheral wetlands. A major flood survey of the lake and peripheral wetlands has not been completed prior to submission of this ERD, due to the lack of a sufficient rainfall event (1:100 year ARI). However, this does not detract from the findings of the work completed for the B2018 Project to date as these utilise both historical and contemporary data.

Typical sample sites during dry conditions are shown in Plate 4-2.

Plate 4-2: Shoreline of Lake Lefroy during dry conditions (top: discharge site; middle: reference site; bottom: peripheral wetland)

4.6.3.2 Groundwater

Groundwater originating from mine dewatering is discharged to turkey nest dams on the surface of lake. Groundwater salinity within the vicinity of Lake Lefroy ranges between 274,000 and 423,000 mg/L TDS. Dissolved metal concentrations are reflective of the mineralogy in the region. Groundwater typically occurs in limited quantities, at depth of between 15 to 30 m bgl, outside of the margins of Lake Lefroy (URS 2010a). The natural (pre-mining) groundwater flow is towards the Lefroy Palaeodrainage.

Groundwater in the region is commonly acidic (pH 3 to 5), except where buffered by alkaline ultramafic rocks, and is saline in the upper part of groundwater bodies. It shifts from acidic to a more neutral range (pH 5 to 7) and is hypersaline at depth, within a few kilometres of the salt lakes (Gray 2001).

These regional variations have major effects on the concentrations of many elements. Aluminium (Al), lithium (Li), and uranium (U) are dominantly controlled by pH and thus have higher concentrations in acidic groundwater. Dissolved concentrations of manganese (Mn), cobalt (Co), nickel (Ni), copper (Cu) and zinc (Zn) are less closely correlated with acidity, and show scope for lithological discrimination (Stantec 2017a).

Dissolved chromium (Cr) shows an absolute correlation with ultramafic rocks, apparently irrespective of pH, possibly due to its presence as chromate (i.e. Cr^{6+} as CrO_4^{2-}). In acidic groundwater, concentrations of arsenic (As), antimony (Sb), molybdenum (Mo), tungsten (W) and bismuth (Bi) are low, higher concentrations are present where groundwater pH is above 6.5 .but are higher in concentration above pH 6.5. Molybdenum (Mo) differs from the other elements in this group in having significant concentrations in acidic groundwater, and is present in even higher concentrations in neutral and alkaline groundwater (Gray 2001).

Hydrogeochemically, groundwater is dominated by sodium chloride, with high proportions of magnesium and sulphate. Calcium concentrations are affected by near or supersaturation status with respect to gypsum, with encrustation of this mineral evident in seeps and leaks, and forming large encrustation sheets on the playa of Lake Lefroy (Stantec 2017a). The variance in groundwater quality across the site is presented in Table 4-45.

Groundwater management is discussed in more detail in section 4.5.

4.6.3.3 Surface Water

Lake Lefroy has predominantly been assessed in dry conditions for annual monitoring, with discharge sites contributing to the majority of surface water data available (MWH 2016b; 2017). In 2010, preliminary water quality trigger values for the lake were developed by Dalcon Environmental (2010a) as part of the B2010, and were recently revised by Stantec (2018c) for the B2018 Project. While these more recent values are considered appropriate for the B2018 project, they are based on sampling that has been undertaken to date from a range of reference sites. During the course of implementation of the B2018 Project, these trigger values will be reviewed and refined as more data becomes available (Stantec 2018c). Water quality data on the peripheral wetlands is based on opportunistic sampling, and basic water quality parameters measured during laboratory-based re-wetting trials.

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Table 4-45: Groundwater Quality Indicators (Stantec 2017a)

Analyte Name	Unit	ANZECC (2000)	Location and Sample Date					
		Guideline Triggers* (mg/L)	Leviathan	Thunderer	Revenge	Argo	Junction	MM Borefield
			Aug-2006	Aug-2006	Aug-2006	Aug-2006	Dec-2006	Aug-2009 (B-14)
pH	pH Unit	-	7.15	6.15	6.75	7.1	7.75	3.26
TDS	mg/L	-	312,000	331,000	348,000	263,000	163,000	30,600
Alkalinity as HCO3	mg/L	-	99	53	63	110	280	<1
Chloride (Cl^-)	mg/L	-	180,000	175,000	180,000	135,000	84,000	19,000
Sulphate (SO_4)	mg/L	-	30,000	29,000	30,000	27,000	17,000	2,700
Nitrogen as N	mg/L	-	13	3.1	5.7	5	6.8	0.3
Calcium (Ca)	mg/L	-	370	270	250	480	1,000	150
Magnesium (Mg)	mg/L	-	17,000	18,000	20,000	16,000	8,300	1,000
Sodium (Na)	mg/L	-	86,000	89,000	91,000	74,000	49,000	9,800
Potassium (K)	mg/L	-	1,400	1,500	1,700	1,300	680	240
Iron (Fe)	mg/L	-		2.1				
Aluminium (Al)	mg/L	0.036	0.008	0.008	0.009	0.006		
Manganese (Mn)	mg/L	-	<0.01	<0.01	<0.01			
Cadmium (Cd)	mg/L	0.008	0.068	0.069	0.14	0.038		
Chromium (Cr)	mg/L	-	0.1	5.1	0.21	0.12	0.04	6.1
Copper (Cu)	mg/L	0.012	<0.1	<0.1	0.2	<0.01		
Lead (Pb)	mg/L	-	3.5	2.6	2.5	2.2	4.5	0.6
Nickel (Ni)	mg/L	0.56	0.036	<0.03	0.073	0.056		
Strontium (Sr)	mg/L	-	9.2	5.7	5.8	6.2	8.5	
WADCN	mg/L	-	0.01	0.02	0.03			
Zinc (Zn)	mg/L	0.043	0.99	0.45	0.61	0.55		

Since 1999, the pH of surface water at Lake Lefroy during predominantly dry and occasional flooded conditions has been classified as circumneutral (Foged 1978), ranging from pH 6.5 to 7.5, with no substantial difference between discharge and reference sites (Table 4-46). Although salt lakes in Western Australia generally display a pH range of between 7.0 and 9.5 (Smith et al. 2004), groundwater in some parts of the Goldfields region is known to be acidic (Clarke 1994; Johnson 2004). In addition, while rare, pH may vary during flood events in response to factors such as surface runoff (which may be poorly buffered), the presence of organic matter and local catchment geology (Boulton and Brock 1999; Gregory 2008; Smith *et al.* 2004). The lake's peripheral wetlands appear to be more alkaline, with a pH above 7.5 (Table 4-46), which appears to be a characteristic of wetlands along the margins of large salt lakes in the Goldfields (Timms *et al*. 2006).

The salinity (measured as TDS) of Lake Lefroy surface water has been consistently classified as hypersaline (>50,000 mg/L) (Hammer 1986), and in predominantly dry conditions has typically exceeded 200,000 mg/L (Table 4-46) (Curtin University of Technology 1999a; Dalcon Environmental 2010a; Outback Ecology 2009a; Phoenix 2014a). The salinity of the discharge water is characteristic of the underlying, hypersaline aquifer system that forms part of the Lefroy Palaeodrainage, along the margins of salt lakes is typically above 300,000 mg/L (Wright 2003).

During flooded conditions on surface water salinities decrease, although remain hypersaline and above 150,000 mg/L (Table 4-46) (Curtin University of Technology 1999a; Phoenix 2014a), suggesting the lake does not support a low salinity phase. This can be attributed to its low catchment-to-lake area ratio (approximately 4:1) (Curtin University of Technology 1999a), as well as the extensive salt crust that covers the majority of the playa (Stantec 2018a). The salt crust is thickest in the vicinity of discharge sites, in comparison to historic discharge and references sites (Stantec 2018b). In contrast, during flooding, the peripheral wetlands of Lake Lefroy were characterised as freshwater to hyposaline (Curtin University of Technology 1999a; Hammer 1986; Phoenix 2014a), with an upper limit of approximately 30,000 mg/L (Table 4-46). While freshwater and low salinity peripheral wetlands are typically associated with salt lakes, substantial variation occurs, with gypsum particularly influential (Timms *et al.* 2006).

The ionic balance of major anions and cations in the surface water of Lake Lefroy have been relatively consistent, following $Cl>SO_4>HCO_3$ and Na>Mg>K>Ca respectively, which is typical of salt lakes in the Goldfields (Geddes *et al.* 1981). However, cation dominance has shown some variation over time, with the dominance pattern Na>Mg>Ca>K recorded in 2004 and 2015 at discharge sites (MWH 2017; Outback Ecology 2005). More broadly throughout Western Australian salt lakes, potassium and calcium are often considered interchangeable, within the cation sequence (Hart and McKelvie 1986), and at Lake Lefroy is likely to be related to the high concentrations of gypsum (calcium sulphate dihydrate) in groundwater (Talis 2015).

Nutrient concentrations have tended to fluctuate in the surface water of Lake Lefroy, with high total nitrogen at the discharge sites (Table 4-46), exceeding 50 mg/L in some instances (MWH 2016b; 2017). Surface water on the lake has also shown substantially lower concentrations of total phosphorous (generally below 0.1 mg/L). These characteristics are considered a feature of Goldfields salt lakes that receive discharge (Gregory 2008). However, during flooded conditions, total phosphorus levels have increased to more than 0.2 mg/L (Curtin University of Technology 1999a). This is often the case during the initial stages of inundation (Boulton and Brock 1999), with an influx of organic matter from the surrounding catchment (Gregory 2008). Based on the data available, the lake's peripheral wetlands in the north appear to have comparatively lower nutrient concentrations than the playa (Table 4-46), although this is likely to fluctuate over the course of the hydroperiod.

Table 4-46: Typical Surface Water Characteristics of Lake Lefroy and Peripheral Wetlands (Source: Stantec 2018a)

Hydroperiod		Discharge Sites*	Reference Sites*
Lake Lefroy	Predominantly dry conditions	circumneutral (pH<7.5)	circumneutral (pH<7.5)
		hypersaline (up to 379,000 mg/L)	hypersaline (up to 358,000 mg/L)
		high metals (Cu, Mn, Pb, Zn >triggers#)	low metals (except Mn >trigger#)
		high nitrogen	low nutrients
	Flooded conditions	**Discharge and Reference Sites***	
		circumneutral (pH<7.5)	
		hypersaline (>150,000 mg/L)	
		low metals	
		variable nutrients	
Peripheral Wetlands	Flooded conditions	**Peripheral Wetlands***	
		alkaline (pH>9)	
		freshwater (<500 mg/L)	
		low metals (except Al, Cu >triggers#)	
		low nutrients	
	Re-wetting trials	**Peripheral Wetlands (Regional)**	
		alkaline (pH>7.5)	
		freshwater (<3,000 mg/L) to mesosaline (up to 32,000 mg/L)	

Note: * = based on limited data; # greater than St Ives reference upper range and/or ANZECC &ARMCANZ (2000) triggers for the protection of 80% marine (lake) and freshwater (peripheral wetlands) species, where available

While not resulting in significant impacts to the lake or its ecology, a number of metals (most commonly manganese, lead and zinc) have typically exceeded the St Ives upper reference site range values in surface water throughout Lake Lefroy, during predominantly dry conditions (Table 4-47). However, metal concentrations generally have not exceeded the ANZECC & ARMCANZ (2000) guidelines trigger values, with some exceptions.

Historically, the discharge sites have tended to exhibit elevated concentrations of copper, lead and zinc (0.008 mg/L, 0.012 mg/L, 0.043 mg/L, respectively), which have exceeded their corresponding ANZECC & ARMCANZ (2000) trigger values for protection of 80% of species in marine water (Table 4-46) (Dalcon Environmental 2010a; MWH 2017; Stantec 2018b). However, it is well-documented that groundwater in the Goldfields region is highly mineralised (Gray 2001; Mann 1983; Morgan 1993), as salt lakes throughout inland Australia effectively function as hydrochemical evapoconcentration sinks (Arakel *et al.* 1990). In addition, during flooding, metal concentrations have typically decreased below the ANZECC & ARMCANZ (2000) trigger values (Phoenix 2014a), attributed to dilution from rainfall (Taukulis et al. 2012).

Based on the data available on metal concentrations of the peripheral wetlands, concentrations appear to be lower than the playa itself. Exceptions include aluminium and copper with elevated concentrations above ANZECC & ARMCANZ (2000) trigger values for protection of 80% of species in freshwater (0.15 mg/L and 0.0025 mg/L, respectively). Elevated concentrations of both metals have also been observed from creeklines and claypans in the north-eastern Goldfields region (Taukulis *et al*. 2012).

Table 4-47: Summary of Metals in Surface Water Exceeding the Upper Reference Site Ranges at Lake Lefroy (Source: Stantec 2018a)

Water Quality Site	2009	2015	2016	2017
Discharge				
Argo Hydroslide	Co, Mn, S	-	-	-
Belleisle	Cd, Cu, Pb, Mn, S, Zn	-	-	-
Cave Rocks	-	Mn, Zn	-	Mn, Ni
Foster	-	-	-	-
GRA	-	Pb, Mn, Zn	Mn, S	-
Grinder				Cu, Pb, Mn, Ni, S, Zn
Intrepide B				Mn, Ni
Invincible (W10)	-	Pb, Mn, Zn	Mn, S	Pb, Mn, Ni, S
Leviathan	-	Pb, Mn, Zn	Mn, S	Cu, Mn, Ni, S, Zn
North*	-	-	-	-
Revenge (GRA)	-	Pb, Mn, Zn	Mn, S	-
Santa Ana	-	-	-	-
Thunderer				Ni
West Dune	-	-	-	-
Historic Discharge				
Junction South	Mn	Pb, Mn, Zn	Mn, S	Mn, Ni, S
Reference				
Junction Reference	-	Mn	-	Mn, Ni, S
Location 170	-	-	Mn	-
Location K	-	-	-	Mn, Ni
North East	-	-	-	-
West	-	Mn	-	-

4.6.3.4 Sediment

As expected, there is significant data available on the Lake Lefroy sediment, predominantly for dry conditions. The dataset has been derived from regular, annual monitoring, and targeted assessment of the discharge, historic discharge and reference sites (MWH 2016c; 2017). As part of the B2010 project, trigger values for metals in sediment were derived (Dalcon Environmental 2010b), and subsequently revised for the B2018 Project (Stantec 2018c). For the peripheral wetlands, sediment quality data is more limited but has been supplemented by recent, opportunistic sampling.

Sediment pH at Lake Lefroy has generally ranged from moderately acidic (<6.0) to moderately alkaline (>7.9) (Hazelton and Murphy 2007), with discharge and reference sites being comparable (Table 4-48). Some sites, including reference sites have also been strongly acidic (MWH 2017), likely affected by natural hydrogeochemical processes (St Ives Gold Mining Company Pty Limited 2010), and acidic groundwater (Clarke 1994b; Johnson 2004). Similarly, the peripheral wetlands have also shown highly variable pH ranging from strongly acidic (<5) to strongly alkaline (>8.5) (Table 4-48). The pH of sediment in temporary systems such as Lake Lefroy can be influenced by the hydroperiod, inputs from groundwater, redox reactions, carbonates and organic matter (Commander 1999; Ponnamperuma 1972). Changes in sediment pH are considered important due to the potential effects on the bioavailability and toxicity of metals to aquatic biota (Miao *et al*. 2006).

Sodium and chloride are the dominant ions contributing to elevated salinities in the sediment of Lake Lefroy, with certain areas of the lake also high in calcium (Dalcon Environmental 2010b; URS Australia Pty Ltd 2013b). The high salinity of the lake also promotes settling of sediment mantled with salts, hardening to form a halite crust (URS Australia Pty Ltd 2013b). This salt crust is thickest at discharge sites; up to 60 cm in some areas (Table 4-48), with salinities in excess of 500,000 mg/kg (Stantec 2018b). The salt crust also appears to prevent a low salinity surface water phase during flooding, which restricts the emergence and productivity of aquatic biota (Taukulis 2016). At the reference sites, there is little to no salt crust and salt loads are typically less than 100,000 mg/kg. In comparison, the sediment salinity of the peripheral wetlands is during flooding is below <500 mg/kg, corresponding to lower surface water salinities, which is likely associated with drainage patterns and geomorphology (Stantec 2018b).

Concentrations of total nitrogen and total phosphorus have been variable in the sediment of Lake Lefroy and the peripheral wetlands (Table 4-48). However, a characteristic of most inland salt lakes and wetlands in the Goldfields region (Gregory 2008), is that the concentrations of total nitrogen generally always exceed total phosphorus. In the lake, total nitrogen has exceeded 950 mg/kg, while total phosphorus levels have been generally below 250 mg/kg (MWH 2017). The abundance and subsequent decomposition of algae and macrophytes in the peripheral wetlands (in contrast to the lake), is likely to have a stronger influence on nutrient dynamics (Boulton and Brock 1999). During flooded conditions, nutrients are released into surface water, reducing sediment concentrations. As the hydroperiod progresses, sediment properties, sorption-related processes and microbial activity also affect nutrient levels (McComb and Qui 1998).

Several discharge sites on Lake Lefroy have shown elevated concentrations of one or more metals above the ANZECC & ARMCANZ (2000) interim sediment quality guidelines (ISQG) trigger values and or the upper reference site range values (Table 4-48, Table 4-49). This has typically been for cobalt, copper, manganese, nickel and zinc (Palaris 2014a; URS 2013b; MWH 2016c; 2017). Most recently, any exceedances have generally been in the order of two to three times higher than corresponding trigger values (MWH 2016c; 2017; Stantec 2018b).

At the discharge sites with lower discharge volumes, sediment has naturally elevated or variable metal concentrations (MWH 2016c; 2017), which is consistent with the historic discharge and reference sites (Table 4-49). This appears to be a reflection of natural sediment properties (particularly for manganese), or catchment mineralisation and subsequent runoff (MWH 2016c;

2017; Palaris 2014a). There have also been a number of isolated and highly localised incidents related to the suspension of sediment following construction and blasting at St Ives, as well as compromises in the effectiveness of controls such as settlement ponds or associated infrastructure, which have contributed to exceedances (Palaris 2014b). While these have been recorded as exceedances, they were localised in nature and therefore had no unacceptable impact with respect to the lake.

In contrast to the lake sediment, the peripheral wetlands exhibit comparatively lower concentrations of metals, with the natural mineralisation of chromium and nickel attributed to the geological setting. Specifically, nickel has been recorded at elevated concentrations (96 mg/kg), almost twice that of the ANZECC & ARMCANZ (2000) high trigger value (52 mg/kg) (Table 4-48). However, this is considered characteristic of lake sediment in some parts of the Goldfields (Förstner 1977).

Table 4-48: Typical Sediment Characteristics of Lake Lefroy and Peripheral Wetlands (Source: Stantec 2018a)

Hydroperiod		**Discharge Sites**	**Reference Sites**
Lake Lefroy	**Predominantly dry conditions**	moderately acidic (pH<6.5) to moderately alkaline (pH>8.5)	moderately acidic (pH<6.5) to moderately alkaline (pH>8.5)
		extremely saline (up to 500,000 mg/kg)	saline (<100,000 mg/kg)
		salt crust up to 60 cm	salt crust up to 8 cm^
		variable nutrients	variable nutrients
		high metals (Cu, Co, Mn, Zn >triggers#)	high metals (Mn >high triggers#)
	Flooded conditions	**Discharge and Reference Sites***	
		Not available	
Peripheral Wetlands	**Predominantly dry conditions**	**Peripheral Wetlands (Regional)**	
		strongly acidic (pH<5.0) to strongly alkaline (pH>8.5)	
		low (<15,000 mg/kg) to moderate (up to 57,000 mg/kg)	
		variable nutrients	
		low metals (Cr#, Ni# >triggers)	
	Flooded conditions	**Peripheral Wetlands***	
		alkaline (pH>8.0)	
		low salinity (<500 mg/kg)	
		variable nutrients	
		low metals (Cr+, Ni# >triggers)	

Note: * based on limited data; # exceeding ANZECC & ARMCANZ ISQG-High value; ^salt crust potentially related to migration of discharge salts to the northern part of the lake; +exceeding ANZECC & ARMCANZ (2000) ISQG-Low value

Table 4-49: Summary of Metals in Sediment Exceeding the Upper Low and High Reference Site Ranges at Lake Lefroy (Source: Stantec 2018a)

Sediment Quality Site	Upper Reference Site Ranges*	2011	2012	2013	2014	2015	2016	2017
Discharge								
Argo Hydroslide	High	-	Co, Mn	Co, Mn	Mn	Cu	-	Co
	Low	Co, Mn, Ni	Co, Fe, Mn, Ni, V	Co, Fe, Mn	Co, Mn	As, Co, Mn	Co, Cu, Mn	Mn, Ni
Belleisle	High	-	-	-	-	Cu	-	-
	Low	-	-	-	-	Al, Ba, Cr, Co, Fe, Mn, Ni, V, Zn	Ba, Cu	Al, Co, Fe, Ni
Cave Rocks	High	-	-	Mn	Mn	As, Mn, Zn	Zn	Cr, Fe, Mn, V
	Low	-	-	Al, Ba, Cr, Co, Fe, Mn, Ni, V	Al, Ba, Co, Cr, Fe, Mn, Ni, V	Cr, Co, Cu, Fe, Ni, V	As, Cr, Co, Fe, Mn, Ni, V	Ba, Co, Ni
Foster	High	-	-	-	-	-	-	-
	Low	-	-	-	-	-	-	-
GRA	High	-	-	-	-	-	-	-
	Low	-	-	-	-	Cu	Al, Ba, Cu	-
Grinder	High	-	-	-	-	-	-	-
	Low	-	-	-	-	-	-	Al, Ba, Co, Fe, V
Intrepide B	High	-	-	-	-	-	-	Ba
	Low	-	-	-	-	-	-	Al, Ba, Cr, Fe, V
Invincible (W10)	High	-	-	-	-	Ba	-	-
	Low	-	-	-	-	Al	-	Al, Ba, Cr,

Sediment Quality Site	Upper Reference Site Ranges*	2011	2012	2013	2014	2015	2016	2017
								Co, Ni, V
Invincible (W18)	High	-	-	-	-	-	-	-
	Low	-	-	-	-	-	-	Ba
Leviathan	High	-	-	-	-	-	-	-
	Low	-	-	-	-	-	-	-
North*	High	-	-	-	-	-	-	-
	Low	-	-	-	-	Cr, Co, Cu, Ni	Ba	Cr, Fe, V
Pistol Club South	High	-	-	-	-	-	-	Ni
	Low	-	-	-	-	-	-	Al, Cr, Co, Fe, V
Revenge (GRA)	High	-	-	-	-	As, Cu	Cu	-
	Low	Cd	Cd	-	-	Ba, Co, Zn	As, Ba, Co, Zn	-
Santa Ana	High	-	-	-	-	Cu, Mn	-	-
	Low	-	-	-	-	Al, Cr, Co, Fe, Ni, Zn	Al, Cu	-
Thunderer	High	-	-	-	-	-	-	Ni
	Low	-	-	-	-	-	-	Ba, Co
West Dune*	High	-	-	-	-	-	-	Co
	Low	-	-	-	-	-	-	Ba, Fe
Historic Discharge								
Junction South	High	-	-	-	-	-	-	-
	Low	-	-	Ba, Mn	Ba, Mn	Ba	-	Ba, Fe, V

Sediment Quality Site	Upper Reference Site Ranges*	2011	2012	2013	2014	2015	2016	2017
Reference								
Junction Reference	High	-	-	-	-	-	-	Ba, V
	Low	-	-	Ba, Mn	Ba, Mn	Ba	-	Fe
Location 170	High	-	-	-	-	-	-	-
	Low	-	-	Ba, Mn	Ba, Mn	Ba	As, Ba, Fe, V	Fe, V
Location K	High	-	-	-	-	-	-	-
	Low	-	-	-	-	-	-	-
North East	High	-	-	-	-	Mn	Mn	Al, Mn
	Low	-	-	-	-	Al, Cr, Co, Cu, Fe, Ni, V, Zn	Al, Cr, Co, Cu, Fe, Ni, V, Zn	Ba, Cr, Co, Fe, Ni, V
North West 2	High	-	-	-	-	-	-	Ba, Cr, Fe, Mn, V
	Low	-	-	-	-	-	-	Al, Co, Ni
West	High	-	-	-	-	-	-	Mn
	Low	-	-	-	-	As, Ba, Cu, Mn	As, Ba	Al, Ba, Co, Fe, Ni, V

Note: * indicates “low” and “high” upper range values of the references sites dataset (St Ives Gold Mining Company Pty Limited 2010)

4.6.3.5 Aquatic Biota

Previous studies investigating the aquatic biota of Lake Lefroy were mainly undertaken during dry conditions. Two studies have been carried out during flood events that included the lake, limited to 1999 (Curtin University of Technology 1999a) and 2014 (Phoenix 2014a). While an opportunistic study of several flooded peripheral wetlands was undertaken in 2017 (Stantec 2018a). Laboratory based re-wetting trials have also been completed by Dalcon Environmental (2010a) and Stantec (2018a) to simulate flooded conditions. However, while the range of studies completed over time is considered extensive and resulted in a significant dataset being generated, these datasets for algae and aquatic biota are somewhat fragmented, due to discrepancies in methodology, reporting of results and taxonomic resolution. There is, however, a general consensus that the abundance and diversity of aquatic biota is significantly lower in the lake compared to the peripheral wetlands (Curtin University of Technology 1999a; and Phoenix 2014a; Stantec 2018a).

Algae

In total, 56 phytoplankton taxa have been recorded from Lake Lefroy and the peripheral wetlands (Table 4-50), although only three of these taxa were associated with the playa. Phytoplankton sampling in 2014 yielded one cyanobacterium (Cyanophyceae) and two chlorophytes (Chlorophyceae) from the lake. Of these, the chlorophyte *Dunaliella* sp., was prevalent (Phoenix 2014a). This taxon is considered a dominant component of salt lake environments around the world and Australia (Borowitzka 1981; Oren 2005), with some species able to tolerate salinities in excess of 350,000 mg/L (Williams 1998).

In contrast to the phytoplankton results from 2014, 55 planktonic taxa were identified from peripheral wetlands in 2017 (Table 4-50). The majority of these were chlorophytes, commonly associated with freshwater conditions across the south-west of Western Australia (John 2002), such as the filamentous *Oedogonium* sp., and single-celled *Closterium* sp. The latter also tends to be well represented in acidic waters (John 2002). Diatoms were also diverse, with minor contributions from several other classes of algae. The higher diversity of phytoplankton in the surface water of the peripheral wetlands is likely to reflect the freshwater and low salinity conditions (Hammer 1986).

Algal productivity appears to be high in both the surface water and benthos of the peripheral wetlands, while mostly being confined to the latter in the playa, considered characteristic of salt lakes (Handley 2003). Of the 92 benthic algal taxa recorded over time, 29 taxa have been identified from Lake Lefroy (Table 4-50). Cyanobacterial mats comprising *Schizothrix* sp. were found during the 1999 flood event, and were considered pivotal to the lake ecosystem (Curtin University of Technology 1999a). This taxon has been documented in salinities of up to 150,000 mg/L from waterbodies throughout the Goldfields and wheatbelt regions (Handley 2003). Other cyanobacteria with similar tolerance limits (Handley 2003) including *Oscillatoria* sp. and *Chroococcus* sp., have also been recorded from the lake (Curtin University of Technology 1999a), and are associated with coastal and saline environments throughout Western Australia (John *et al*. 2009).

In the peripheral wetlands, cyanobacterial mats of *Phormidium* sp. and *Microcoleus* sp. have been identified, and are typical of benthic communities in waterbodies throughout the wheatbelt and Pilbara regions of Western Australia (Paling 1989). Desmids, which are single-celled chlorophytes (such as *Cosmarium* sp.) were also prevalent in flooded wetlands in 2017. This group of algae are found exclusively in freshwaters (John 2002), and are common throughout Australia (Entwisle et al. 1997). Diatoms, often associated with benthic communities (Handley 2003; John *et al.* 2009), have also been frequently observed in association with cyanobacterial mats in the peripheral wetlands and Lake Lefroy over time, with many of the taxa identified during re-wetting trials. Similar to phytoplankton, benthic algae in the playa were not as diverse as the peripheral wetlands, however productivity may still be high, supporting higher order

consumers including aquatic invertebrates and waterbirds (Curtin University of Technology 1999a).

Table 4-50: Summary of Algal Taxa per Phyla Recorded from Lake Lefroy and Peripheral Wetlands (Source: Stantec 2018a)

Algal Class	Phytoplankton		Benthic Algae	
	Playa	Peripheral Wetlands	Playa	Peripheral Wetlands
Bacillariophyceae	0	16	5	30
Chlorophyceae	2	28	1	15
Chrysophyceae	0	1	0	0
Cryptophyceae	0	1	0	0
Cyanophyceae	1	7	23	35
Euglenophyceae	0	2	0	1
Diversity	**3**	**55**	**29**	**81**
Total Diversity	**56**		**92**	

Diatoms

Diatoms (a type of microalgae), can persist in the moist sediment of salt lakes in dry conditions, and are one of the few groups of biota that have been consistently assessed at Lake Lefroy since 2004 during annual monitoring. However, in several instances, identification to species level has not occurred. Not taking into account unidentified taxa 66 species in total have been recorded from the lake and peripheral wetlands, of which 34 taxa have been recorded from the lake, and 52 taxa have been recorded from the peripheral wetlands (Table 4-51).

In dry conditions, the diversity of diatoms on the playa typically ranges from 10 to 15 taxa (MWH 2017), comprising *Amphora*, *Hantzschia* and *Navicula* representatives (Table 4-51), which are characteristic of saline waters in Western Australia (Campagna 2007; Gregory 2008; Taukulis 2007). The most frequently recorded diatoms include *Navicula* sp. aff. incertata and *Amphora* coffeaeformis and (21 and 15 records, respectively), with *Hantzschia amphioxys*, Hantzschia sp. aff. baltica, *Navicula* sp. aff. salinicola and *Luticola mutica* also common (>10 records) (Table 4-52). These taxa are associated with hypersaline conditions and have documented salinity tolerance limits mostly exceeding 100,000 mg/L (Taukulis 2007). They are also considered widespread throughout salt lakes in the Goldfields region (Taukulis et al. 2012). *Hantzschia* and *Luticola* taxa are aerophilic; known from non-submerged habitats (Ehrlich 1995), or eroded sediment (John 2000), reflecting the exposed nature of the playa. Several *Pinnularia* taxa have also been recorded from the lake over time, related to the acidic conditions (Thomas 2007) that occur in some parts of the lake (Clarke 1994b).

In the peripheral wetlands, opportunistic sampling and re-wetting in 2017 showed that diatoms were abundant, with some overlap of taxa found in the lake. This included *Amphora coffeaeformis*, which appears to be dominant throughout the area. However, species known from freshwater environments (John 2000; Joh 2014), such as *Hantzschia distinctepunctata* and *Nitzschia palea* were also commonly recorded in the peripheral wetlands (Appendix O). The latter has an optimal salinity of below 3,000 mg/L, and is considered widespread throughout inland waters in Western Australia (Taukulis *et al.* 2009). Genera indicative of freshwaters and low pH have also been identified from the peripheral wetlands, including *Achnanthidium*, *Pinnularia* and *Brachysira* (John 2000), and are likely to reflect the potentially acidic nature of some of these waterbodies when in flood.

Table 4-51: Summary of Diatom Taxa per Genera Recorded from Lake Lefroy and Peripheral Wetlands (Source: Stantec 2018a)

Diatom Genera	Playa	Peripheral Wetlands
Achnanthidium	3	3
Amphora	1	5
Brachysira	0	1
Caloneis	1	1
Craticula	1	3
Cyclotella	1	1
Gomphonema	0	1
Hantzschia	3	5
Luticola	2	3
Navicella	1	1
Navicula	8	11
Nitzschia	4	7
Pinnularia	4	7
Proschkinia	1	1
Rhopalodia	1	1
Sellaphora	1	0
Stauroneis	1	0
Synedra	1	0
Tryblionella	0	1
Diversity	**34**	**52**
Total Diversity	**66**	

Table 4-52: Common Diatom Taxa (≥10 records) from Lake Lefroy (Playa Only) (Source: Stantec 2018a)

Diatom Taxa	Number of Records
Navicula sp. aff. *incertata*	21
Amphora coffeaeformis	15
Hantzschia sp. aff. *baltica*	12
Navicula sp. aff. *salinicola*	11
Luticola mutica	10
Hantzschia amphioxys	10

Over time, studies have shown that the dewatering discharge appears to be having a localised impact on diatom assemblages in the lake sediment, likely attributed to high salinity, a key factor known to adversely affect productivity (Battarbee *et al*. 2001; Stanish and Nemergut 2011). The thick salt crust is also likely to be a limiting factor (MWH 2017; Outback Ecology 2009a). However, the distribution of diatoms in the sediment of Lake Lefroy also appears to be naturally heterogeneous (MWH 2017), with low diversity and abundance recorded from reference sites, related to differences in sediment properties such as moisture content, salinity, nutrients, and microtopography (Battarbee *et al*. 2001; van Kerckvoorde et al. 2000; Wolfe 1996). In comparison, the peripheral wetlands remain relatively unaffected, with freshwater and low salinity conditions, as well as more variable habitat, providing conditions conducive to a diverse diatom assemblage. This in turn may support a range of higher order consumers including aquatic invertebrates (Padhi *et al*. 2010).

Macrophytes

To date, a total of nine macrophyte taxa have been identified from Lake Lefroy and the peripheral wetlands (Table 4-53). However, only dormant propagules (resting stages) only from the lake, with no macrophytes observed germinating during major flood events. The propagules have belonged to three taxa with a submerged habit; two charophytes (Charophyceae; large green algae) and one angiosperm (Ruppiaceae). In comparison, all nine taxa, which includes charophytes, as well as an angiosperm (Ruppiaceae) and bryophyte (Marchantiopsida; liverworts) representative, have been recorded from the peripheral wetlands. Both dormant propagules and mature specimens have been observed in the peripheral wetlands after flooding, and based on re-wetting trials.

Charophytes are commonly associated with inland lakes and wetlands (Porter 2007), and in shallow waters are considered pioneer vegetation of recently inundated areas (Casanova and Brock 1999). The oospores of two of the most common taxa; *Nitella* sp. and *Lamprothamnium* sp., have been found in the sediment of Lake Lefroy and the peripheral wetlands (Table 4-53), with the latter commonly associated with saline waters throughout Australia (Porter 2007). The propagules (oospores) belonging to another charophyte; *Chara* sp., as well as mature specimens of *Chara* sp. and *Nitella* sp. have also been recorded from the peripheral wetlands (Stantec 2018a). These taxa are generally associated with freshwater and low salinity conditions of less than 5,000 mg/L and are common in Australian waters (Garcia 1999). As charophytes generally require lower surface water salinities for germination (Garcia 1999; Porter 2007), it is also more likely that these taxa would occur in the peripheral wetlands during flooding, rather than the playa.

In contrast, elevated salinities are known to promote germination in *Ruppia* sp. (Porter 2007), the seeds of which were identified in the lake sediment (Table 4-53). In 2016, *Ruppia* sp. was observed growing within localised areas of a creekline along the margins of Lake Lefroy (MWH 2017), with this genus known to persist in salinities over 200,000 mg/L (Rogers and Paton 2009). There are four *Ruppia* species recognised in Australia (Jacobs and Brock 1982), of which *R. tuberosa* appears to be most commonly associated with inland waterbodies in the Goldfields region (Taukulis *et al*., 2014).

In Lake Lefroy, macrophytes appear to be generally absent or have a limited presence, which corresponds to the depauperate sediment propagule bank. While many factors such as light, temperature and water level can influence the germination of macrophytes (Bonis and Grillas 2002), the apparent elevated salinity of the lake during flooding is likely to be most prohibitive to emergence and development. In addition, the thick salt crust may present a barrier preventing the germination of submerged macrophytes, or affect the viability of the propagules. The peripheral wetlands have comparatively higher diversity and a more abundant propagule bank, similar to other large salt lakes in the Goldfields region (Taukulis *et al*. 2012), and provide a more suitable environment for macrophytes, as well as providing a source of biological material for the playa.

Table 4-53: Dormant Propagules Recorded from Lake Lefroy and Peripheral Wetlands (✓ Indicates Mature Plants, ● Indicates Dormant Propagule)

Taxa	Playa	Peripheral Wetlands
Charophyceae		
Chara sp. SIGM01 (Stantec)		✓
Chara sp. SIGM02 (Stantec)		✓
Chara sp. SIGM03 (Stantec)		✓
Chara sp.		●
Lamprothamnium sp.	●	●
Nitella sp. SIGM01 (Stantec)		✓
Nitella sp.	●	●✓
Marchantiopsida		
Marchantidae sp. SIGM01 (Stantec)		✓
Ruppiaceae		
Ruppia sp. SIGM01 (Stantec)	●	●✓
Diversity	**3**	**9**
Total Diversity	**9**	

Aquatic Invertebrates

Several studies have investigated the aquatic invertebrate communities of Lake Lefroy and the peripheral wetlands during flooding, including 1999, 2014 and 2017 (Curtin University of Technology 1999a; Dalcon Environmental 2010a; Phoenix 2014a), and based on re-wetting trials (Curtin University of Technology 1999a; b; Stantec 2018a). There is also data available from discharge sites over time (Dalcon Environmental 2010a; MWH 2016c; 2017). Together, these studies have yielded a total of 103 taxa; predominantly crustaceans and insects. The majority of taxa have been recorded from the freshwater and low salinity peripheral wetlands (101 taxa), in comparison to the playa (13 taxa) (Table 4-54). A more detailed comparison of species found over time is provided in Appendix O, with varying levels of taxonomic resolution, which have recently improved, suggesting the total taxa numbers are likely to be over-estimate.

The findings of studies on Lake Lefroy have consistently indicated that the diversity of aquatic invertebrates is low. Most of the taxa identified have also been considered widespread (Curtin University of Technology 1999a; Phoenix 2014a). During flooding, the lake has been dominated by dipterans and specifically ceratopogonids; biting midge larvae (Table 4-55) (Curtin University of Technology 1999a; b; Dalcon Environmental 2010a; Phoenix 2014a). In addition, one ceratopogonidae taxon has been recorded in relatively high abundance from discharge sites on the playa (Dalcon Environmental 2010a). This group are well-known colonisers of newly inundated areas, and have mobile adult stages (Ivarsson 2016). There is also some evidence to suggest that they may have desiccation-resistant life stages (Wissinger and Gallagher 1999). Ceratopogonids are common in hypersaline environments (Kay *et al*. 2001; Timms 2002), and known to tolerate salinities in excess of 100,000 mg/L (Pinder *et al*. 2005).

Table 4-54: Summary of Aquatic Invertebrate Taxa per Group Recorded from Lake Lefroy and Peripheral Wetlands

Taxa	Playa	Peripheral Wetlands
Arachnida		
Trombidiformes	0	1
Crustacea		
Anostraca	2	6
Cladocera	0	6
Copepoda	5	9
Notostraca	0	1
Ostracoda	2	15
Spinicaudata	0	5
Insecta		
Diptera	4	26
Coleoptera	0	13
Ephemeroptera	0	2
Hemiptera	0	8
Odonata	0	5
Trichoptera	0	1
Foraminifera	0	1
Rotifera	0	2
Diversity	**13**	**101**
Total Diversity	**103**	

Crustaceans (considered resident fauna; laying desiccation-resistant eggs), have also been represented in the playa to a lesser extent, comprising several copepods, such as *Calamoecia* cf. *salina* and *Meridiecyclops baylyi*, and ostracods, including '*Dragoncypris outbacki'* (Table 4-55). The latter species has also been recorded from the peripheral wetlands (Dalcon Environmental 2010a; Phoenix 2014a; Stantec 2018a). The copepod taxa are known from the wheatbelt and coastal regions of Western Australia, and have been documented from salinities in excess of 90,000 mg/L (Hammer 1986; Nowicki *et al*. 2009; Pinder and Quinlan 2015). '*Dragoncypris outbacki*' has a broad distribution throughout the Goldfields, and is also known to persist in salinities over 120,000 mg/L (Stantec unpublished data).

There are also several records of the anostracan (brine shrimp) *Parartemia* sp. nov. from Lake Lefroy (Table 4-55, which potentially represents *Parartemia serventyi*, which has been hatched during re-wetting trials using sediment from the lake and peripheral wetlands in 1999 (Curtin University of Technology 1999a), and 2017 (Stantec 2018a). This species is commonly associated with salt lakes in the southern Goldfields and wheatbelt (Timms 2012), and has been found in salinities over 200,000 mg/L (Timms 2012). Although data on the lake during flooded conditions is limited, the results of studies to date indicate there have been no differences between discharge and reference sites (Dalcon Environmental 2010a; Phoenix 2014a), likely due to the extremely hypersaline conditions during major flood events.

Table 4-55: Common Aquatic Invertebrate Taxa (Records ≥2) from Lake Lefroy (Playa Only)

Aquatic Invertebrate Taxa	Number of Records
Insecta	
Diptera	
Ceratopogonidae sp. 3	11
Ceratopogonidae sp. 1	5
Dasyhelea sp.	5
Crustacea	
Anostraca	
Parartemia sp. nov.	4
Copepoda	
Calamoecia cf. salina	2
Calamoecia sp.	2
Meridiecyclops baylyi	2
Ostracoda	
'Dragoncypris outbacki'	2

Both *Parartemia* and ostracod eggs have been recorded in the sediment of Lake Lefroy (Curtin University of Technology 1999a; MWH 2017; Outback Ecology 2009a), and form part of the dormant egg bank, consistent with salt lake environments throughout Australia (Campagna 2007; Timms 2007; Williams 1981). The distribution of invertebrate eggs within salt lake sediment is also considered heterogeneous (Brendonck and De Meester 2003), due to the influence of factors such as prevailing winds and geomorphology (Thiéry 1997). The presence of the thick salt crust and causeway bisecting the lake is also likely to be affecting distribution patterns. These factors tend to override any trends relating to discharge and reference sites (MWH 2017).

In contrast to the playa, the peripheral wetlands of Lake Lefroy are known to support a greater diversity of aquatic invertebrates and have greater productivity, particularly during flooded conditions (Chaplin and John 1999; Dalcon Environmental 2010a; Phoenix 2014a). The assemblage appears to consist mostly of crustaceans including anostracans (brine shrimp), ostracods (seed shrimp), notostracans (shield shrimp) and spinicaudatans (clam shrimp) and copepods, as well as insect groups such as dipterans (fly larvae), coleopterans (beetle larvae), hemipterans (true bugs) and odonatans (dragonfly larvae) (Table 4-54).

Ostracods such as *Bennelongia barangaroo* (known from salinities <3,000 mg/L) (Pinder and Quinlan 2015; Susac *et al*. 2009), and copepods including *Calamoecia ampulla* var. B01 have been dominant in the peripheral wetlands in 2017, with dipterans (*Polypedilum nubifer*) also prevalent. They are also known to have supported taxa associated with low salinities such as the shield shrimp *Triops australiensis* (<5,000 mg/L) (Timms *et al*. 2006), common to waterbodies throughout inland Australia (Timms *et al*. 2006; Williams 1980).

Freshwater taxa (<3,000 mg/L) including the copepod *Australocyclops australis* (<3,000 mg/L) (Halse *et al*. 2000), and cladoceran *Daphnia carinata* s.l. (Timms et al. 2006) were also common in the peripheral wetlands, and have been recorded from the wheatbelt region (Cale *et al*. 2004), southwest of Western Australia, and more broadly throughout Australia (Benzie 1988; Morton 1985; Pinder and Quinlan 2015). Re-wetting trials have also hatched numerous

crustacean taxa from the peripheral wetlands, of which the ostracod '*Dragoncypris outbacki*' was the most abundant. The presence of this taxon, and several others throughout the area, demonstrates there is some degree of overlap between aquatic invertebrate assemblages across the peripheral wetlands. This reflects propagule exchange during flooding (Taukulis *et al*. 2012), and reflects the higher salinity of some of the wetlands along the lake margins.

It has been suggested that the aquatic invertebrates of Lake Lefroy may be depauperate in comparison to other salt lakes in the Goldfields region (Curtin University of Technology 1999b), such as Lake Carey (Taukulis *et al.* 2012), primarily due to elevated salinity. This elevated salinity is, at least to some degree natural however, is also likely to be influenced by historical mining and related activities. From the limited monitoring data associated with major flood events (Dalcon 2010; CSIRO 2001), the lowest lake salinities initially may approximate 60,000 to 80,000 mg/L TDS, rapidly increasing to over 100,000 mg/L TDS as the hydroperiod progresses. Given the high salinity and known low diversity of aquatic biota in Lake Lefroy, the investigation of impacts from the dewatering discharge on aquatic biota is problematic and has not been conducted for this assessment. Although it is likely that the increased salt loads in the discharge water will further reduce the potential for the emergence of aquatic biota, at least in proximity to discharge points.

While the salinity of surface water at the discharge sites is already prohibitive to aquatic invertebrates, the thick salt crust may also be adversely affecting the viability of dormant eggs in the sediment, with hatching typically occurring at lower salinities (Campagna 2007; Pinder *et al*. 2005; Timms 2014). Similar to other primary producers such as algae and macrophytes, high surface water salinities in major flood events are likely to prevent the emergence of aquatic invertebrates. This in turn potentially decreases egg replenishment opportunities, as well as the productivity and ecological value of the lake.

4.6.3.6 Conservation Significant Aquatic Invertebrates

Database searches indicated that there were no listed algae, macrophytes or aquatic invertebrates of conservation significance that have been recorded from Lake Lefroy or the peripheral wetlands (DBCA 2017b; Department of the Environment and Energy 2017a). Based on the data available, many of the aquatic biota recorded to date are typically considered widespread throughout wetlands in the Goldfields or more broadly across Australia. Further survey effort, taxonomic resolution and updates to database lists will continue to refine these conclusions.

A review of the current threatened and priority fauna rankings (DBCA 2017b) and Wildlife Conservation (Specially Protected Fauna) Notice (Department of Biodiversity, Conservation & Attractions 2017) identified three Priority 1 *Branchinella* species (fairy shrimp) known from the Goldfields region; *Branchinella apophysata*, *Branchinella denticulata* and *Branchinella simplex* (Appendix C). The studies completed to date suggest that these species do not occur within Lake Lefroy or the peripheral wetlands.

In addition, the Stantec (2018a) ecological assessment found that there are five potentially new and or potentially restricted aquatic invertebrate taxa that have been identified from the peripheral wetlands comprising:

- *Calamoecia ampulla* var. B01 – copepod recorded from northern and south eastern peripheral wetlands in abundance;
- *Eocyzicus* sp. MWH01 – clam shrimp (single specimen) recorded from northeastern wetland, also known from wetlands throughout the Goldfields (based on morphology);
- *Ilyodromus* sp. BOS1031 – relatively abundant copepod recorded from northern peripheral wetlands;
- *Parartemia* nr *serventyi* MWH01 – recorded (in limited numbers) from a central western peripheral wetland; and

- *Parartemia* sp. (juvenile) – recorded (in limited numbers) from a southern peripheral wetland.

These records are based on the most recent sampling and rewetting trials undertaken by Stantec in 2017 (Stantec 2018a). The five taxa were recorded from the peripheral wetlands only and not from Lake Lefroy itself. Of these five, *Eocyzicus* sp. MWH01 was the only taxon restricted to within the B2018 Project Development Envelope (Figure 4-30) at Lake Lefroy; however, it is also known from several freshwater wetlands throughout the Goldfields (Taukulis *et al*. 2012). The remaining taxa were recorded from peripheral wetlands located either within the exclusion zone (with no expected impacts to these wetlands), or outside of the B2018 development envelope (Figure 4-32). Consequently, assessment of impacts on Lake Lefroy itself should consider the baseline of low numbers of all aquatic biota and an absence of conservation significant biota.

While not all individual peripheral wetlands within the development envelope have been studied due to the practicalities of such work, a substantial survey effort has been undertaken to inform the B2018 Project. This data suggests broad consistencies between the wetlands and indicates that it is highly unlikely that any new aquatic invertebrate taxa will be found that are restricted to the Development Envelope. This is due to the high connectivity of surface water throughout the area during major flood events (Taukulis *et al*. 2012). For this reason it is also considered unlikely that any new taxa would be confined to a single wetland on the lake's periphery.

4.6.3.7 Acidic and Metalliferous Drainage

SIGMC is undertaking waste rock characterisation studies and assessment of acidic and metalliferous drainage (AMD) on a regular basis as well as for specific projects/project approvals and any issues that may arise. These results are compiled into site wide geological and geochemical database.

MWH was engaged to undertake a review and assessment of the AMD data collected at SIGMC as part of the preparation of the Mine Closure Plan (MCP) for the site in 2016 (MWH 2016a) (Appendix P). Existing information on characterisation of mine waste and tailings materials with respect to AMD was reviewed as part of this study. The review focussed on AMD characterisation information relating to waste rock and tailings materials which are considered the major sources of AMD in St Ives.

A number of previous studies related to the AMD characterisation and assessment of risk related to AMD potential of mined waste materials and tailings have been undertaken at the SIGMC. These studies are summarised in Table 4-56.

The studies have mainly been undertaken post-2000. As part of the AMD assessment, a total of 3175 individual analysis relating to acid generation potential were collated from over 100 individual consultant or laboratory reports. Data mainly comprised paste pH and paste EC, Acid Base Accounting (ABA) testwork (sulfur analyses, Acid Neutralising Capacity (ANC), NAPP (Net Acid Production Potential), carbon species analysis (as part of modified-NAPP procedures) and NAG (Net Acid Generation) testwork and calculations to assist with classification of samples (MWH 2016a).

Acid and/or metalliferous drainage generally originates from the exposure of iron sulfide minerals (e.g. pyrite, chalcopyrite) to oxygen and water resulting in the production of sulphuric acid. The exposure of geological materials to oxygen and water can occur through microbial activity (which produces oxygen) in saturated conditions, or through the mechanical breakdown and sub aerial exposure of materials when disturbed during mining activities (either through mining and materials movement or through dewatering). As the resulting acidic drainage moves through surrounding soil and rock (in waste rock landforms, stockpiles and other mine features), it can react with other minerals to dissolve and liberate metals and salts. AMD can also react

with neutralising minerals resulting in neutral drainage. Occasionally neutral drainage may still contain elevated metal concentrations (MWH 2016a).

Table 4-56: AMD Characterisation Studies Reviewed as part of the AMD Risk Assessment

Author	Title	Data type	Year Published	Number of sources
ALS	Laboratory report	Primary laboratory reports	2008-2015	101
AMMTEC	Laboratory report	Primary laboratory reports	2005	2
Dames and Moore	Public Environmental Review - Gold Mining Developments on Lake Lefroy	Tables in report	1999	1
Graeme Campbell and Associates	Characterisation of Process Tailings and Mullock Testing	Data in report	2003	2
MBS Environmental	Redback Mining Proposal	Original laboratory results in report	2013	1
Mehling Environmental Management Inc. & O'Kane Consultants Inc.	Waste Rock Characterisation and Implications from Site Waste Rock Management - with addendums	Tables in report	2005-2006	2
MESH Environmental Inc. & O'Kane Consultants Inc.	Geochemical Characterisation of Tailings	Tables in report (transcribed)	2008	1
MESH Environmental Inc. & O'Kane Consultants Inc.	Leviathan Waste Rock Assessment	Tables in report (some data missing)	2006	1
MWH Global	A5 Open Pit Mine AMD Assessment	Original laboratory results in report	2015	1
MWH Global	AMD Data Review	Original laboratory results in report	2015	1
SGS	Laboratory	Primary laboratory reports	2006-2007	3
St Ives Gold Mine	Annual Environment Management Plans and Annual Environment Reports	Tables in report	2001, 2009, 2011	3
St Ives Gold Mine	Athena, Apollo and Hamlet Mining Operations Mining Proposal	Table in report	2009	1
St Ives Gold Mine	Cave Rocks Mining Proposal	Original laboratory results in report	2006	1
St Ives Gold Mine	Diana Mining Proposal	Tables in text	2011	1
St Ives Gold Mine	Neptune Mining Proposal	Tables in report	2013	1
SWC Group	AMD Summary Report	Tables in report	2013	1
Terrenus Earth Sciences	Invincible Mining Proposal	Original laboratory results in report	2013	1
URS Australia	Review of Potential Issues at St Ives Gold Mines	Tables in report	2000	1
Western Mining Corporation	Paris Mine Soil report	Tables in report	1997	1

Figure 4-30
New Aquatic Invertebrate Taxa Recorded from Lake Lefroy and Peripheral Wetlands

LEGEND

Development Envelope

Potentially New/Undescribed and Restricted Taxa

- Calamoecia ampulla var. B01
- Eocyzicus sp. MWH01
- Ilyodromus sp. BOS1031
- Parartemia nr serventyi MWH01
- Parartemia sp.

0 3 6 9 12

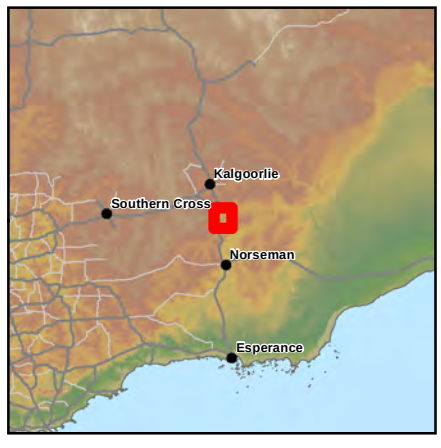
kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	B Harvey
Reviewed:	N King
Checked:	G Barrett
Project No:	TE16034
Revision:	B
Date:	27/09/2018

LOCALITY MAP



Document Path: \\server\Talis\SECTIONS\Environment\Projects\TE2016\TE16034 - SIGM B2018 EPA Process\10. GIS\Maps\ERD_Mapping\TE16034_ERD_4-30_NewAquaticInvertebrates_RevB.mxd

Mineralogical testing conducted in several studies over the SIGMC operations has provided some information on sulfur mineralogy present in the waste materials tested. Sulfide minerals identified in field descriptions and in x-ray diffraction testwork included pyrite, pyrrhotite and arsenopyrite (MEMi and O'Kane, 2005; SIGM internal site note on Geology). Sulfide mineral occurrence at St Ives is closely related to gold mineralisation, so it varies in type and distribution depending on the host lithology. It has been observed that sulfide mineralogy displays a zonation from north to south along strike of the mineralised shear zone. Where mineralisation is hosted in the lower units of the stratographic sequence, pyrite is dominant mineralogy. Moving upwards through the sequence, host rocks in the central parts of the sequence are dominated by pyrite-magnetite, while sulfide mineralogy in the southern mining areas, which are hosted in younger stratigraphies have higher proportions of pyrrhotite and arsenopyrite with pyrite (Connors et al., 2005; annotated in MEMi and O'Kane, 2005).

Mineralogical testwork conducted on various waste rock samples (geology not noted) found pyrite as a major sulfide mineral located in ore zones, with accessory amounts of pyrrhotite, chalcopyrite, marcasite, molybdenite, galena, and sphalerite. Secondary iron oxide and oxyhydroxide minerals were also detected (magnetite, ilmenite, goethite and haematite) (AMMTEC, 2002). Carbonate mineralogy included calcite, dolomite as well as silicate minerals (including clay minerals and feldspars) that provide minor acid neutralising properties compared to carbonate minerals (AMMTEC, 2002). On this basis, the estimation of risk of AMD generated from oxidation of pyrite is considered to be a reasonable approach to the evaluation of previous data sources (MWH 2016a). Although other sulfide minerals may be present, assessment based on the assumption that all sulfide minerals occur as pyrite is considered to be an appropriately conservative assumption (MWH 2016a).

For the purposes of the study, the assessment of AMD potential was conducted by lithology in order to identify data gaps and opportunities for optimisation of AMD characterisation in the future (MWH 2016a). This approach provides a site-wide approach to the understanding of AMD characteristics for rock types that are mined across several mining areas. Descriptions of the different lithologies is provided in Appendix P and the hierarchical and simplified classification of these lithologies was undertaken based on the GARD Guide (INAP, 2009) and the AMIRA International ARD Test Handbook (AMIRA, 2002) as summarised in Table 4-57 (MWH 2016a).

The assessment of impact due to release of metals and metalloids is traditionally conducted through the comparison of levels of total metals in solid materials, and leachable or dissolved metals in liquid materials to published guideline criteria developed for the purposes of assessing risk to ecological receptors (e.g. ANZECC 2000 Guidelines).

In the absence of reliable site specific background data, the guidelines generally recommend that impact to receptors in salt lake environments is assessed using marine water quality guidelines. The impact associated with solid components entering water bodies is assessed by comparison of total metals results to interim sediment quality guidelines (ISQG), which comprise two guideline values; low, and high. The low value indicates the concentration above which biological effects rarely occur, while the high value indicates the concentration above which biological effects would possibly occur. The ISQG values are generally considered to be conservative estimation of potential impact, but provide an indication of the levels at which metals and metalloids may be bioavailable (ANZECC, 2000).

Table 4-57: Classification Scheme for Identification of Potential AMD Risk

Hierarchy	ABA	NAGpH	%S	Classification
One	NAPP < 0 kg H_2SO_4/t	pH >4.5	<0.1	NAF - barren
			>0.1	NAF
		pH < 4.5	<0.1	Potentially NAF
			>0.1	UNC
	NAPP > 0 kg H_2SO_4/t	pH >4.5	<0.1	Potentially NAF
			>0.1	UNC
		pH < 4.5	>0.1 and <0.3	PAF – Low capacity
			>0.3	PAF – High capacity
Two	NAPP < -10 kg H_2SO_4/t	NA	>0.1	Potentially NAF
	NAPP between 0 and -10 kg H_2SO_4/t	NA	>0.1	UNC
	NAPP < 0 kg H_2SO_4/t	NA	<0.1	Potentially NAF
	NAPP > 0 kg H_2SO_4/t	NA	<0.1	Potentially NAF
		NA	>0.1	Potentially PAF

Previous research on Lake Lefroy has identified preliminary site specific background values for lake sediment and water quality (Dalcon 2010b). Dissolved or leachable metals concentration data are reported in few of the previous AMD reports; however, variable leaching ratios were used and different metals are reported and analysed in each case. Due to this variability in the data, MWH decided that the assessment of elevated metal potential would be assessed on a qualitative assessment of the total metals data provided in the SIGMC drillhole database (MWH 2016a). Due to the large amount of metal data provided in this database, the MWH study (2016a) focused on assessing the potential risk of elevated metals in sediment entering Lake Lefroy. The trigger levels are based on screening criteria developed using the reference sediment quality data and ISQG trigger values of those metal species that have the potential to accumulate in aquatic species, with a further limitation to metals that are likely to remain soluble at pH 6.0 to pH 8.0. This includes arsenic, chromium, copper, lead, selenium and zinc.

The lowest values from the three criteria (ISQC low and high and reference sediment data) were adopted as a trigger value. These are summarised in Table 4-58.

An overall assessment of AMD risk was determined by MWH (2016a) through examination of sample representation, pH, sulfide sulfur, ABA results, acid drainage potential classification (with a reliability assessment of the classification results) and elevated metals potential. In general, waste rock located near the mineralised zone is likely to have a higher risk of generating acid independent of the lithology (MWH 2016a). This is due to sulfide mineral distribution.

Specific lithologies that are identified as high risk are Kapai Slate and Cave Rocks Sediment. Lithologies that are identified as moderate risk are Cave Rocks Dolerite. Full results of the AMD risk assessment are summarised in Table 4-59 below. Further detail on the assessment process is provided in the MWH (2016a) report contained in Appendix P.

Table 4-58: Criteria for Assessment of Potential Risk Associated with Elevated Metals

Element	Reference Sediment Data (mg/kg)[10]	ISQG-Low (mg/kg)[11]	ISQG-High (mg/kg)[12]	Adopted Trigger Value (mg/kg)
Arsenic	9.3	20	70	9
Chromium	195.6	80	370	80
Copper	16.	65	270	16
Lead	<5	50	220	50
Selenium	<5	ND	ND	5
Zinc	29	200	410	29

Although Kapai Slate is identified as a high risk lithology, it has been known to have a potentially high risk with respect to AMD potential since 2000, and therefore, current site management practices have prioritised selective handling of the waste materials to be placed within open pit voids, or in core areas of WRLs. It also represents a small proportion of the mined materials at the site (5%). Figure 4-31 depicts the extent of the Kapai Slate which is considered to have the highest AMD risk within the Development Envelope.

Tertiary sediment is rated as low to moderate risk. The reliability of the data is low, due to the low proportion of NAG results reported. Some samples are classified as PAF, and although majority of samples have sulfide sulfur (majority of samples are classified as Barren), there is uncertainty around the acid generating characteristics of the samples with respect to sulfur mineralogy, nature of existing acid (where PAF samples have low NAG) and samples with conflicting NAPP and NAG results.

Sediment and dolerite from Cave Rocks is highlighted in the risk assessment as having moderate to high potential to generate acid, and also as having low reliability in classification, due to a high proportion of samples with a positive ABA, moderate to high sulfide sulfur and samples classified as PAF and UNC. The risk associated with potential acid generation in these lithologies is not well understood, and will be further defined as part of ongoing operations at Cave Rocks. These lithologies are located outside the Development Envelope and therefore the focus of B2018 Project is not with these lithologies but in the identification and testing of Kapai Slate and tertiary sediment.

[10] Represents 95th percentile low value (Dalcon 2010b)
[11] ISQG – Low: concentrations above which biological effects rarely occur
[12] ISQG – High: concentrations above which biological effects would possible occur
ND = no trigger value published

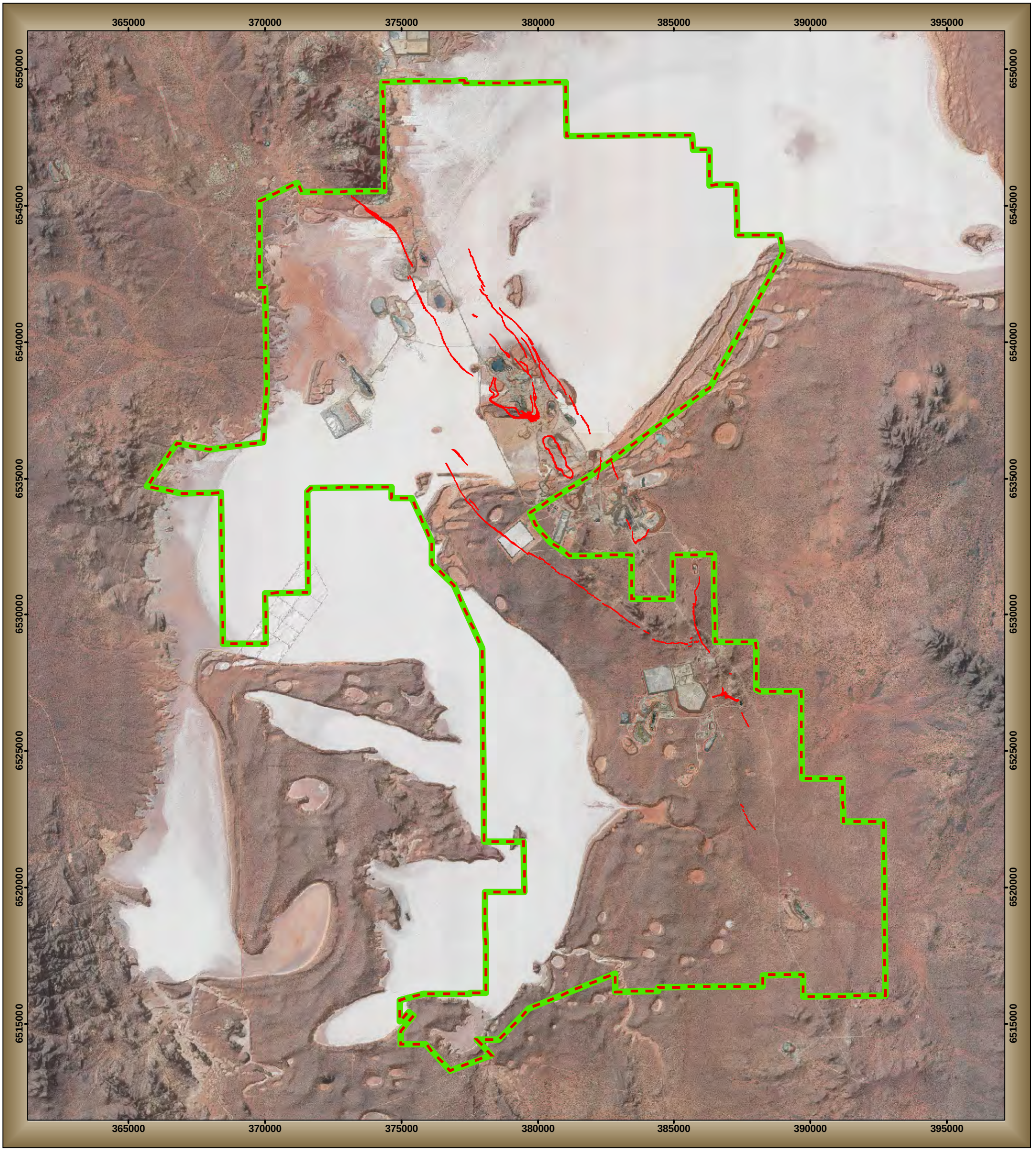
Table 4-59: Summary of Acid Drainage and Metals Risk Potential Results and Overall Assessment of AMD Risk by Lithology

Lithology	Sample representation	pH	Sulfide sulphur	ABA	Potential Acid Drainage Classification	Reliability in Classification	Elevated Metals Present	Overall AMD Risk
Lake Sediment	Good	Neutral	Barren	Negative	NAF	Good	Not determined	Low
Tertiary Sediment	Good	Neutral	Barren	Negative	NAF	Low	Not determined	Low - Moderate
Upper Saprolite	Good	Neutral to Slightly acidic	Barren	Negative	NAF	Good	Not determined	Low
Merougil Creek Beds	Low	Alkaline	Low	NP/AP >2	NAF	High	Cr, Cu, Zn	Low
Black Flag Beds	Good	Alkaline	Low	NP/AP >2	NAF	High	Cr, Cu, Zn	Low
Cave Rocks[13] Sediment	Good	Alkaline	High	Majority Positive	PAF	Low	Cr, Cu, Zn	High
Kapai Slate	Low	Neutral to Slightly acidic	High	Majority Positive	PAF	Good	Cr, Cu, Zn	High
Condenser Dolerite	Low	Alkaline	Low	NP/AP >2	NAF	Good	Not significant in reported data	Low
Defiance Dolerite	Good	Alkaline	Low	NP/AP >2	NAF	Good	Not significant in reported data	Low
Cave Rocks Dolerite[13]	Good	Alkaline	Moderate	Positive	NAF	Low	Not significant in reported data	Moderate
Devon Consols Basalt	Good	Alkaline	Low	NP/AP >2	NAF	Good	As, Cr, Cu, Zn	Low
Lunnon Basalt	Low	Alkaline	Moderate	NP/AP >2	NAF	High	As, Cr, Cu, Zn	Low - Moderate
Paringa Basalt	Low	Alkaline	Low - Barren	NP/AP >2	NAF	Good	As, Cr, Cu, Zn	Low
Tripod Hill Komatiite	Good	Alkaline	Moderate	Negative	NAF	Good	Cr, Cu, Zn	Low

[13] Found at Cave Rocks operations which is located outside the Development Envelope

Lithology	Sample representation	pH	Sulfide sulphur	ABA	Potential Acid Drainage Classification	Reliability in Classification	Elevated Metals Present	Overall AMD Risk
Felsic Intrusive	Good	Neutral to Slightly acidic	Low	Negative	NAF	Good	Cr, Cu, Zn	Low
Intermediate intrusive	Good	Alkaline	Low - Barren	Negative	NAF	Good	Cr, Cu, Zn	Low
Mafic Intrusion	Low	Alkaline	Moderate	Negative	NAF	Low	Cr, Cu, Zn	Low - Moderate
Tailings	Good	Neutral to Slightly acidic	Moderate	NP/AP >2	NAF	Good	As, Cr, Cu, Zn	Low

Figure 4-31
Locations of High AMD Risk Areas within the Development Envelope



LEGEND

Development Envelope

High AMD Risk Area

0 3 6 9 12

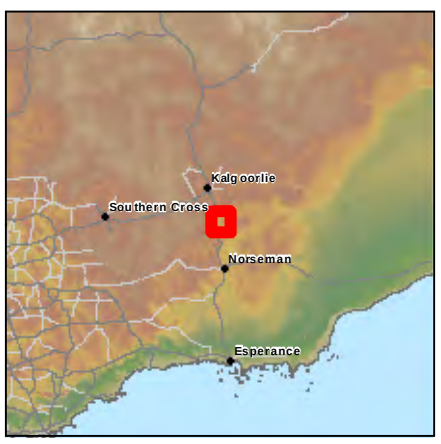
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	24/07/2018

LOCALITY MAP



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4.6.4 Potential Impacts

4.6.4.1 Direct disturbance to Lake Lefroy and peripheral wetlands

Direct disturbance to the surface of Lake Lefroy and its peripheral wetlands will further reduce habitat for aquatic biota. While the lake itself has been shown to be relatively depauperate in terms of biodiversity, the peripheral wetlands are more diverse and productive, and occupy a smaller area in comparison to the playa.

Whilst these wetlands are considered to be more biologically active than the lake, the data available indicates that such activity is typical and common of other waterbodies throughout other regions of WA including the Goldfields, Wheatbelt and Pilbara as well as presenting characteristics that are broadly represented on a national scale.

4.6.4.2 Discharge of potential contaminants to Lake Lefroy

Mine dewatering is discharged to turkey nest dams on the surface of Lake Lefroy. Monitoring around discharge points has been routinely conducted for many years. Hydrocarbons, dissolved metals, ammonium nitrate (from blasting) and sediment may occur in groundwater in open pit operations. Pit dewatering may result in these substances being discharged into the turkey nest dams. While the dams capture sediments, they are not constructed to be permanent water-holding facilities. Hypersaline water, together with any dissolved constituents, 'leaks' from the dams onto the lake surface where it evaporates. While the lake habitat around discharge points may be compromised, these discharge points occupy a very small proportion of the lake surface. However, there may be potential for contaminants to spread more widely across the lake surface where unrestricted discharge occurs, potentially reducing the quality of habitat in locations away from the discharge points.

4.6.4.3 Indirect disturbance to peripheral wetlands

No dewatering discharge occurs into peripheral wetlands and none is proposed in the Beyond 2018 Project. However, the ecology of the peripheral wetlands may also be subject to indirect impacts such as changes to the surface hydrology and or the hydrogeological regime (refer to section 4.5). There is also a risk of potential contaminants entering the peripheral wetlands via unmanaged runoff or seepage. These indirect impacts may for example alter drainage patterns, or the quality or quantity of runoff received by the peripheral wetlands.

4.6.4.4 Management of potentially acid-forming materials

If the generation of acidic, metalliferous, and/or acidic and metalliferous drainage is unmanaged, it has the potential to impact soil and water quality and degrade habitat in the surrounding environment. While SIGMC has identified materials with the potential to be acid-forming, they form a relatively small component of the total volume of waste rock (< 11%).

4.6.5 Assessment of Impacts

4.6.5.1 Overview of impacts

The Proposal may have an impact on particular environmental values of inland waters as defined in the EPA's factor guideline for inland waters environmental quality (EPA 2016e), outlined in Table 4-60.

Table 4-60: Inland waters environmental quality – relevant environmental values

Environmental value	Relevant to Proposal?	Comments
Wetlands which are Ramsar listed, Conservation Category, or listed in the Directory of Important Wetlands in Australia.	×	Lake Lefroy or associated peripheral wetlands do not have particular conservation status.
Wild and scenic rivers.	×	Do not occur.
Wetland types which may be poorly represented.	×	Salt lakes and associated peripheral wetlands occur throughout the region.
Natural springs and pools, particularly in arid areas.	×	No known examples.
Ecosystems which support conservation significant flora/vegetation and fauna species or communities, including migratory waterbirds and subterranean fauna.	✓	Wetlands peripheral to Lake Lefroy support intermittent aquatic communities. Lake Lefroy itself has substantially lower values.

A broad risk assessment was also completed by Stantec (2018a), as part of the ecological assessment of Lake Lefroy and its peripheral wetlands (Appendix O). Risk was assessed according to the direct and indirect impacts, on the basis of the ecological values. The ecological values of the lake were lower (due to existing salt loading and historic impacts), in comparison to the peripheral wetlands, which appear to be of greater ecological significance.

4.6.5.2 Direct disturbance to Lake Lefroy and peripheral wetlands

Disturbance to the surface of Lake Lefroy, primarily through mining, has reduced the area of habitat available for aquatic biota. Table 4-61 compares the extent of current disturbance to the lake area (excluding peripheral wetlands), with the approved cumulative disturbance area approved to date and that planned for the B2018 Project.

With the disturbance proposed under the B2018 Project, a total of up to 46 km^2 (8.3%) of the lake surface will be directly disturbed (Table 4-61). This may be a slight underestimate as additional salt crust accumulation around the discharge points may also reduce the effective habitat available. However, if the area affected by dewatering discharge is estimated at 10 km^2, the overall impact on the lake surface remains at approximately 10%. This should provide sufficient lake habitat for basic ecological processes to be maintained, provided key areas such as the northern and southern extremities (which are relatively intact) and the riparian zone, are not disproportionately affected.

Table 4-61: Lake Lefroy – existing and approved disturbance compared with B2018 Project

Disturbance	Actual to date (km^2)	% of lake surface	Approved to date (km^2)	% of lake surface	Approved to date plus B2018 Project (km^2)	% of lake surface
SIGMC operations	14.5	2.6	20.6	3.7	40.6	7.3
Salt harvesting ponds (inactive)	5.4	1.0	5.4	1.0	5.4	1.0
Total	**19.9**	**3.6**	**26**	**4.7**	**46**	**8.3**

Note: Total area of Lake Lefroy is 552.4 km^2.

SIGMC has mapped a total extent of 2103.2 ha of peripheral wetlands within a zone of approximately 2 km around the playa (Figure 4-32; Table 4-62). Some of these wetlands have already been lost during the early stages of mine development at St Ives, however the majority remain. Of the remaining wetlands, a total of 1002.0 ha (47.6 %) occurs within the B2018 Project Development Envelope.

While the peripheral wetlands are known to have a higher ecological value than the lake (and are therefore at greater risk), the studies completed to date have sampled most of the wetlands within the Development Envelope and some regional wetlands. The results have shown that of the new aquatic invertebrate taxa recorded, none were restricted to within the Development Envelope for the B2018 Project, and have been recorded from the broader lake environment, or occur in the wider Goldfields region and beyond (including Wheatbelt, Pilbara and more broadly across Australia). This demonstrates that, whilst the peripheral wetlands might be considered to be more biologically active than the lake itself, the relative scale of activity is not unusual and certainly not considered to be significant or a concern in terms of impacts given the broad distribution of species within the state and nationally.

Notwithstanding the above, SIGMC has taken a conservative approach to the protection of peripheral wetlands and has determined that mitigation of impacts (limited as they might be) should occur via the development of exclusion zones and the maintenance of peripheral wetlands in the broader area. Whilst SIGMC is of the view that there will be no significant impact to the lake or its peripheral wetlands' ecological values, the inclusion of these measures as part of the B2018 project will assist in maintaining biodiversity and ecological function.

4.6.5.3 Discharge of potential contaminants to Lake Lefroy

There is little evidence that the dewatering discharge to Lake Lefroy has resulted in any significant impact to water quality on Lake Lefroy, with the exception of elevated salinity (section 4.5). The potential for salt encrustation arising from discharge of hypersaline groundwater from the B2018 Project is primarily expected to occur in the central and westernmost parts of the lake (in close proximity to discharge points). It is not expected that the northern and southern extremities of the lake will be impacted, where aquatic habitat currently remains relatively intact (Stantec 2018a).

As existing salt loads on the playa are already considered substantial, additional contributions from the B2018 Project dewater discharge will not cause any further adverse effects outside of the current lake status (Stantec 2018a). In addition, the high salinity, clay content and natural mineralisation associated with the lake environment indicate that any potential metal contaminants will remain immobilised and biologically unavailable, by forming stable and

insoluble compounds. Therefore, metals are unlikely to pose a risk to aquatic biota within the playa (Stantec 2018a).

Current water monitoring and the practice of pre-treatment via a turkey nest on the surface of the lake should also continue, prior to discharge onto Lake Lefroy. Some risks remain – hydrocarbon spillage and AMD within pits that are actively being dewatered (see section 4.6.5.4) has the potential for poor quality water to be indirectly discharged to the lake surface if not appropriately monitored.

4.6.5.4 Management of potentially acid-forming materials

The majority of waste rock at SIGMC is not acid-forming. However, two lithologies, Kapai Slate and Cave Rocks Sediments, are known to be acid-forming and several others have some potential to oxidise and produce acid drainage. Regardless, there is expected to be limited risk to the lake and peripheral wetlands from potentially acid-forming material associated with the B2018 Project, with appropriate management in place.

The Mine Closure Plan (MWH 2016d) acknowledges some historical instances where acid-forming waste rock has not been contained. Instances of this, while not common, have been scheduled for remedial works. Current management practices involve identification and selective handling of the 'risk' waste materials, with placement within open pit voids or in core areas of WRLs. The AMD Optimisation Study (Appendix P) concluded that "current management practices and procedures in place at SIGM are considered to be at a standard that is consistent with current industry practice and appropriate for the management of AMD risk at the site". The same study also recommended further work to refine the AMD risk assessment, including ongoing testwork to understand longer lag-time AMD characteristics.

4.6.6 Mitigation

The assessment considered direct disturbance and loss of habitat to both the surface of Lake Lefroy and separately to peripheral wetlands within a few kilometres of the main body of the lake. The assessment concluded that ecological processes should be maintained within the lake, although some commitments have been made to adopt a more structured approach to the construction and operation of dewatering discharge structures (section 4.5.6, Commitment 6) to ensure that metal content in discharge water is minimised, and the potential for impacts on the riparian zone and the location and extent of salt crust formation are considered.

The ecological value of peripheral wetlands distributed around the margins of Lake Lefroy has been quantified and has been found to be broadly consistent with similar systems throughout WA and indeed nationally. Almost half of the existing peripheral wetlands occur within the Development Envelope, the studies have found that their ecological values, whilst greater than Lake Lefroy's, are not considered to be locally or regionally significant as there is broad representation of their ecology in the Goldfields and wider localities. Notwithstanding this, SIGMC proposes that the exclusion zones developed for the further protection of biodiversity can also be used to protect peripheral wetlands (sections 4.2 and 4.3). Figure 4-32 shows all peripheral wetlands occurring within 2 to 2.5 km of Lake Lefroy. While almost half of the peripheral wetlands occur within the Development Envelope, a significant proportion (617.1 ha) falls within the Exploration 1, Pistol Club West, and Implacable exclusion zones (Table 4-62). The potential for direct impacts falls to 18.3 % when exclusion zones are applied. This will be adequate to ensure ecological function and biodiversity is maintained, with no expected loss of the newly described aquatic invertebrate taxa from the B2018 Project and particularly considering the high connectivity of surface water throughout the area during major flood events meaning it is unlikely that any new taxa would be confined to a single wetland on the lake's periphery.

Table 4-62: Proposed Disturbance to Peripheral Wetlands – Effect of Exclusion Zones under the B2018 Project

Location	No Exclusion Zones (ha)	%	Exclusion Zones applied (ha)	%
Inside Development Envelope (not protected)	1002	47.6	384.9	18.3
Inside Development Envelope (protected)	0	0.0	617.1	29.3
Outside Development Envelope	1101.2	52.4	1101.2	52.4
Total	**2103.2**	**100**	**2103.2**	**100**

While there is a strong understanding of the aquatic biota likely to occur in these areas on which to base an impact assessment, further investigation of peripheral wetlands will continue to assess productivity and biodiversity under flood conditions, should these conditions occur during the project's life. The investigations will incorporate playa areas north of Lake Lefroy and potentially regionally, to provide additional context on ecological values.

Historically, the discharge of sediment (as suspended solids) and other constituents within dewatering discharge water has not been significant. This is not expected to change in the future, or for the B2018 Project, provided the current management measures are maintained.

There are some risks associated with indirect impacts to peripheral wetlands. While no peripheral wetland will be used for dewatering discharge, mine developments occurring within the same sub-catchment could alter the runoff received by individual wetlands. This will continue to be considered as part of SIGMC's Surface Disturbance Permit Procedure process and measures identified to ensure surface water movement within subcatchments containing peripheral wetlands are maintained.

Similarly, the existing AMD management practices will be appropriate but will also be refined to provide for additional testing to better understand lag times in potential AMD reactions. In relation potentially acid forming waste material it is expected that this will be backfilled into underground or open pits (land-based), placed below the water-table of lake-based open pits to prevent oxidisation of sulfide minerals in material, or encapsulated with benign, non-acid producing, or acid consuming materials above the lake surface. This is expected to minimise the risk of potential runoff or seepage into the lake or peripheral wetlands.

Lake-based disturbance under the Beyond 2018 Project is limited to an additional 2,000 ha. SIGMC also proposes the mitigation measures as outlined in Table 4-61. These align with the EPA's mitigation hierarchy.

Figure 4-32
Peripheral Wetlands and Monitoring Sites

GOLD FIELDS
ST IVES GOLD MINE

360000 365000 370000 375000 380000 385000 390000 395000 400000 405000

6555000 6550000 6545000 6540000 6535000 6530000 6525000 6520000 6515000 6510000

LEGEND

Development Envelope

Potentially New and/or Restricted Taxa

- Calamoecia ampulla var. B01
- Eocyzicus sp. MWH01
- Ilyodromus sp. BOS1031
- Parartemia nr serventyi MWH01
- Parartemia sp.

Peripheral Wetlands

- B2018
- Exclusion Zone
- Lake Lefroy ~2km Buffer
- Exclusion Areas
- Aquatic Survey Sites 1999 to 2018

0 4 8 12 16

Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	G Barrett
Project No:	TE16034
Revision:	A
Date:	24/07/2018

LOCALITY MAP

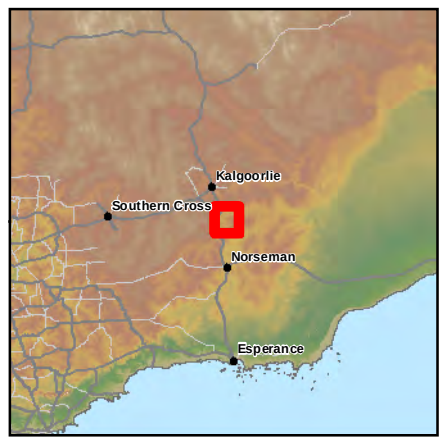

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Table 4-63: Predicted Impacts and Mitigation Strategies for Inland Waters Environmental Quality

Predicted Impact from the B2018 Project	Mitigation Hierarchy	Mitigation
Direct disturbance to peripheral wetlands	Avoid	To protect peripheral wetlands, establish three exclusion zones – Exploration 1, Pistol Club West and Implacable - within the Development Envelope within which no mine-related activities may occur (Commitment 8).
Direct disturbance to peripheral wetlands	Avoid/Minimise	Continue to refine datasets to progress the understanding the ecological values of the peripheral wetlands and the lake within a regional context (Commitment 9).
Discharge of potential contaminants to Lake Lefroy	Minimise	Maintain an annual ecological monitoring program for all dewatering discharge to the surface of Lake Lefroy. This activity can be managed under Part V of the *Environmental Protection Act 1986*.
Indirect disturbance to peripheral wetlands	Avoid/Minimise	Incorporate an assessment of potential subcatchment drainage impacts into the Surface Disturbance Permit Procedure and develop appropriate management measures. This activity can be managed under the *Mining Act 1978*.
Management of potentially acid-forming materials	Avoid/ Minimise	Maintain implementation of existing management practices whereby risk materials are identified and placed within open pit voids or in core areas of WRLs. These activities can be managed under the *Mining Act 1978*.
Management of potentially acid-forming materials	Avoid/ Minimise	Undertake further work to refine the AMD risk assessment, including ongoing testwork to understand longer lag-time AMD characteristics. These activities can be managed under the *Mining Act 1978*.

The following commitments are made with respect to Inland Water.

Commitment 8: To protect peripheral wetlands, establish three exclusion zones – Exploration 1, Pistol Club West and Implacable - within the Development Envelope within which no mine-related activities may occur.

Commitment 9: Continue to refine datasets to progress the understanding the ecological values of the peripheral wetlands and the lake within a regional context.

Note also that Commitment 5 is also relevant to this factor, as discussed in section 4.5. This Commitment requires a dewatering discharge strategy to be developed for each new open pit operation, including a more systematic approach to the construction and operation of dewatering discharge structures. This will reduce the potential for sediments to reach the lake environment outside of these structures. There is also a measure identified to look at the viability of removal of salt crusts associated with dewatering discharge structures at closure.

4.6.7 Predicted Outcome

SIGMC considers that EPA's objective for Inland Waters Environmental Quality to '*maintain the quality of the groundwater and surface water so that environmental values are protected*' can be achieved. The following outcomes are predicted:

- No impact to any wetlands which are Ramsar-listed, Conservation Category, or listed in the Directory of Important Wetlands in Australia;
- While peripheral wetlands around the main playa of Lake Lefroy are significantly more biodiverse than the lake itself, the function and representation of these wetlands is common within the Goldfields, Wheatbelt, Pilbara and more widely. These values will be maintained as over 80% occur either outside the Development Envelope or in exclusion zones within the Development Envelope;
- No expected impact to new described aquatic biota as none is limited to the Development Envelope; and
- There is some potential for acid production as waste rock oxidises but the proportion of waste rock with acid-forming potential is small and readily managed.

By implementing the management measures detailed above, the residual impact is not considered significant and no offsets are being proposed.

5 OTHER ENVIRONMENTAL FACTORS OR MATTERS

During the assessment of the proposals, EPA often identifies other environmental factors or matters as relevant to a proposal. These factors are not significant enough to warrant full assessment by the EPA or can be regulated through other regulatory processes and agencies to meet the EPA's objectives. For SIGMC's proposal the other environmental factors or matters identified include:

- Social Surroundings (Heritage);
- Social Surroundings (Amenity);
    - Recreational Land Sailing
    - Visual Amenity
    - Noise; and
- Air Quality (Greenhouse Gas (GHG) Emissions).

Social Surroundings (Heritage) is referring to the potential for new Aboriginal heritage sites to be located within the proposed disturbance area, whereas Social Surroundings (Amenity) has been listed in relation to impacts to visual amenity, noise and the recreational land sailing club and their access to lake. EPA has also requested an annual GHG emission estimate as a result of the proposal.

It is also important to recognise that for the purposes of the definition of environment within the EP Act, the social surroundings of man are his aesthetic, cultural, economic and social surroundings to the extent that those surroundings directly affect or are affected by his physical or biological surroundings (Subsection 3(2) of the EP Act). This suggests that there is the potential for the benefit that the operations associated with SIGMC brings to local stakeholders and the community of Kambalda to be considered in terms of an impact should the B2018 Project not proceed. The B2018 Project needs to also be considered in that light, noting that there are many positive benefits brought to these stakeholders by the project in terms of their economic and social surroundings (refer to Sections 2 and 3 for further information).

Such consideration is discussion within the DPE (2017) "Social Impact Assessment Guideline" whereby the positive impacts are afforded an opportunity to be considered against the negative. Whilst this is not explicitly considered within the EPA's guidance, the EP Act arguably allows for such consideration to occur. The commentary in the following sections should therefore be considered in light of these potential positive impacts.

5.1 Social Surroundings (Heritage)

5.1.1 EPA Objective

The EPA's environmental objective for the factor Social Surroundings is:

To protect social surroundings from significant harm.

5.1.2 Policy and Guidance

The following policies and guidelines apply to Social Surroundings (Heritage):

- EPA Environmental Factor Guideline - Social surroundings (EPA 2016f).

5.1.3 Receiving Environment

Surveys undertaken

The Development Envelope has been extensively surveyed for Aboriginal heritage values over the years. Prior to a survey conducted for the B2018 Project, a total of 35 archaeological and ethnographical surveys were conducted throughout and in the vicinity of B2018 Development Envelope. These surveys are summarised in Table 5-1.The scopes of previous surveys have varied considerably and were also influenced by the requirements of the former Department of Aboriginal Affairs (DAA) and heritage assessment standards of the time. To address this, an assessment was undertaken to determine the confidence level of these surveys categorising the surveys as being either high, medium or low confidence. Only the areas categorised as medium or low were revisited as part of the recent survey undertaken by Dortch & Cuthbert Pty Ltd. (2017).

A review of previous archaeological research helps predict the locations and assess the significance of archaeological sites. Relatively little archaeological research has been conducted in the southern Goldfields region to date, resulting in a paucity of detailed information on the nature and chronology of Aboriginal occupation of the area (Dortch & Cuthbert Pty Ltd. 2017). The State's listing of Aboriginal Sites and Other Heritage Places includes around 139 heritage places (including 60 registered sites) in the Ngadju native title determination area (c.100,000 km^2). The majority of these sites and places has been recorded as a result of heritage surveys commissioned in advance of mining and other developments. This work has not been collated or synthesised in any form (Dortch & Cuthbert Pty Ltd. 2017).

Ethnographic evidence from these adjoining regions indicates that past Aboriginal hunter-gatherers of the arid interior of WA followed a nomadic lifestyle with high residential mobility. Archaeological research in the arid interior of WA and on the Nullarbor Plain suggests that occupation of the southern Goldfields region was relatively sparse until the middle Holocene (5000-7000 years ago) (Marun 1972, Martin 1973, O'Connor & Veth 1996, O'Connor et al. 1998, Thorley 1998). Environmental conditions at this time appear to have improved as a result of increased rainfall (Wyrwoll 1979). Similarly, the archaeological record of occupation of inland lakes in the arid region suggests that Aboriginal use of these locations intensified during the late Holocene (McNiven 1998). It is likely that the occupation of these areas depended on heavy rainfalls around such lakes (Williams 1988) and the resultant presence of migratory birds. This suggests that occupation of archaeological sites around arid zone lakes may have been intermittent and intensive only during seasons when the lakes filled. At other times ancestors of the Ngadju may have occupied the area in smaller groups relying on smaller water sources such as gnamma holes (Smith 1994).

Historic observations post-dating the 1893 gold rush, in which thousands of non-Aboriginal people settled the region, confirm the impression of mobility among the Ngadju. They also indicate that Ngadju people continued to occupy traditional country after European colonisation, by finding work on sheep stations, and continuing to use traditional resources (Smith 1994).

Surveys undertaken over the Priority 1 survey area indicate small artefact concentrations are typical for the area and surrounding land. Average site density is c.0.65 sites/km^2, or 1 site every 1.53 km^2. This is a relatively low site density compared to other parts of WA and possibly reflects the low density of water and plant resources in the areas surveyed. Ngadju informants indicate that the survey areas are good for game resources. Apart from one modified tree, the sites are concentrations of stone artefacts mostly reflecting relatively short-lived occupation episodes, consistent with arid zone occupation patterns in locations distant from water sources. The artefacts are usually made of chert and quartz, both outcropping locally. Larger sites suggesting more intensive occupation are likely to be found at larger or more permanent water sources – seemingly absent in the SIGMC tenements surveyed to date (Dortch & Cuthbert Pty Ltd. 2017).

Table 5-1: Summary of Ethnographic and Archaeological Surveys Completed within Development Envelope to Date

Date	Survey location	Report Title	Consultant	Survey Type	Confidence rating (SIGMC)	No. of sites found	Registered or Lodged Site? DPLH?
Feb-97	Expansion Project Area	Archaeological Survey of the St Ives Expansion Project Area	Archae-aus (Hook 1997)	Archaeological	Low	10	No
Feb-97	Expansion Project Area	Ethnographic Report of an Aboriginal Heritage Assessment (Murdeeu) of St Ives Expansion Project Area	Consultant Anthropologist Daniel de Gand	Ethnographic	Low	0	No
Mar-97	TSF3 Project Area	Archaeological Survey of St Ives Gold Proposed TSF3 Project Area	Archae-aus (Hook et al. 1997)	Archaeological	Low	1	No
Mar-97	Expansion Project Area	Ethnographic Report of an Aboriginal Heritage Assessment (Ngadju) of St Ives Expansion Project Area	Consultant Anthropologist Daniel de Gand	Ethnographic	Low	0	No
May-97	Expansion Project Area	Ethnographic Report of an Aboriginal Heritage Assessment of St Ives Expansion Project Area	Consultant Anthropologist Daniel de Gand	Ethnographic	Low	0	No
Jul-97	Kambalda Nickel and St Ives Gold Operations	Ethnographic Survey at the Kambalda Nickel and St Ives Gold Operation Areas	Ken Macintyre of Macintyre Dobson and Associates	Ethnographic	Low	5	No

Date	Survey location	Report Title	Consultant	Survey Type	Confidence rating (SIGMC)	No. of sites found	Registered or Lodged Site? DPLH?
Feb-98	Kambalda Nickel operations	Ethnographic Field Inspection (Kalaako People) of WMC and St Ives Gold Leases	John Gleason (1998a)	Ethnographic	Low	0	No
Sep-98	Kambalda Nickel operations and St Ives Gold Leases	Ethnographic Field Inspection (Karonie People) of WMC and St Ives Leases	John Gleason (1998b)	Ethnographic	Low	2	No
Oct-98	WMC and St Ives Leases	Enthographic Field Inspection (Murdeeu People) of WMC and St Ives Leases	John Gleason (1998c)	Ethnographic	Low	0	No
Nov-98	Heap Leach Project - Desktop	Archaeological and Ethnographic Heritage Asessment - SIG Heap Leach Project	John Gleason (1998d)	Archaeological, Ethnographic	Low	NA – desktop	No
Dec-99	Argo, North Orchin, Leviathan	St Ives Gold Argo, North Orchin and Leviathan Open Pits - Aboriginal Heritage Issues	John Gleason (1999)	Archaeological, Ethnographic	Low	0	No
Jan-02	Kambalda West Project	Supplementary Enthographic Survey of New Hampton Goldfields NL Kambalda West Project	R. and E.O'Connor Pty Ltd (2002)	Ethnographic	Low	0	No

Date	Survey location	Report Title	Consultant	Survey Type	Confidence rating (SIGMC)	No. of sites found	Registered or Lodged Site? DPLH?
May-03	Desktop - Within ML15/198, ML 15/320, ML 15/321	Desktop Study of Proposed St Ives Gold Plant, Located within ML15/198, ML15/320 and ML15/321	Wayne Glendenning (2003a)	Archaeological, Ethnographic	Low	NA desktop	No
Jun-03	Within ML15/320, ML15/321, ML15/193, ML15/268	Archaeological Survey of Proposed St Ives Gold Treatment Plant	Wayne Glendenning (2003b)	Archaeological	Low	0	No
Dec-05	TSF-4 East, TSF4-West, Leviathan, Nelson's Fleet	Heritage Survey of TSF-4 East, TSF-4 West, Leviathan and Nelson's Fleet Project Area	Western Heritage Research Pty Ltd (Glendenning 2005)	Archaeological, Ethnographic	Low	2	Yes
Jun-08	E15/288, E15/306, E15/320, E15/388, E15/3702, E15/3703, E15/698, M15/719, M15/843, P15/3594, P15/4663	Aboriginal Heritage Survey of BHPB Billiton Nickel West Tenements, Woolibar Station, Kambalda WA	Deep Woods Surveys (WA) Pty Ltd	Archaeological, Ethnographic	Medium	5	No
Jul-08	E15/288, E15/338, P15/3702	Ethnographic Survey of BHPB Billiton Nickel West Tenements, Woolibar Station WA	Deep Woods Surveys (WA) Pty Ltd	Ethnographic	Medium	0	No
Jan-09	Triple A Development Area	Aboriginal Heritage Survey of the St Ives Gold Mine 'Triple A' Development Area, Kambalda WA	Deep Woods Surveys (WA) Pty Ltd (Cue and Greenfeld 2009)	Archaeological, Ethnographic	Medium	1	No

Date	Survey location	Report Title	Consultant	Survey Type	Confidence rating (SIGMC)	No. of sites found	Registered or Lodged Site? DPLH?
Mar-09	Athena Project (M15/1595)	Ethnographic Heritage Survey St Ives Athena Project (Ngadju People)	Goldfields Land and Sea Council	Ethnographic	Medium	0	No
Dec-09	Bellerophon, Clifton/Blue Lode, Diana, Junction, Idough, Lake Based Projects	Heritage Survey (Widji) of Bellerophon, Clifton/Blue Lode, Diana, Junction, Idough and Lake Project	Deep Woods Surveys (WA) Pty Ltd (Cue et al. 2009a, b)	Archaeological, Ethnographic	Medium	6	Yes
Dec-09	Bellerophon, Clifton/Blue Lode, Diana, Junction, Idough, Lake Based Projects	Heritage Survey (Ngadju) of Bellerophon, Clifton/Blue Lode, Diana, Junction, Idough and Lake Project	Deep Woods Surveys (WA) Pty Ltd (Cue et al. 2009a, b)	Archaeological, Ethnographic	Medium	6	Yes
May-11	Lake Lefroy Riparian Zone, Bellerophon Expansion, Gulf Expansion, 66KV Extension	Heritage survey of St Ives GM Lake Lefroy Riparian Zone, Bellerophon and Gulf Expansion and 66KV Ext	Deep Woods Surveys (WA) Pty Ltd (Cue and Greenfeld 2011)	Archaeological, Ethnographic	Medium	2	No
Jun-11	Ethnographic - Bellerophon Expansion, Gulf Expansion, 66KV Extension	Heritage survey of St Ives Bellerophon and Gulf Expansion and 66KV Extension Projects	Outback Heritage Consulting (Barrett 2011)	Archaeological, Ethnographic	Medium	3	No
Sep-11	Bellerophon Expansion, Gulf Expansion, 66KV Extension	Clearance Survey of the Proposed Extension Programs at St Ives Gold Mine	Terra Rosa Cultural Resource Management (Monks and Chisholm 2011)	Archaeological	Medium	2	No

Date	Survey location	Report Title	Consultant	Survey Type	Confidence rating (SIGMC)	No. of sites found	Registered or Lodged Site? DPLH?
Feb-12	Southern and Central Heron Leases	Ethnographic Heritage Survey for St Ives Gold Mine - Southern and Central Heron Leases	Outback Heritage Consulting	Ethnographic	Medium	16	No
Apr-12	Cave Rocks Dewatering Line	Ethnographic Heritage Survey St Ives Gold Mine Cave Rocks Dewatering Line	Outback Heritage Consulting	Ethnographic	Medium	0	No
Apr-12	Cave Rocks Dewatering Pipeline	Heritage Survey of St Ives Gold Mine Cave Rocks Dewatering Pipeline, Kambalda WA	Deep Woods Surveys (WA) Pty Ltd	Archaeological, Ethnographic	Medium	0	No
Jan-13	Cave Rocks, Heron Leases	Clearance Heritage Survey of Cave Rocks and Ethnographic Survey of Heron Leases	Terra Rosa Cultural Resource Management	Archaeological, Ethnographic	High	4	No
Sep-13	SIGM Kambalda West Tenements	Desktop Heritage Assessment SIGM Kambalda West Tenements	Terra Rosa Cultural Resource Management	Archaeological, Ethnographic	High	N/A-desktop	No
Dec-14	Caves West, White Dam, Survey Dam, Lonely Island, Epis, Depot Granite	Archaeological and Ethnographic Heritage Assessment of Kambalda West Project Area	Terra Rosa Cultural Resource Management	Archaeological, Ethnographic	High	10	No
Sep-15	Pistol Club Mine Area	Archeaological and Ethnographic Site Identification Survey of the Pistol Club Area	Terra Rosa Widji & Kalamaia Archaeo-Ethno	Archaeological, Ethnographic	High	3	Yes

Date	Survey location	Report Title	Consultant	Survey Type	Confidence rating (SIGMC)	No. of sites found	Registered or Lodged Site? DPLH?
Oct-15	M15/1802, Pistol Club	Archaeological Site Identification Survey and Site Assessment - Lake Lefroy and Pistol Club	Dortch and Cuthbert Pty Ltd	Archaeological	High	0	No
Oct-15	M15/1802, Pistol Club	Anthropological Heritage Survey Work Area Clearance and Site Identification - M15/1802 and Pistol Club	Dr James Taylor	Ethnographic	High	0	No
May-16	Beyond 2016 Survey Area	Archaeological and Ethnographic Site Identification Heritage Survey Beyond 2016 Survey Area	Terra Rosa Cultural Resource Management	Archaeological, Ethnographic	High	0	No
Jul-16	Beyond 2016 Survey Area	Anthropological Heritage Survey Site Identification Survey Beyond 2016 Project	Dr James Taylor	Ethnographic	High	0	No
Sept-17	Various	Archaeological Site Avoidance Survey on Gold Fields St Ives Gold Mine Tenement	Dortch and Cuthbert Pty Ltd	Archaeological	High	1	No

*Registered

These areas lie in the Ngadju Peoples (Ngadju) native title determination boundary (WCD2014/004; WAD6020/1998).

Registered Aboriginal Heritage Places

A search was undertaken on the Department of Planning, Lands and Heritage (DPLH) Aboriginal Heritage Inquiry System (AHIS). The results show that there are five known heritage places within the B2018 Development Envelope. These are listed below in Table 5-2 and shown in Figure 5-1.

Table 5-2: Registered Aboriginal Heritage Places (DPLH 2017)

Place ID	Name	Status	Type
16016[14]	KAMBALDA	Registered Site	Artefacts / Scatter
19180	Kambalda Site	Other Heritage Place	Artefacts / Scatter, Quarry, Arch Deposit, Natural Feature, Water Source
22940[15]	TSF4 East 1	Other Heritage Place	Artefacts / Scatter
22941[2]	TSF4 East 2	Other Heritage Place	Artefacts / Scatter
22942	TSF4 East Isolated Finds	Other Heritage Place	Artefacts / Scatter

Other Heritage Sites

One heritage site of significance (Jarramur 1) has been identified within the Development Envelope (Figure 5-1). Jarramur 1, an artefact scatter, is not listed on the Register of Places and Objects administered by DPLH. However, the scatter is "the product of practices connected to the traditional cultural life of Aboriginal people and may be considered to be of cultural and archaeological importance. As such, it may be considered an Aboriginal site under section 5 of the *Aboriginal Heritage Act 1972*" (Dortch and Cuthbert 2017). In addition to Jarramur 1, approximately 80 other sites have been recorded in surveys and are listed by SIGMC but are not considered to be Aboriginal Sites. A register of all identified sites is maintained by SIGMC Environment Department.

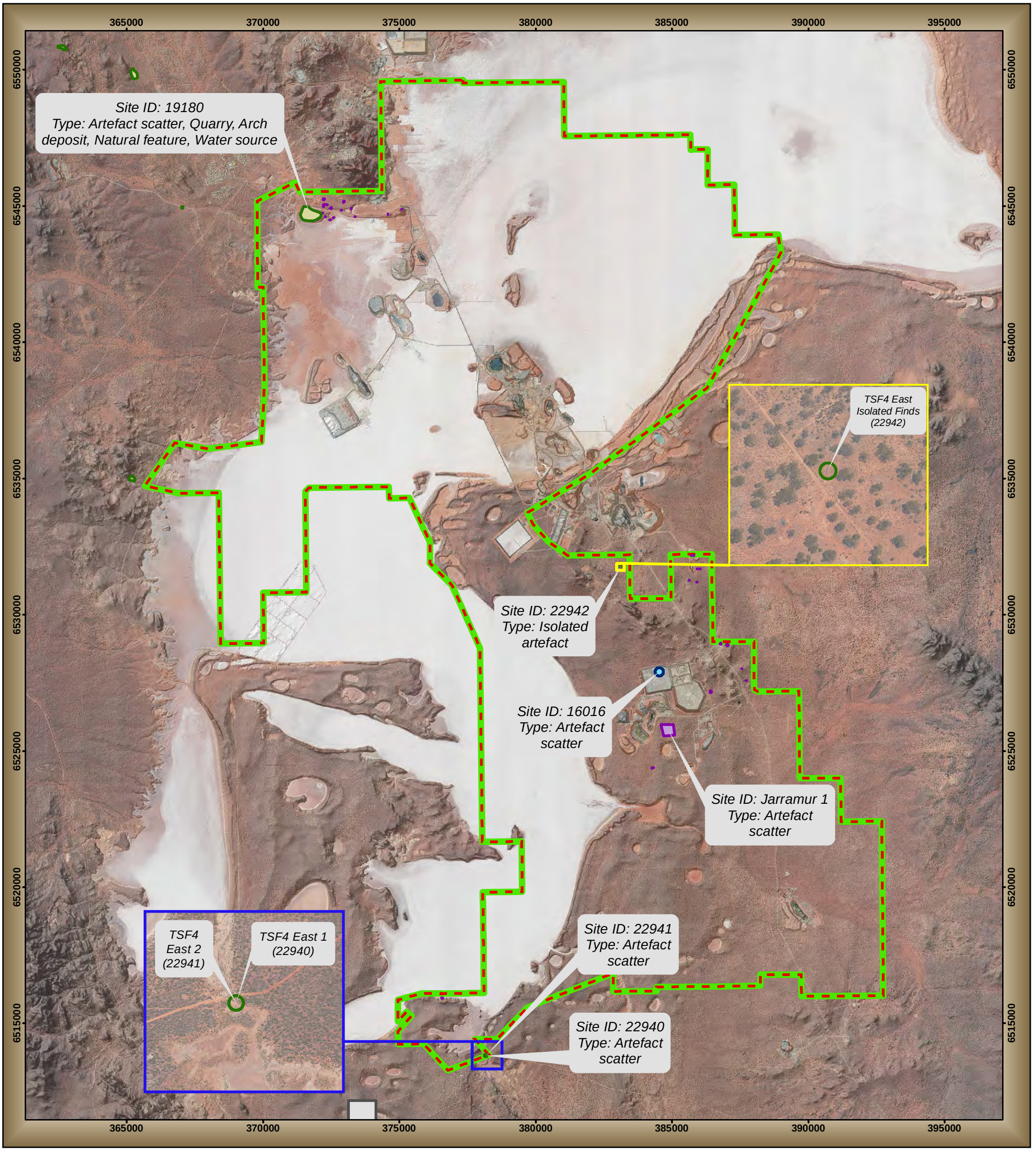
There is a range of site types in the wider Goldfields region, which may be represented in or near the Development Envelope. These are likely to include concentrations of stone artefacts on undisturbed surfaces and possibly below surface as well. Archaeological, ethnographic and historic evidence points to the dunes bordering Lake Lefroy being used for camping and foraging by Aboriginal groups ancestral to the Ngadju people and neighbouring groups (Dortch & Cuthbert Pty Ltd. 2017).

[14] SIGMC has sent a request to DPLH to review the site 16016 in 31 January 2017. This heritage site was removed in early 2000 as part of the ground disturbance for TSF3. Approval to disturb an Aboriginal Heritage site was appropriately processed at the time via Section 18 of the AH Act. Consequently SIGMC has requested that Aboriginal Cultural Material Committee reassess the site so the status can be changed from 'Registered' to 'Stored Data'.

[15] The coordinates for the sites lodged as part of the TSF4 construction (22940, 22941 and 22942) appear to be incorrect. It is noted that TSF4 East 1 and 2 are located 19 km south of the TSF4 and well outside the heritage survey area for TSF4. The coordinates in the AHIS match the ones provided in the report (Glendenning 2005) so these coordinates are recorded incorrectly in the report.

Figure 5-1
Aboriginal Heritage Places

GOLD FIELDS
ST IVES GOLD MINE



LEGEND

SIGMC Heritage Places

Status

- Registered Site (DPLH Database)
- Other Heritage Place (DPLH Database)
- Identified but not on DPLH Database
- Development Envelope

0 3 6 9 12

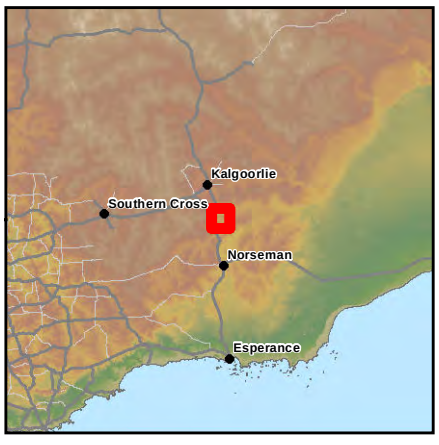
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	B
Date:	31/01/2018

LOCALITY MAP



Document Path: \\server\Talis\SECTIONS\Environment\Projects\TE2016\TE16034 - SIGM B2018 EPA Process\10. GIS\Maps\ERD_Mapping\TE16034_ERD_5-1_AboriginalHeritage_RevB.mxd

5.1.4 Potential Impacts

The ground disturbance associated with the proposed B2018 Project may have an impact on the previously undisturbed, undiscovered or in situ archaeological deposits. The proposed development involves earth-moving machinery excavating and grading within various areas to build mine infrastructure. Most earth-moving activities that may be proposed would constitute a major impact on any archaeological remains at or near surface because such material, if it is present, would either be damaged by heavy machinery or removed from its stratigraphic context.

5.1.5 Assessment of Impacts

As identified above, one Registered Site, four Other Heritage Places and one other heritage site (Jarramur 1) occur within the Development Envelope, as well as a number of other sites, mainly isolated artefacts. These sites may be disturbed during the development of the B2018 Project.

5.1.6 Mitigation

SIGMC has implemented a Heritage Management Plan (HMP) (SIG-ENV-PL043) and relevant procedure (Heritage Assessment Procedure (HAP) SIG-ENV-PR035) to mitigate any potential impact to Aboriginal heritage sites. The HMP is intended to provide high level guidance for the management of heritage through the life of the B2018 Project and subsequent operations. The primary objective of the HMP is to maintain access to areas required for mining while ensuring Aboriginal and also European cultural heritage is managed, respected and, as far as it is practicable to do so, protected.

These objectives are achieved through having:

- A documented process for the management and protection of cultural heritage (via HAP);
- Open and respectful relationship based on two way effective engagement between SIGMC and Aboriginal groups;
- Increased knowledge and understanding within the workforce of cultural values and heritage; and
- Programs to promote Aboriginal business, employment and community program opportunities.

The purpose of the HAP is to document the specific actions required for the assessment of cultural heritage at St Ives. The procedure ensures that:

- Heritage sites are identified and as far as it is practicable to do so, protected from disturbance;
- SIGMC will comply with the requirements of the AH Act and the Heritage Agreement; and
- A standardised process is in place for heritage assessment.

In accordance with the HAP, the areas that have not been previously disturbed will have to be surveyed for the Aboriginal heritage. A surface disturbance permit (SDP) (an internal procedure which ensures that all key environmental and social issues are considered ahead of disturbance works progressing) will not be issued for a location that has not been subject to heritage survey or where a heritage site has been identified. Adherence to the SDP Procedure (SIG-ENV-PR049) is a key component for the protection of cultural heritage across SIGMC tenure. The SIGMC Environment Department maintains a register of heritage survey coverage and identified heritage sites and issues SDPs for operations to ensure correct procedure is followed. It may be a requirement of any SDP that heritage sites in proximity to works are buffered and flagged off as no go areas.

SIGMC will always endeavour to avoid registered Aboriginal heritage sites. However where this is not possible SIGMC will apply for Section 18 Consent from the Minister of Aboriginal Affairs to disturb the site.

In the event that material with potential to be of cultural heritage value (artefacts, skeletal remains or other evidence of past human presence – including human skeletal material) is uncovered while undertaking any site works or mining, works will be stopped in the immediate vicinity and the area demarcated as a no go area. The following procedure will be followed:

1. Demarcate, barricade or flag off the immediate area to identify the locations as a no go zone. Works may continue around the site provided the site can still be accessed by an archaeologist to assess the find;
2. Inform The Environment Department of the find;
3. An archaeologist and the Aboriginal consultants shall be commissioned to inspect the cultural material, skeletal material that is not unequivocally animal or possible site;
4. Where skeletal remains that are not unequivocally animal are identified, the archaeologist and Aboriginal consultants must inspect the area and assess the skeletal remains. If the remains are potentially human the archaeologist will contact the WA Police and DPLH. Work will only recommence at that location when written authorisation is received from the appropriate authority;
5. In the case of discovering cultural material the archaeologist and Aboriginal consultants will verify the material and complete the appropriate recording. The outcome of the assessment will be provided to SIGMC. Work will recommence at that location only when written authorisation is received from the archaeologist and/or DPLH as applicable. The archaeologist in consultation with the Aboriginal consultants will prepare a report of the new Site which will be forwarded to DPLH.

To summarise, SIGMC proposed to manage the risk to Aboriginal heritage sites through the following actions:

- Conduct all works to comply with statutory requirements for the protection and management of heritage;
- As far as it is practicable to do so the disturbance of new ground (land and lake) shall be minimised by maximising the use of existing disturbed areas;
- Surface disturbing activities will need to be authorised through the SDP process for operational activities and environmental clearance for exploration activities;
- Where it is not possible to avoid disturbing new ground, a heritage survey of the area to be impacted shall be conducted prior to any disturbance activity. A SDP will not be issued for a location that has not been subject to heritage survey or where a heritage site has been identified;
- Spatial data, including heritage site records and survey coverage, from heritage surveys completed at St Ives are maintained by the Environment Department;
- The Environment Department will only issue SDPs when all relevant clearances are in place;
- All heritage sites are to be avoided. If disturbance is required within these areas a Section 18 Consent will be applied. This is a statutory process that may require several months to complete;
- In the event that material with potential to be of cultural heritage value is uncovered while undertaking any site works or mining, works will be stopped in the immediate vicinity and the area demarcated as a no go area; and
- No off-road vehicle movements are allowed without an approved SDP in place.

Also note that the DPLH registered site number 19180 (Kambalda Site) is included in the Pistol Club West Exclusion Zone (refer to Figure 4-8).

5.1.7 Predicted Outcome

The B2018 Project meets the EPA's objective for Social Surrounding (Heritage) with potential impacts from the proposed operations not considered significant. SIGMC has implemented internal heritage management procedures which ensure that no unauthorised clearing of sites of Aboriginal significance will be undertaken. In the event that disturbance to registered heritage sites is unavoidable, a Section 18 Consent from the Minister of Aboriginal Affairs will be applied for. In light of this, Social Surroundings (Heritage) is not considered to be a key environmental factor. SIGMC considers that this matter can be addressed under the AH Act.

5.2 Social Surroundings (Amenity)

5.2.1 EPA Objective

The EPA's environmental objective for the factor Social Surroundings is:

To protect social surroundings from significant harm.

5.2.2 Policy and Guidance

The following policies and guidelines apply to Social Surroundings (Amenity):

- EPA Environmental Factor Guideline - Social surroundings (EPA 2016f).

5.2.3 Receiving Environment

5.2.3.1 Recreational Land Sailing

The EPA has noted in the ESD that the western-most area proposed for lake-based mining would occur within the vicinity of a recreational land sailing club.

Lake Lefroy is considered one of the best places in WA to sail a land yacht due to its size and the texture of its surface. Land yachting has been a popular recreational activity within the area since the establishment of Kambalda East and West communities in 1970s and the area has played a host to some major land yachting events in the past. Lake Lefroy Land Sailing Club (LLLC) was established in 1972 and the club house was constructed to the east of the Intrepide Pit within SIGMC tenure. The club house has since been dismantled and due to the significant reduction in member numbers, the club has been dissolved and administration of the LLLC has been moved from Kambalda to Perth, although land sailing still occurs on lake.

The majority of Lake Lefroy is covered by an existing mining tenure. The agreement between SIGMC and the LLLC allows club an access to non-operational areas within SIGMC tenure. Sailing in areas that are operational is considered a safety hazard and access is prohibited. Overall LLLC is allowed to engage in recreational activities within SIGMC tenements on Lake Lefroy only with permission from SIGMC.

5.2.3.2 Noise

To date, noise has been considered for each of SIGMCs major environmental approvals. The assessments undertaken include:

- SVT Engineering Consultants (2010). Environmental Noise Impact Assessment for the Proposed Pistol Club Pit at St Ives Gold Mine; and
- SVT Engineering Consultants (2016). Environmental Noise Impact Assessment for Proposed Mining Operations of Pistol Club Pit at St Ives Gold Mine.

Talis was engaged to undertake a noise assessment for the proposed B2018 Project (Talis 2017b – Appendix R). The objective of this assessment was to quantify the noise and vibration impacts from the proposed Project and determine if the proposed operations would comply with the *Environmental Protection (Noise) Regulations 1997* (Noise Regulations). The noise assessment area was determined based on the proposed Project's proximity to sensitive receptors in the Township of East Kambalda and West Kambalda as well as the meteorological conditions in the area (Figure 5-2). Areas further south are not shown to have an impact on noise emissions observed at sensitive receptors.

The assessment modelled a number of different mining scenarios to ensure that all possible configurations were considered. Similar to the studies completed for other environmental factors, the assessment considered the mine layout, configuration and equipment to be identical with respect to the scenarios considered, in order to ensure that the emissions and potential impacts were directly comparable to each other and the assigned noise levels defined in the Noise Regulations. The modelled scenarios were as follows (as detailed in the Talis 2017b):

- Mining in the proposed SW Dome Disturbance Area;
- Mining in the proposed Playa Disturbance Area;
- Mining in the proposed Rialto Disturbance Area; and
- Mining in the proposed SW Dome and Playa Disturbance Areas simultaneously.

The model was designed to represent conservative 'worst case' predictions and as such the following was assumed:

- 100% utilisation of equipment i.e. all equipment operating simultaneously; and
- No stockpiles in place to shield noise.

5.2.3.3 Visual Amenity

To date, visual amenity has been considered for each of SIGMCs major environmental approvals. Historically, there has been no unacceptable impact to visual amenity due to the SIGMC operations. The impact assessment process has varied across the approvals with the assessment for the B2018 Project being the most intensive to date.

Talis was engaged to undertake a visual impact assessment for the proposed B2018 Project. This involved the identification of key viewpoints on the basis that they were visible or accessible via public roads or they have the potential to attract tourists. These viewpoints were, Red Hill Carpark East, Red Hill Carpark South, Red Hill Lookout, BHP Dam and Salt Works (Figure 5-3). Two methods of visual impact analysis were undertaken, viewshed and photomontage.

A viewshed is an area that is visible from a specific location. Viewshed analysis is the method for determining the visibility from a given point, using the digital elevation model (DEM) of the surrounding landscape. Using this method, items on the landscape that do not form part of the DEM such as sparse vegetation were not considered to impact the visibility. Additionally, any impact from dust or haze obscuring the landscape did not affect the analysis. The analysis was limited to the extent of the DEM, and took the curvature of the earth into consideration.

Figure 5-2
Noise Assessment Area

ST IVES GOLD MINE

370000 372000 374000 376000 378000 380000

6550000 6548000 6546000 6544000 6542000 6540000 6538000

KAMBALDA WEST

KAMBALDA EAST

R1 R2 R3 R4

Pistol Club North

Pistol Club South

SW Dome

Rialto

Playa

LEGEND

- Development Envelope
- Sensitive Receivers
- Approved Disturbance - Greater Pistol Club
- Proposed Disturbance Area
- Lake Based Operation (layout for modelling purposes only)
- Lake Based Pit (layout for modelling purposes only)

0 1 2 3 4

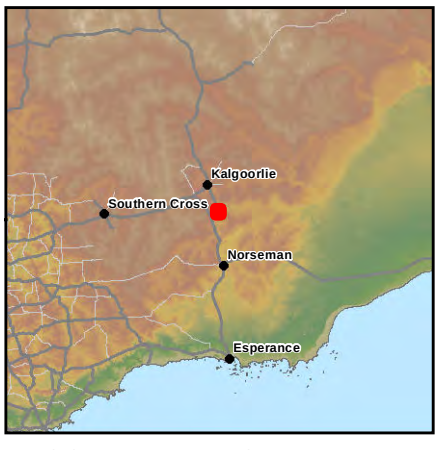
Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

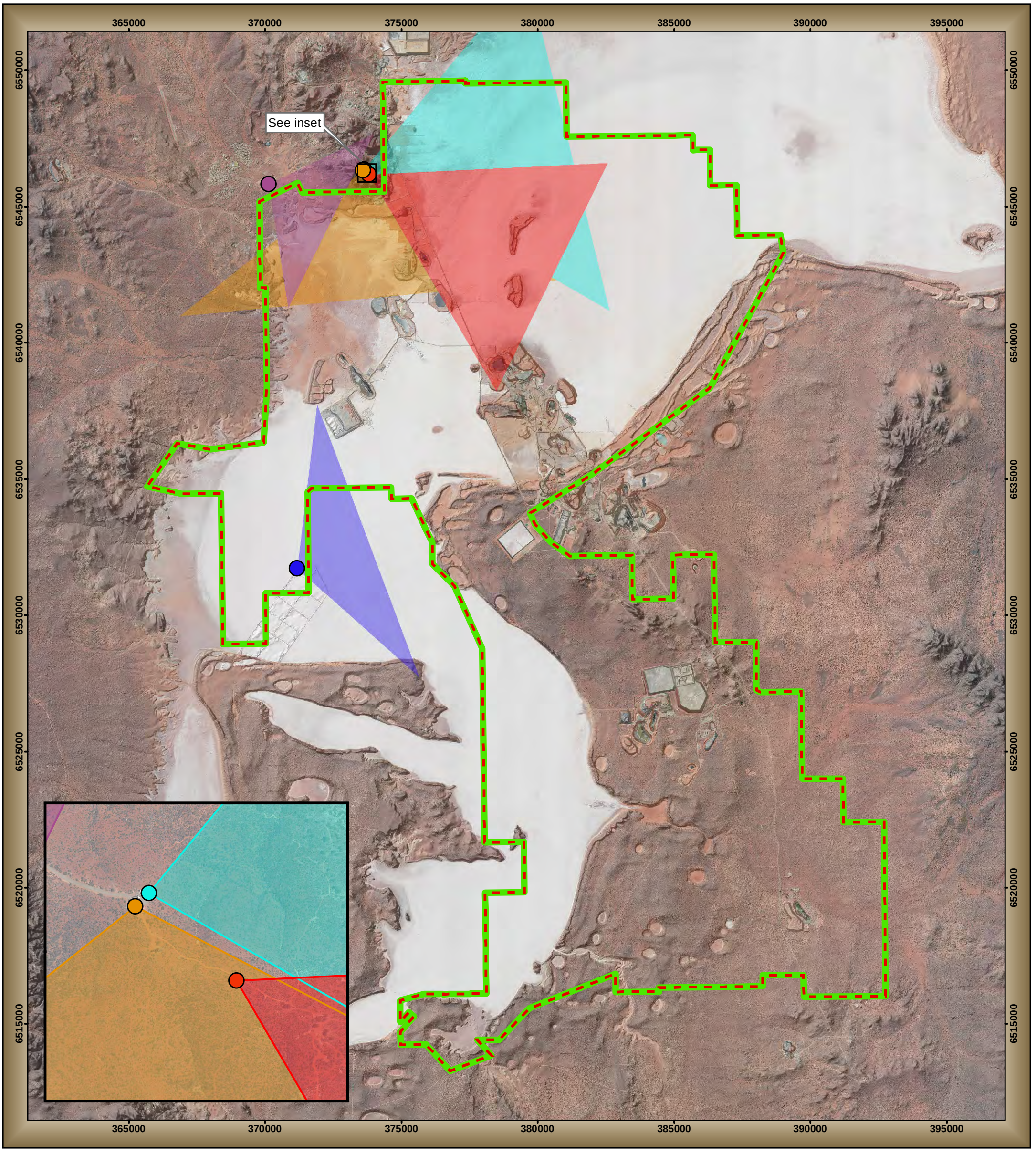
Prepared:	F Walker
Reviewed:	N King
Checked:	E Vuorenmaa
Project No:	TE16034
Revision:	A
Date:	31/01/2018

LOCALITY MAP



Document Path: \\server\Talis\SECTIONS\Environment\Projects\TE2016\TE16034 - SIGM B2018 EPA Process\10. GIS\Maps\ERD_Mapping\TE16034_ERD_5-2_NoiseAssessmentArea_RevA.mxd

Figure 5-3
Viewpoint Locations



LEGEND

Development Envelope

Photopoints

- BHP Dam
- Red Hill Carpark South
- Red Hill Carpark East
- Red Hill Lookout
- Salt Works

Azimuthal Range of Panoramas

- BHP Dam
- Red Hill Carpark South
- Red Hill Carpark East
- Red Hill Lookout
- Salt Works

0 3 6 9 12

Kilometres

N

Datum: Geocentric Datum of Australia (GDA94)
Map Grid: Map Grid of Australia (MGA)
Projection: Universal Transverse Mercator Zone 51

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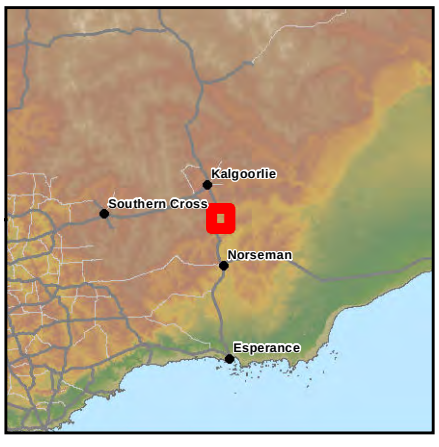
LOCALITY MAP



Document Path: \\server\Talis\SECTIONS\Environment\Projects\TE2016\TE16034 - SIGM B2018 EPA Process\10. GIS\Maps\ERD_Mapping\TE16034_ERD_5-3_ViewpointLocs_RevA.mxd

Viewsheds for each viewpoint were calculated using the baseline and B2018 Project DEMs, in order to determine the visual impact of the B2018 Project. The output of the analysis was a binary layer, with values representative of either visible, or not visible, from the viewpoint. Through manipulation of the two viewsheds for each point, the view of the terrain can be classified as:

1. Always visible;
2. Made visible by B2018 operations;
3. Obscured by B2018 operations; and
4. Always obscured.

A photomontage is a visual representation of the proposed B2018 Project. It aimed to illustrate what the B2018 operations will look like from a specified viewpoint. This was achieved by superimposing a 2D model of the changes to the landscape over a photograph of the landscape taken prior to the changes occurring. The photomontage analysis incorporated the vegetation and other screening objects (such as signs and powerpoles etc.) that were either too small or sparse to be captured in the DEM, or were edited out of the DEM (which aimed to represent ground-level elevation). This allowed a realistic view of the changes to the landscape from the observation point.

The series of photographs taken at each viewpoint were stitched together to form a panorama, and these outputs were used in the photomontage analysis. 3D models of the DEM, focussed on the aspect of each viewpoint, were generated to illustrate the changes to the landscape at each viewpoint. Photo editing software was then used to alter the panoramic photographs to insert the proposed landform features.

For the purposes of the assessment it was assumed that that all operations will include a WRL of ~20m height above the surrounding terrain, and that they will all occur simultaneously. In reality, the development is expected to be staged over a decade, allowing for progressive rehabilitation including backfilling of sterilised pits. Backfilling will eliminate the need for WRL construction and the resulting number of WRLs is likely to be reduced from what was assessed as part of this VIA.

It was assumed that a 20 m WRL represents an average WRL across the SIGMC operations but for the purposes of the VIA, an assessment for 40 m high WRLs was also undertaken to represent the worst-case scenario.

The Visual Impact Assessment Report is provided in Appendix S.

5.2.4 Potential Impacts

5.2.4.1 Recreational Land Sailing

Implementation of the Project will decrease the lake surface area available for sailing.

5.2.4.2 Noise

The proposed B2018 operations have the potential to result in exceedances of the assigned noise levels as stipulated in the Noise Regulations. Exceedances of these noise levels have the potential to cause community annoyance, sleep disturbance and long-term effects on cardiovascular health.

Blasting on the other hand is an irregular mining activity that creates high instantaneous noise levels at the source. Blast vibration has the potential to cause sleep disturbance which can result in fatigue. It is therefore considered a safety concern.

5.2.4.3 Visual Amenity

Proposed B2018 operations have the potential to alter the surface of Lake Lefroy as a result of proposed pits and WRLs and make the landscape less visually pleasing.

5.2.5 Assessment of Impacts

5.2.5.1 Recreational Land Sailing

Implementation of the Project will decrease the lake surface area available for sailing. To manage this, the proposed operations will be mined sequentially reducing the number of restricted areas at each time. Further to this progressive rehabilitation undertaken throughout the Project aims to return some operational areas as part of the lake surface once the mining ceases. These areas will include exploration, causeway and mining infrastructure disturbance. Larger landforms such as WRLs and open pits (even when backfilled) are likely to remain areas with a restricted access.

SIGMC has undertaken extensive stakeholder consultation with LLLC to keep the club updated on the proposed expansion (refer to Section 3) and their specific request to maintain a navigable path through developments on the lake is acknowledged. This consultation will continue throughout the B2018 Project preparation and operation. SIGMC has also implemented a Stakeholder Engagement Plan for the B2018 Project which details the stakeholder engagement process, level of engagement and grievance mechanisms in the event of any stakeholder concerns or complaints.

On the basis of the above, Social Surroundings (Amenity) is not considered to be a key environmental factor and can be managed by using the existing SIGMC procedures and management plans.

5.2.5.2 Noise

Historically, based on the proximity of the site to sensitive receptors (i.e. the Kambalda Townships) and the implementation of appropriate mitigation when required, the site has not contributed to noise effects in the area. The impact assessment process has varied throughout the life of the operation with the assessment for the B2018 Project being the most intensive to date.

All modelled scenarios as part of the B2018 Noise Assessment were predicted to comply with the Noise Regulations under the ‘worst case’ operational conditions at all times of the day (Talis 2017a).

5.2.5.3 Visual Amenity

The visual impact assessment undertaken by Talis (2017a) determined that the viewsheds for the Red Hill locations show similar results, as these viewpoints were in close geographical proximity (within 300 m of each other), and at a similar elevation (range of 5m). As expected from an elevated position, the proposed B2018 WRLs close to the viewpoint locations obscure less of the surrounding landscape than those WRLs at a further distance. The viewsheds for the BHP Dam and Salt works viewpoints show that a large portion of the Development Envelope is always obscured. This is due to the low elevation of these points with respect to the surrounding landscape features.

Based on the photomontage analysis, the changes to the landscape from elevated viewpoints are obvious (Appendix R). However, from the less elevated viewpoints (BHP Dam and Salt works), the visual impacts are minimal. At BHP Dam, there were no visible changes to the landscape due to the proposed operations being obscured by existing landforms.

Increase of WRL height from 20 m to 40 m does not appear to have a significant impact on the landscape although changes to the viewshed as a result of the increase are likely to be more evident.

The implementation of the B2018 Project does not change the nature of the landscape, it only adds features that have been part of the landscape since the beginning of mining operations on Lake Lefroy in the early 1980s (Gold Fields Limited 2013).

5.2.6 Mitigation

5.2.6.1 Recreational Land Sailing

No specific mitigation measures are proposed. SIGMC will continue to consult with LLLC and will accommodate any requests, subject to safety and logistical factors associated with operations on the western side of the lake.

5.2.6.2 Noise

Notwithstanding that noise is not predicted to exceed the assigned noise levels stipulated in the Noise Regulations, SIGMC has developed a Noise Management Plan (NMP) (SIG-ENV-PL047) for the B2018 Project as well as the already approved Pistol Club North Mine (2016 assessment).

The NMP aims to reduce noise emissions from significant noise contributors, prevent possible exceedances of the Noise Regulations and to minimise the impacts from noise as far as practicable.

A number of noise mitigation measures are detailed in the NMP, these are listed below:

- Trucks and dozers have been identified to be the largest noise source and noise from these sources can be reduced by:
    - Avoiding operating the equipment in noise sensitive areas during night time hours;
    - Reducing the number of simultaneously operating dozers and trucks during night time hours until the pit reaches a depth of 20 m;
- Scheduling of mine operations:
    - Single blasting event per mine during the day time hours (7am to 6pm); and
    - No night-time blasting.
- Sequential operation of operations wherever possible to reduce the cumulative noise impacts, i.e. completion of Pistol Club Project prior to starting B2018 operations;
- Implementation of a complaints management process; and
- Environmental noise training for mine managers, planners and operators as part of the site specific induction process.

5.2.6.3 Visual Amenity

In order to mitigate impacts to the landscape, the following management measures will be implemented:

- Siting and design of mining infrastructure to make it more visually pleasing;
- Using higher features such as WRLs as screens for other mining infrastructure;
- Staged and sequential mining where appropriate; and
- Progressive rehabilitation involving backfilling of sterilised pits and rehabilitation of WRLs as soon as practicable.

Land-based operations are not expected to be visible from areas that are accessible by the public. Closure of land-based features will be undertaken in accordance with the Rehabilitation and Mine Closure Plan focusing on revegetation which will reduce the prominence of constructed features.

5.2.7 Predicted Outcome

The B2018 Project meets the EPA's objective for Social Surrounding (Amenity) with potential impacts from the proposed operations not considered significant. Noise can be managed under the Part V of the EP Act.

5.3 *Air Quality (Greenhouse Gas Emissions)*

5.3.1 EPA Objective

The EPA's environmental objective for the factor Air Quality is:

To maintain air quality and minimise emissions so that environmental values are protected.

5.3.2 Policy and Guidance

The following policies and guidelines apply to Air Quality (Greenhouse Gas Emissions):

- EPA Environmental Factor Guideline - Air Quality (EPA 2016c).

5.3.3 Receiving Environment

5.3.3.1 Background

SIGMC reports all greenhouse gas (GHG) and other emissions annually in accordance with the requirements of the Commonwealth National Greenhouse and Energy Reporting (NGER) Scheme and National Pollutant Inventory (NPI).

The NGER Scheme operates under the *National Greenhouse and Energy Reporting Act 2007* (NGER Act) and provides a framework for national greenhouse gas and energy reporting requirements. The NPI does not include GHG emissions, but instead provides an emission estimate across 93 substances that have been identified as important due to their possible effect on human health and the environment.

The GHG emissions that are reported under the NGER Scheme include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6) and specific kinds of hydro fluorocarbons and perfluorocarbons. CO_2-e, or carbon dioxide equivalent, is a standard unit for measuring carbon footprints, used to express the impact of each GHG in terms of the amount of CO_2 that would create the same degree of global warming potential.

Gold mining activities that have the potential to impact air quality include:

- Electricity diesel generation;
- Transport diesel (light and heavy vehicles);
- Stationary diesel (generators);
- Combustion of Leaded Petroleum Gas (LPG) (process of gold extraction in the gold room);
- Combustion of Unleaded Petroleum (ULP) for stationary sources;
- Combustion of ULP for transport (ULP operated light vehicles);
- Combustion of petroleum based oils (engine oil);
- Combustion of petroleum based greases (engine grease);

- Fugitive SF_6 (from aerosols); and
- Fugitive emissions from wastewater (such as methane from Waste Water Treatment Plants).

The NGER Act establishes a national framework for Australian corporations to report Scope 1 and Scope 2 GHG emissions, reductions, removals and offsets and energy consumption and production. It is designed to provide robust data and was envisaged as a foundation to the proposed Carbon Pollution Reduction Scheme (CPRS). Scope 3 emissions are not required to be reported under the NGER Act. The different scopes are defined as follows:

- Scope 1: Direct greenhouse gas emissions. Direct greenhouse gas emissions occur from sources that are owned or controlled by a company. These may include:
    - Emissions from boilers, furnaces and vehicles, use of explosives etc.;
    - Emissions from gold plant; and
    - Emissions from on-site power generators
- Scope 2: Indirect emission from activities that generate electricity, heating, cooling or steam that is consumed by the facility but do not form part of the facility. This accounts for GHG emissions from the generation of purchased electricity consumed by the company. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organisational boundary of the company. Scope 2 emissions physically occur at the facility where electricity is generated but they are allocated to the organisation that owns or controls the plant or equipment where the electricity is consumed. Scope 2 example for SIGMC operation includes:
    - Electricity supply via connection to the Kambalda electrical grid, as no power station is located on site and electricity is sourced from powerlines extending from Kambalda. Electricity is produced by Southern Cross Energy which is wholly-owned by TransAlta and comprises of an open cycle power station in Kambalda.
- Scope 3: Indirect GHG emissions other than scope 2 emissions that are produced through a broader contribution. Scope 3 GHG emissions occur as a consequence of the activities of a facility. They are sources not owned or controlled by the operations (in this occasion SIGMC). For example, delivery of purchased fuels and impact of cleared vegetation on GHG emissions fall under Scope 3 emissions.

5.3.3.2 Existing Impacts

SIGMC existing operations including workshops, ore haulage, use of vehicles and the gold processing plant are the primary facilities contributing to the combustion and energy consumption causing release of GHG emissions.

Table 5-3 below summarises estimated GHG emissions between 2015 and 2017 reported under the NGER Scheme. Scope 1 emissions include CO_2-e amounts calculated from contributors such as fuel combustion from vehicles, methane from WWTPs and use of synthetic gases. Scope 2 emissions involve electricity use off the grid. Scope 1 & 2 represents the total GHG emissions produced annually from the site. The CO_2-e amounts are tabulated with the tonnes of Material Moved from 2015 to 2017.

Table 5-3: GHG Emissions Reported 2015-2017

Reported GHG Emissions	Unit	2015	2016	2017
Scope 1	TCO_2-e	78,720	90,739	101,589
Scope 2	TCO_2-e	92,034	87,650	90,059
Scope 1 & 2	TCO_2-e	170,755	178,389	191,648
Material Moved	Tonnes	19,776,745	36,219,759	42,758,373

These results indicate that the amount of CO_2-e has increased progressively over the years, which is directly correlated with an increase in Material Moved. Note that during 2015 the amount of Material Moved was recorded as a lower tonnage, which is associated with the amount of waste material stored underground during UG operations. Operations are expected to focus mainly on open pit mining during 2018 and beyond, therefore the predicted amount of Material Moved will be more representative of material tonnages moved in 2016 and 2017.

5.3.4 Potential Impacts

The proposed B2018 Project operations have the potential to increase emissions of GHG as a result of the expansion to operations.

5.3.5 Assessment of Impacts

Greenbase Environmental Accountants (Greenbase) was engaged to provide an estimate of GHG emission projections for the B2018 Project (Greenbase 2017; Appendix T). For the GHG emission estimate, Greenbase elected to use the estimates as per the NGER Scheme Technical Guidelines (DEE 2017b) for a proposed 10 year operational period of B2018 Project, from 2019 to 2028. Year 2018 was included in the projections to establish understanding on GHG emissions prior to commencement of B2018 Project. The operational scope included the current SIGMC operations and new mining proposed to be undertaken during the B2018 Project.

Only Scope 1 (direct) and Scope 2 (energy direct) GHG emissions were explored for the B2018 Project. Scope 3 GHG emissions were not included as their contribution was considered minimal compared to overall emissions.

The method of estimating a GHG emission intensity values was calculated using Scope 1 and Scope 2 emissions from the 2016 financial year (FY) data. These values were then multiplied by the forecasted Material Movement values provided by SIGMC to determine Scope 1 and Scope 2 CO_2-e amounts for the B2018 operational period.

A number of assumptions were made around the GHG emission forecast for the B2018 Project. These include:

- GHG emissions have been assessed as being proportionate to the Material Moved from existing facilities for SIGMC operations (Material Moved is defined as the volume of ore and waste mined from surface operations);
- The 2016 data included Cave Rocks diesel consumption, this area is presumed to have a minor impact on emissions post 2017 operations; and
- The 2016 FY GHG emissions are considered representative of subsequent years of operation; and
- Scope 3 emissions are excluded from the assessment.

The proposed B2018 Project operations have the potential to increase air pollution contributing to existing GHG emissions as a result of the expansion to operations.

Figure 5-4 and Table 5-4 below display the forecast of material movement and the amount of GHG emissions from Scope 1, Scope 2 and Scope 1 & Scope 2 combined for 2018 and duration of B2018 Project (2019-2028).

Table 5-4: GHG Emission Projections and Material Moved for 2018-2028

Predicted GHG Emissions	Unit	2018	2019	2020	2021	2022
Scope 1	TCO_2-e	83,389	65,683	62,174	34,522	38,802
Scope 2	TCO_2-e	80,551	63,447	60,058	33,347	37,481
Scope 1 + 2	TCO_2-e	163,941	129,130	122,232	67,869	76,283
Material Moved	Tonnes	33,286,114	26,218,249	24,817,775	13,780,019	15,488,408

Predicted GHG Emissions	2023	2024	2025	2026	2027	2028
Scope 1	44,712	39,284	69,804	60,940	73,248	62,121
Scope 2	43,190	37,947	67,428	58,866	70,755	60,007
Scope 1 + 2	87,902	77,232	137,232	119,806	144,002	122,129
Material Moved	17,847,422	15,680,909	27,863,250	24,325,177	29,237,915	24,796,706

Figure 5-4: GHG Emission Projections for 2018-2028

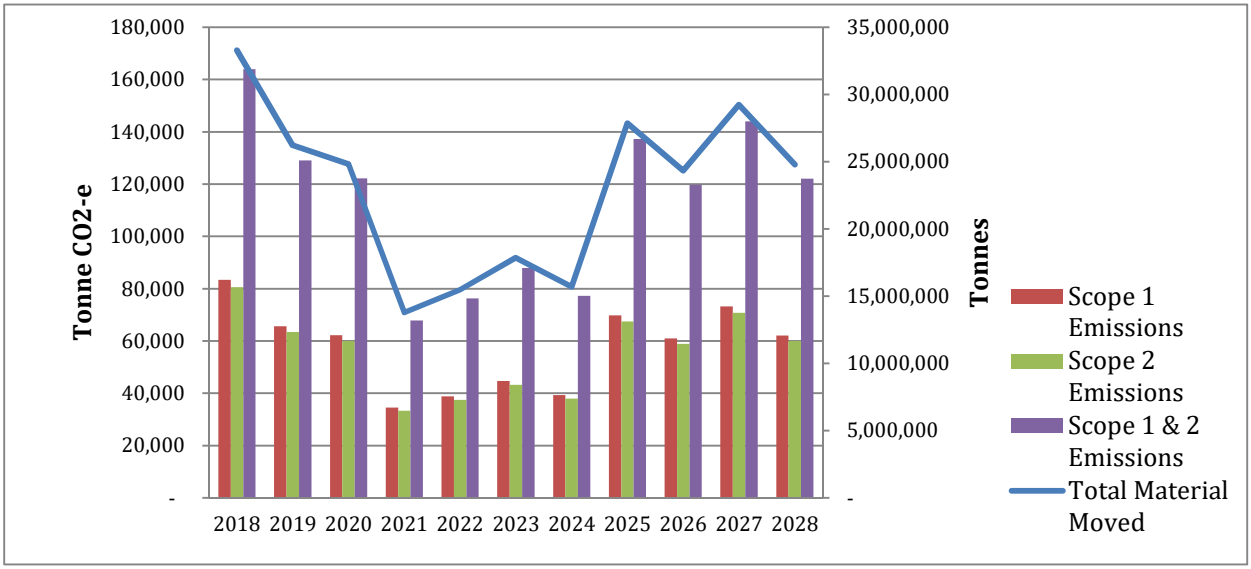


Figure 5-4 and Table 5-4 above illustrate that the GHG emissions produced are directly related to the amount of Material Moved. GHG emissions from B2018 Project are therefore directly proportional to the proposed scale of operations and rate of mining. It is worth of mentioning that while the total mine footprint is due to expand, the rate of mining and the primary contributing facilities are likely to remain the same. As a result, the GHG emissions from the B2018 Project are predicted to be the same or lower as compared to the current levels.

5.3.6 Mitigation

SIGMC will develop best practice measures to avoid or minimise the emission of pollutants from point sources during the B2018 Project. Existing air quality management measures for the SIGMC operations will be further developed as best practice measures to avoid, minimise, and mitigate air pollution associated with GHG emissions from point sources.

Further to this, SIGMC will implement programs to optimise energy efficiencies wherever possible. In addition, fuel consumption will be reduced as far as possible by reducing the distances and gradients travelled by vehicles during the B2018 operations.

5.3.7 Predicted Outcome

Taking the above into consideration, it is predicted that the B2018 Project will produce the same or lower overall GHG impact compared to the current operations.

Based on the GHG assessment undertaken and the proposed mitigation measures, B2018 Project meets the EPA's objective for Air Quality (GHG Emissions) with potential impacts not considered significant. In light of this, GHG emissions is not considered to be a key environmental factor.

6 OFFSETS

Environmental offsets are a means by economic and social development may occur while supporting long term environmental and conservation values. In accordance with the WA Environmental Offsets Policy and Western Australian Government's Environmental Offsets Guideline (Government of Western Australia 2014), offsets may be applied after other mitigation measures have been considered, as per the following hierarchy:

- Avoid;
- Minimise;
- Rehabilitate;
- Offset.

As noted in WA Environmental Offsets Guidelines, "Environmental offsets address significant environmental impacts that remain after on-site avoidance and mitigation measures have been undertaken. Environmental offsets will only be considered after strategies to avoid and mitigate significant environmental impacts have been applied." In other words, where there are significant residual impacts that result from a proposal despite strategies enacted to avoid, minimise or rehabilitate the impacts, offsets may be considered to address the residual impacts.

The guidelines define significant residual impacts as those that include impacts on:

- Rare and endangered plants and animals (such as declared rare flora and threatened species that are protected by statute),
- Areas within the formal conservation reserve system,
- Important environmental systems and species that are protected under international agreements (such as Ramsar-listed wetlands) and
- Areas that are already defined as being critically impacted in a cumulative context.

Impacts may also be significant if, for example, they could cause plants or animals to become rare or endangered, or they affect vegetation which provides important ecological functions.

In the context of the B2018 Project, the work and assessment that has been undertaken has been done so with the specifics of the mitigation hierarchy in mind. As has been identified in many parts of this ERD, the project is a continuation of the existing approach to mining. The throughput of the operations will not be affected by the approval of B2018 and the outcome, if approved, will be a further 10-year continuation of the existing operations.

While the assessment approach which is discussed in this ERD will ultimately provide for a flexible mine plan to be developed (in as much as the active footprints for the operations are yet to be defined), this has required a more detailed consideration of the environmental issues associated with the project and how these are to be managed.

The assessment has resulted in both 'avoidance' and 'minimisation' of impacts wherever practicable. As discussed elsewhere within this ERD, a number of key locations within the Development Envelope have been identified as having potentially significant environmental values which are worthy of retention. While SIGMC is of the view that the project could progress the project with these areas included and potentially developed, the decision has been made to avoid these to ensure any significant environmental values are retained where practicable. These areas of 'avoidance' are shown in Figure 4-10 and reflect both flora and fauna values and a wider ecological consideration. Further to this, areas have been identified that retain significant heritage values within the Development Envelope. These locations have also been avoided and will not be developed as part of the B2018 Project.

SIGMC has also taken a proactive and best-practice approach to mine closure and rehabilitation. An extensive and detailed Mine Closure Plan (MCP) has been developed for the site in 2016 (MWH 2016d). The final iteration of this document was being considered by DMIRS for approval at the time of writing and has been lauded by them as setting a benchmark for the industry. Current operations will be developed, progressed, closed and rehabilitated in accordance with this MCP and the B2018 Project will follow suit. The MCP and the RMCP specifically prepared for the B2018 Project (Appendix H) incorporate closure objectives and completion criteria addressing post mining landforms and soil profile reconstruction, native vegetation and habitat for conservation significant flora and fauna and establishes vegetation and fauna reference and analogue sites, to inform completion criteria. The MCP is a leading example of how strategic and holistic mine closure and rehabilitation can be achieved across a large and complex land system.

Given the approach taken by SIGMC across the consideration of the B2018 Project, the investigations and surveys that have been completed and the response to the information and data elicited from this work, SIGMC is of the view that there is no significant residual risk to the environment or any environmental value resultant from the project, particularly given the approach taken to avoid, minimise and rehabilitate the identified impacts. As a result, SIGMC concludes that there is no requirement for offsets to be proposed for the B2018 Project.

7 MATTERS OF NATIONAL ENVIRONMENTAL SIGNIFICANCE

Based on the desktop work undertaken for the B2018 Project there are a number of species that are listed pursuant to the EPBC Act as Matters of National Environmental Significance (MNES) and have the potential to be located within the Development Envelope. These species are:

- *Gastrolobium graniticum* (Endangered flora);
- *Tecticornia flabelliformis* (Vulnerable flora);
- *Leipoa ocellata* (Malleefowl) (Vulnerable fauna); and
- *Pezoporus occidentalis* (Night Parrot) (Endangered fauna).

A range of detailed studies have been completed to address the potential impacts to flora and fauna species within the B2018 Development Envelope. These are detailed in Sections 4.2.3 and 4.3.3 and summarised below.

7.1 *Gastrolobium graniticum*

Gastrolobium graniticum is listed Endangered (EN) under the EPBC Act. The species have the potential to occur in the vicinity of Lake Lefroy, but no species have been recorded within 40 km of the Development Envelope (Phoenix 2018b). Records of the species on Florabase list the suitable habitat for the species as granite rocks and granite outcrops (Western Australian Herbarium 2017). Comprehensive flora surveys undertaken over the area to date have not identified the species and the habitat type suitable for the species has not been mapped in any of the surveys undertaken over the Development Envelope or wider SIGMC tenure (refer to Section 4.2 for further information).

In light of this, SIGMC considers that the likelihood of occurrence for *Gastrolobium graniticum* is extremely low and no further management measures are proposed.

7.2 *Tecticornia flabelliformis*

Tecticornia flabelliformis is listed Vulnerable (VU) under the EPBC Act and Priority 1 species under the DBCA listing. The species has previously been recorded in the Eastern Goldfield subregion of the Murchison bioregion and the Avon Wheatbelt P1 subregion of the Avon Wheatbelt bioregion (DPaW 2017). The species is known from 170 records (ALA 2017) in Australia, including six records in Western Australia (DPaW 2017) representing three populations with habitat described as saline flats, evaporation pan of salt lake in red-brown clayey sand, clay and dull orange sand. The majority of records in Australia occur in South Australia with a smaller number in Victoria (Phoenix 2018a).

The species has been previously recorded within 40 km of the Development Envelope (Phoenix 2018b) but it was not recorded within the Development Envelope during any of the field surveys undertaken in 2016 and 2017 (Phoenix 2017b, 2018b, 2018a). Two new populations were however recorded during the additional riparian survey outside the Development Envelope (Phoenix 2018a) which represent two new locations/populations for the species in WA and extend distribution considerably around Lake Lefroy, as desktop records for the area only show one previous location at the lake.

Tecticornia flabelliformis specimens were collected from two locations on the western and eastern shores of Lake Lefroy. Habitat for the species was similar at both sites and comprised the mud flats of the lake playa in red-brown clay. A total of 99 plants were recorded, 44 in one population and 45 in the other (Phoenix 2018a).

Considerable work has already been undertaken around Lake Lefroy and none of this work has identified *Tecticornia flabelliformis* within the Development Envelope. The species are also known to occur outside the Development Envelope so B2018 operations are expected to have a minimal impact on *Tecticornia flabelliformis.*

7.3 *Malleefowl* (Leipoa ocellata)

Based on the work conducted by SIGMC and in particular the survey efforts completed by Phoenix, the B2018 Project is unlikely to result in a significant impact to Malleefowl.

As discussed in Section 4.3, three old inactive previously identified Malleefowl mounds were revisited and recorded in the fauna survey effort conducted for the B2018 Project, but only one of these is located within the Development Envelope.

One inactive mound was recorded within 10 m of an access track in the south-east of the Development Envelope however the condition of the mound and vegetation growth occurring on the mound indicated that the mound has remained unused for some time. This mound was also recorded during a previous survey within the Development Envelope (Bamford 2010).

Two additional inactive mounds have previously been recorded from approximately 100–200 m north of the northern boundary of the Development Envelope, close to Red Hill (Terratree 2015). Both mounds were examined during the field survey and both showed no sign of recent use.

Given the location of previous Malleefowl records within and in the broader vicinity of the Development Envelope, and the presence of suitable habitat for the species throughout large areas of the Development Envelope, it is considered likely to occur in areas of open to dense shrubland and woodland. Additional mounds may be located with additional targeted searches or clearance surveys for the species (Phoenix 2017c).

Despite being of the opinion that the B2018 Project is unlikely to present a significant risk to the species, SIGMC recognises that mobility of the species and the duration of the B2018 Project which may give rise to potential impacts in future as mining progresses. Given the proposal will be realised over a ten year period, it is logical that surveys are undertaken in a fit for purpose manner and that data is obtained as close to real-time as possible. As such, SIGMC has decided to enact a programme of pre-clearing survey work (targeted Malleefowl surveys) to determine the presence of Malleefowl in a suitable habitat (dense woodland on plain) of any of the B2018 Project areas identified to be progressed. Such a commitment will allow for early and timely survey of the locations in question to ensure that the findings of the 2017 work remain consistent. When or if Malleefowl are identified to be present within the footprint of mining/infrastructure, the site's Environment Department will be notified immediately and a suitable management plan will be developed to ensure that the given work does not proceed until the risks to the Malleefowl appropriately managed.

The pre-clearing survey work will be undertaken by suitably qualified personnel no less than 6 months prior to the scheduled start date for the given ground disturbing works. If a Malleefowl mound (or other Malleefowl sign) is identified that has evidence of use (i.e. in the last ~3 years), the area will be appropriately demarcated and no disturbance will be undertaken until the situation is fully understood and management measures are in place to avoid disturbance to area.

It is expected that this commitment will be conditioned and will subsequently form part of the annual reporting requirements for the operation.

7.4 *Night Parrot* (Pezoporus occidentalis)

The work conducted in relation to the B2018 project with respect to the Night Parrot failed to detect any evidence of the species being present in the Development Envelope (both in terms of visual evidence as well as a lack of calls being recorded).

The Development Envelope is located in the Coolgardie IBRA region, subregion COO3 “Eastern Goldfields” (Cowan 2001). Based on previous records of Night Parrots, this subregion is only of ‘moderate priority’ for Night Parrot surveys (DBCA 2017a). As noted earlier in this document, there is a record of the species approximately 286 km southeast of the Development Envelope; however, the record lacks information to determine its accuracy and validity (DPaW 2016b).

Notwithstanding this outcome, it is important to reiterate that no available survey technique can irrefutably demonstrate that the species is absent from a site. Where habitat is suitable, even if the species was not confirmed to be being present, it might still frequent the area at other times. SIGMC recognises this and will continue to ensure that the Night Parrot is considered as part of B2018 operations by undertaking impact assessments for the likelihood of occurrence and to ensure that impacts to the species (in the unlikely event that it is identified to be present) are minimised as far as practicable.

7.5 *Summary*

Based on the work conducted by SIGMC in relation to MNES, there is unlikely to be any significant impact to any species resulting from the project. It is worth pointing out that measures have been taken to avoid or minimise disturbance to a number of locations within the Development Envelope. These actions will further decrease the likelihood of an unacceptable impact to significant flora species occurring.

Given the work completed by SIGMC, it is highly unlikely that a significant impact to a MNES will result from the B2018 Project. Further to this, SIGMC’s progressive approach to closure and rehabilitation will assist in reducing any perceived impacts following completion of the operations.

8 HOLISTIC IMPACT ASSESSMENT

The B2018 Project is proposing an expansion of existing land- and lake-based mining at Lake Lefroy, in the Goldfields region of Western Australia. The key characteristics/elements of the B2018 Project are:

- New open cut pits;
- New underground operations;
- Expansions to existing open cut pits and underground operations;
- Construction of new waste rock landforms;
- Construction of new tailings facilities;
- Construction of mining and ancillary infrastructure (workshops, offices, laydown areas etc.);
- Construction of new dewatering discharge structures; and
- Increase in dewatering discharge volume.

In order to assess the environmental impacts associated with this expansion, a significant amount of investigation has been required, building on past studies and operational experience.

This work has resulted in the development and refinement of the B2018 proposal and, as a result, a number of environmental factors were identified by the EPA for the proposal and were described in the ESD.

During the assessment of the proposal the following key environmental factors were identified by the EPA to be relevant for the B2018 Project:

- Flora and Vegetation;
- Terrestrial Fauna;
- Subterranean Fauna;
- Hydrological Processes; and
- Inland Waters Environmental Quality.

Further to the above, the EPA also often identifies other environmental factors or matters as relevant to a proposal but not significant enough to warrant full assessment by the EPA or that can be regulated through other regulatory processes and agencies to meet the EPA's objectives. For B2018 Project the other environmental factors or matters identified include:

- Social Surroundings (Heritage);
- Social Surroundings (Amenity); and
- Air Quality (Greenhouse Gas (GHG) Emissions).

These factors have been assessed in the ERD with particular consideration of the following principles outlined in the EP Act:

- The precautionary principle;
- The principle of intergenerational equity;
- Principles relating to improved valuation, pricing and incentive mechanisms;
- The principle of the conservation of biological diversity and ecological integrity; and
- The principle of waste minimisation.

Importantly, and as part of this assessment, SIGMC has recognised that the factors referred to above are inherently linked and that they can be considered both in isolation as well as part of the overall ecology at Lake Lefroy. How one part of that system is managed will indirectly affect other aspects of the system as a whole. For example, surface water flow from a terrestrial perspective will have implications for terrestrial playa systems and their ecology and resultant implications as that water flows through the playas to Lake Lefroy as well as having implications for infiltration to support those species that rely on such inflow. Figure 8-1 provides an overview of the key environmental factors - the receiving environment, potential impacts and key mitigation measures, some of which are common to more than one factor.

The studies and project framework have been undertaken in keeping with the mitigation hierarchy which seeks to:

- Avoid – through relocation or reduction of areas or actions to avoid impacts to certain environmental values;
- Minimise – where avoidance of impacts is not possible, a reduction of impacts to an environmental value may be achieved through relocation or reduction of areas or through appropriate project design and management; and
- Rehabilitate – once impacts are avoided or minimised, the residual impacts may be responded to through employment of appropriate techniques to restore/rehabilitate areas of impact.

An important outcome of these studies was the identification of a number of Exclusion Zones which form part of the Development Envelope but area areas from which mine-related activities will be excluded. This decision was made by SIGMC on the basis of the identified floristic, faunal and wetland values which were worthy of retention and protection within the framework of the project.

The work that has been undertaken draws the conclusion that the overall B2018 would result in no impacts that would present an unacceptable risk to the environment. This work also responds to the requirements of the ***Precautionary Principle*** through avoidance, minimisation and rehabilitation.

Whilst the studies that have been completed have concluded that the project has been found to result in no unacceptable risk to the environment, there is also recognition that ongoing work will be beneficial in ensuring the project continues to be reviewed as it progresses. Importantly, the nature of the project being undertaken over a 10-year period provides a very good opportunity for further data to be generated through monitoring and management. This allows for better project definition and optimisation whilst providing additional information that will guide future operations and also ensuring that the operations are planned for ultimate closure and rehabilitation.

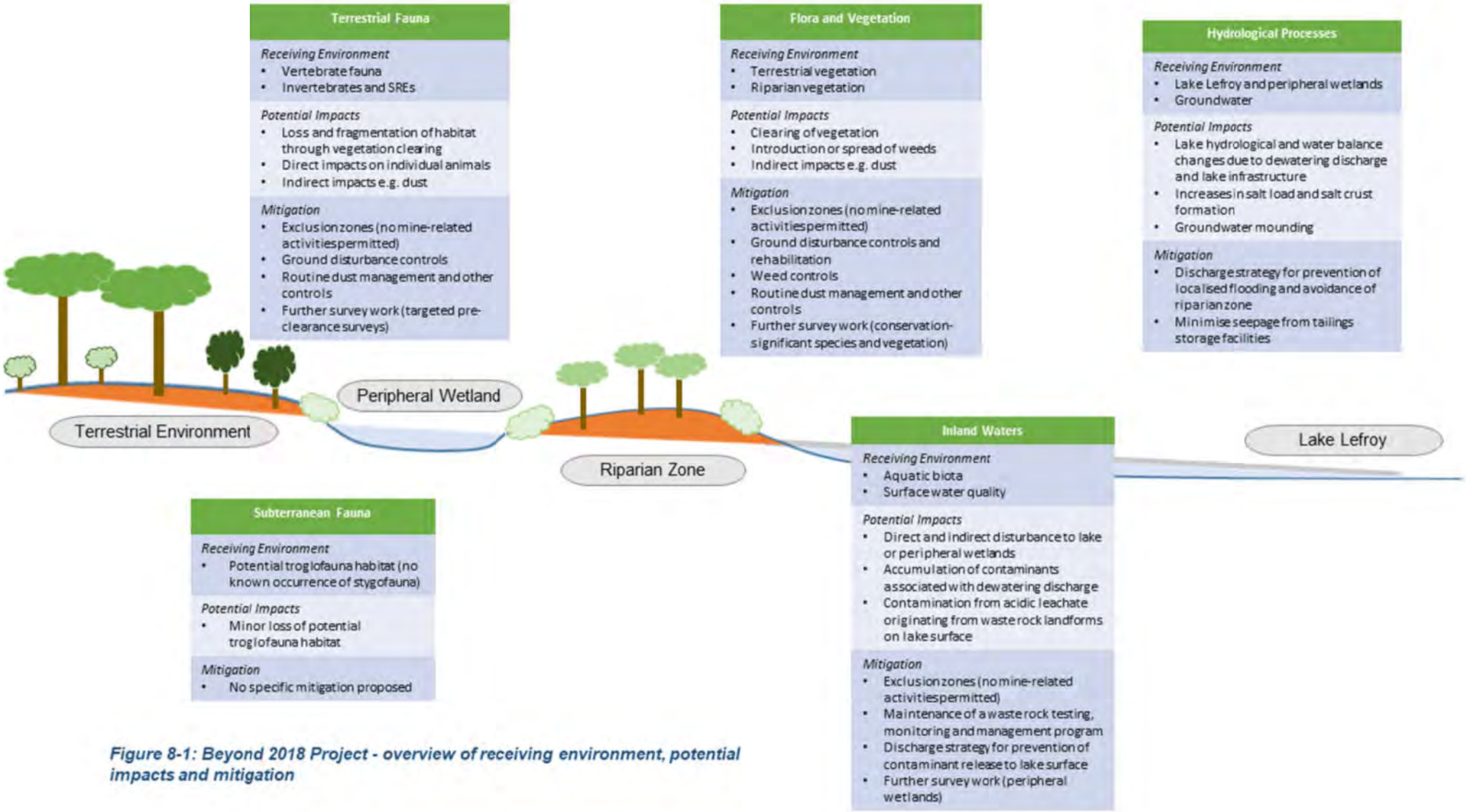


Figure 8-1: Beyond 2018 Project - overview of receiving environment, potential impacts and mitigation

The additional work that is proposed is considered through the following project commitments made by SIGMC:

Commitment 1: To protect flora and vegetation, establish five exclusion zones – Exploration 1, Oyster and Coral Islands, Pistol Club West, Pilbailey and Implacable - within the Development Envelope within which no mine-related activities may occur.

Commitment 2: The total clearing of native vegetation is limited to 3,000 ha on land for the duration of the B2018 Project.

Commitment 3: Further targeted surveys will be conducted outside the Development Envelope during the B2018 Project to build on the understanding of conservation significant vegetation types and flora.

Commitment 4: To protect terrestrial fauna, establish three exclusion zones – Exploration 1, Pilbailey and Implacable - within the Development Envelope within which no mine-related activities may occur.

Commitment 5: Undertake further SRE survey work prior to ground disturbing works to clarify the status of fauna only known from the Development Envelope.

Commitment 6: A dewatering discharge strategy will be developed for each new open pit operation on the lake, prior to its commencement. The strategy will consider:

- **Existing dewatering practices elsewhere and impacts, if any;**
- **Likely discharge volumes;**
- **Potential for localised flooding;**
- **Likely extent and location of salt crust formation; and**
- **Potential for impact to the riparian zone and, where necessary, measures for protection of the riparian zone.**

Commitment 7: SIGMC will commence routine monitoring of salt crust formation around lake discharge points.

Commitment 8: To protect peripheral wetlands, establish three exclusion zones – Exploration 1, Pistol Club West and Implacable - within the Development Envelope within which no mine-related activities may occur.

Commitment 9: Continue to refine datasets to progress the understanding the ecological values of the peripheral wetlands and the lake within a regional context.

The commitments above utilise avoid and minimise from the mitigation hierarchy and address the ***Principle of Intergenerational Equity*** by providing for the health, diversity and productivity of the environment into the future. This principle is also embodied in the premise that the B2018 project will afford ongoing benefit to the local and regional community as well as the State Government. The positive social impacts that can be realised through the B2018 Project are identified elsewhere within this ERD and include (Department of Planning and Environment 2017):

- Community investment targeted at social development, and associated enhancements to sense of place;
- Health, wellbeing and community cohesion
- Local and regional employment (direct and indirect) opportunities, and associated increases in living
- Standards and community wellbeing
- Business and procurement opportunities for local and regional small and medium-sized enterprises

- Building local and regional workforce skills
- Contributions towards, or the development of, shared infrastructure
- Facilitating or supporting initiatives aimed at community development, capacity building and strengthening
- Community institutions
- Ongoing localised control of feral cats; and
- The payment of royalties.

These benefits are particularly relevant and tangible at the local level, given recent concerns regarding the town of Kambalda.

Environmental benefits include localised control of feral cats and rehabilitation of disturbed land.

In addition to the aspects raised within this ERD and identified through the B2018 project, there are other management measures also proposed which are framed within the concept of mitigation referred to above, but provisions for these measures already or will exist under other legislation. These include:

- *Mining Act 1978* – tenement conditions, Mining Proposals, Mine Closure Plan;
- Part V *Environmental Protection Act 1986* – Operating Licence; and
- *Rights in Water and Irrigation Act 1914* – Groundwater Licence.

As might be expected, the commitments described above focus on the consideration of the negative aspects of the project and, whilst no particular consideration suggests any level of 'unacceptability', provide additional mitigation and management of the issues and associated risks. A true holistic approach however must by definition consider the entirety of the matter, not just a part or parts thereof. As the EP Act identifies, the environment includes man's social surroundings which "are his aesthetic, cultural, economic and social surroundings to the extent that those surroundings directly affect or are affected by his physical or biological surroundings". A holistic consideration of this inherently looks at the positive as well as the negative impacts.

This ERD considers both the negative (as a primary driver for assessment) but also the positive impacts and ultimately presents a considered and balanced approach to the EIA of a long-term project which maximises the opportunity for SIGMC to continue its operations and facilitates long-term benefits (the positive impacts) being afforded to the local community and wider region through a further 10 years of operation. Importantly, the culmination of the work described in this document demonstrates that the B2018 is environmentally acceptable and that SIGMC has taken appropriate steps to mitigate some identified impacts through avoidance, management and rehabilitation. Significant time, effort and expense has gone into this ERD as well as the broader operations at the St Ives mine. SIGMC recognises their responsibility to pay for the full environmental cost of its activities in accordance with the ***Principle relating to Valuation, Pricing and Incentive***. The expectations from regulators and the community is that SIGMC's operations will operate in a manner that represents environmental leading practice, achieves and maintains statutory compliance, considers as far as practicable its operations and their impact on the environment (including discharges) and prepares a robust and realistic approach to rehabilitation and closure. GFA's vision, "To be the global leader in sustainable gold mining" echoes these expectations and, together with SIGMC, will see a leading-practice operation continue within the Development Envelope through operation, progressive rehabilitation, closure and relinquishment.

As noted elsewhere in this document, the progression of the B2018 project will necessarily result in impacts to various components of the environment (as shown in Figure 8-1 above). Such impacts can be considered through the mitigation hierarchy and initially avoided (where practicable through project design and the use of exclusion areas), minimised (through appropriate project design and management through operation and closure) and rehabilitated (through appropriate design, closure design and implementation). Whilst, the B2018 project will

result in up to 3,000ha of terrestrial disturbance and up to 2,000ha of lake-based disturbance over a 10-year timeframe, the assessment that has been undertaken by SIGMC and is discussed within this ERD together with the mitigation measures proposed, demonstrates that the ***Principle of Conservation of Biological Diversity and Ecological Integrity*** has been at the forefront of the project's development.

Further to this, in order to develop a proposal of this nature, a thorough consideration of the potential for discharges to the environment needs to occur. As demonstrated through discussion within this ERD and visually represented within Figure 8-1, all aspects of the environment are interconnected and any discharge of waste material has the potential to result not only in direct impacts to the environment, but also indirect impacts to other aspects and features. SIGMC has been mindful of these risks throughout the development of the B2018 project and has designed appropriate mitigation (avoidance, minimisation and rehabilitation) and management measures that are responsive to the project and the expectations of environmental best practice and the ***Principle of Waste Minimisation***.

It is important to recognise that the B2018 project has been conceptualised by SIGMC and brought to fruition as a proposal through careful consideration of a wide range of different considerations. Whilst the B2018 project is obviously a continuation of operations at the St Ives mine which incorporates some level of environmental impact, the project has been carefully considered by SIGMC and developed in a manner that aligns with the expectations of the EP Act and the mitigation hierarchy. This approach has considered impacts throughout the environment at a range of scales as well as the interrelationships between various aspects of the environment and the environmental factors which were identified by the EPA as being relevant.

The B2018 project and its consideration, as documented within this ERD, also consider the other potential implications of the project, both in terms of its progression as well as the possibility of it not progressing. In terms of a holistic assessment, the consideration of the environmental, financial and social implications of the project by SIGMC have determined that there are no significant risks from B2018 and that the project can proceed as proposed, subject to the mitigation and management outlined within this ERD.

9 ABBREVIATIONS AND ACRONYMS

Abbreviation or Acronym	Explanation
95th percentile	The level at which 95% of the water quality samples for a given parameter are at or below. Conversely, 5% of the samples may be above this level
ABA	Acid Base Accounting
AH Act	*Aboriginal Heritage Act 1972* (WA)
AHD	Australian Height Datum
AHIS	Aboriginal Heritage Inquiry System, a database on Aboriginal heritage in WA maintained by DPLH
AMD	Acid Mine Drainage
ANC	Acid Neutralising Capacity
ANZECC	Australian and New Zealand Environment and Conservation Council
ARI	Average Recurrence Interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
B2018 Project	Beyond 2018 Operational Continuation Project
BAM Act	*Biosecurity and Agriculture Management Act 2007*
Beyond 2010	Beyond 2010 Operational Continuation Project
bgl	Below Ground Level
BIF	Banded Iron Formation
BOM	Bureau of Meteorology
CCWA	Conservation Council of WA
CET	Community Endeavour Team
CHMP	Cultural Heritage Management Plan
CID	Channel Iron Deposit
CKB	City of Kalgoorlie-Boulder
CO_2-e	CO_2 equivalent, a measure for the impact of each different greenhouse gas in terms of the amount of CO_2 that would create the same amount of warming.
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFWA	Department of Agriculture and Food Western Australia
DBCA	Department of Biodiversity Conservation and Attractions (WA)
DBLH	Drilling, Blasting, Loading and Hauling
DEE	Department of the Environment and Energy (Commonwealth) (formerly Department of Environment)
DEM	Digital Elevation Model
DER	Department of Environment Regulation (now Department of Water and Environmental Regulation)
DIA	The Department of Indigenous Affairs (now part of the Department of Planning, Lands and Heritage)
DMA	Decision Making Authority
DMIRS	Department of Mines, Industry Regulation and Safety (formerly Department of Mines and Petroleum)
DMP	Department of Mines and Petroleum (now Department of Mines, Industry Regulation and Safety)
DO	Dissolved Oxygen

Abbreviation or Acronym	Explanation
DoE	Department of Environment (Commonwealth) (now Department of Environment and Energy)
DOM	Dissolved Organic Matter
DoW	Department of Water (WA) (now Department of Water and Environmental Regulation)
DPE	Department of Planning and Environment (NSW)
DPLH	Department of Planning, Lands and Heritage
DWER	Department of Water and Environmental Regulation
EAG	Environmental Assessment Guide
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EP Act	*Environmental Protection Act 1986*
EP Regulations	*Environmental Protection Regulations 1987*
EPA	Environmental Protection Authority
EPAS	DWER Environmental Protection Authority Services
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
ERD	Environmental Review Document
ESA	Environmentally Sensitive Area
ESD	Environmental Scoping Document
ET	Evapotranspiration
GDE	Groundwater Dependent Ecosystems
GFA	Gold Fields Australia
GFL	Gold Fields Limited
GHG	Greenhouse Gas
GL	Gigalitres
GLSC	Goldfields Land and Sea Council
GML	Gumland Land System
GWL	Groundwater Licence, as issued under the RIWI Act
GWW	Great Western Woodlands
ha	Hectares
HAP	Heritage Assessment Procedure, a documented SIGMC procedure for managing potential impacts on Aboriginal heritage
IBRA	Interim Biogeographic Regionalisation of Australia
ISQG	Interim Sediment Quality Guidelines
JV	Joint Venture
Kh	Lateral Hydraulic Conductivity, a measure of the ability of water to move horizontally through pore spaces or fractures
Kv	Vertical Hydraulic Conductivity, a measure of the ability of water to move vertically through pore spaces or fractures
LAS	Lakeside Land System
LEF	Lefroy Land System
LLLC	Lake Lefroy Land Sailing Club
m bgl	Metres below ground level
MCP	Mine Closure Plan
mg/kg	Milligrams per kilogram
mg/L	Milligrams per litre

Abbreviation or Acronym	Explanation
Mining Act	*Mining Act 1978* (WA)
MNES	Matters of National Environmental Significance, as defined in the EPBC Act
MS548	Ministerial Statement 548, originally issued by the Minister for the Environment in July 2000
MS879	Ministerial Statement 879, originally issued by the Minister for Environment and Water in November 2011
Mtpa	Million tonnes per annum
NAF	Non-Acid Forming
NAG	Net Acid Generation
NAPP	Net Acid Production Potential
NES	National Environmental Significance (see MNES)
NSW	New South Wales
OEPA	Office of the Environmental Protection Authority
PAF	Potentially Acid Forming
PEC	Priority Ecological Community
PER	Public Environmental Review
RCH	Recharge, as considered in hydrological modelling
RMCP	Rehabilitation and Mine Closure Plan
RIWI Act	*Rights in Water and Irrigation Act 1914* (WA)
ROM pad	Run-of-mine pad, for temporary storage of unprocessed ore
SIGMC	St Ives Gold Mining Company Pty Ltd
SDP	Surface Disturbance Permit
SRE	Short Range Endemics, invertebrate fauna known to have small distributions that do not move outside their specific habitat due to poor dispersal ability and, as a consequence, are vulnerable to impacts.
SRMS	Scaled Root Mean Squared
Ss	Specific Storage, a concept used in hydrological modelling
St Ives	St Ives Gold Mine
Sy	Specified Yield, a concept used in hydrological modelling
TDS	Total Dissolved Solids
TEC	Threatened Ecological Community
TSF	Tailings Storage Facility
UCL	Unallocated Crown Land
UG	Underground
UNC	Uncertain
UPGMA	Hierarchical cluster analysis, a mathematical approach to identifying similarities between different objects such that they ‘cluster’
WA	Western Australia
WC Act	*Wildlife Conservation Act 1950* (WA)
WQPN	Water Quality Protection Note
WRL	Waste Rock Landform
WSWA	Wilderness Society of WA

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