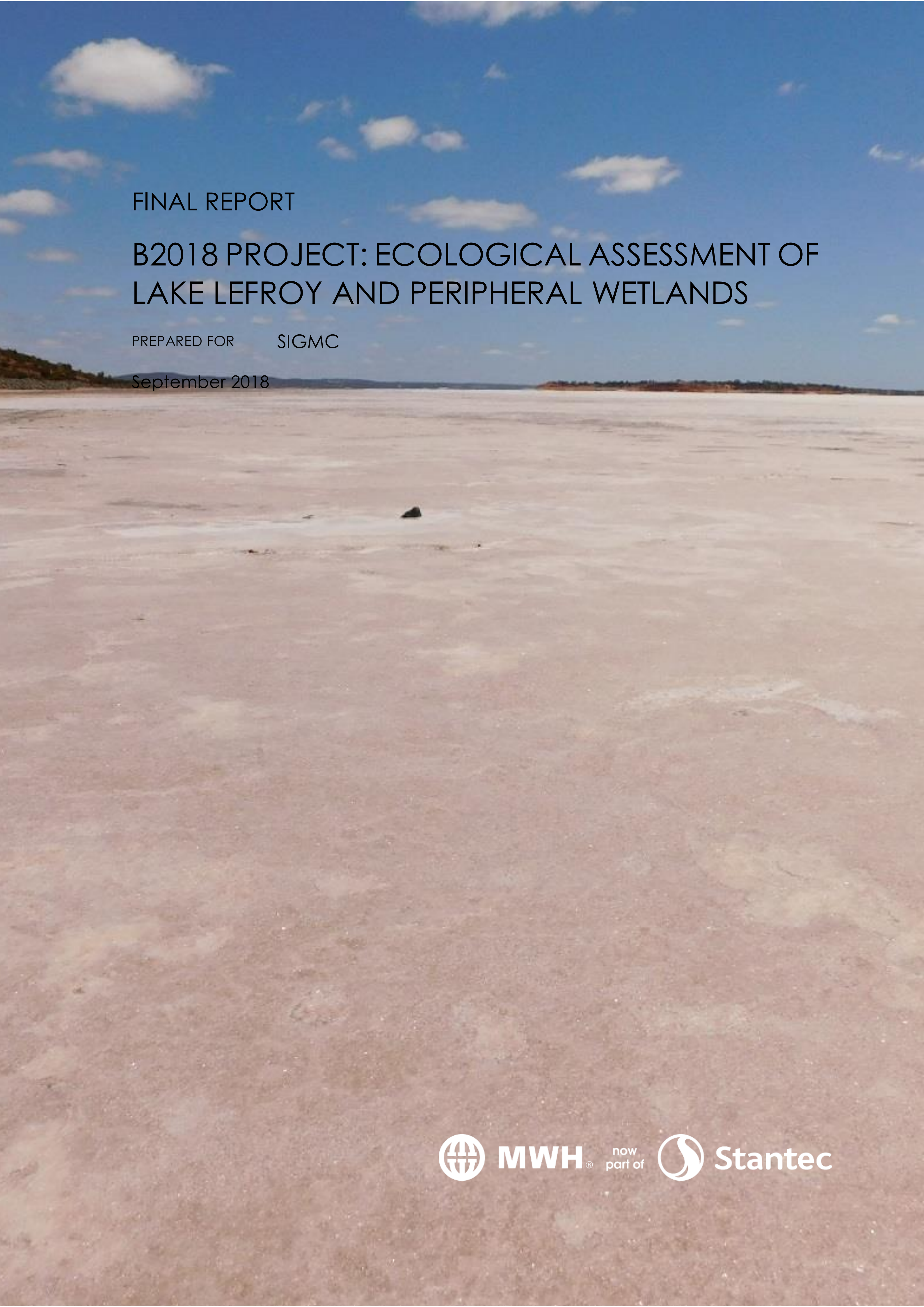
APPENDIX O: ECOLOGICAL ASSESSMENT OF LAKE LEFROY'S PERIPHERAL WETLANDS (STANTEC)



FINAL REPORT

B2018 PROJECT: ECOLOGICAL ASSESSMENT OF LAKE LEFROY AND PERIPHERAL WETLANDS

PREPARED FOR SIGMC

September 2018

MWH now part of Stantec

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QUALITY STATEMENT

PROJECT MANAGER	PROJECT TECHNICAL LEAD
Brooke Hay	Dr Fiona Taukulis

PREPARED BY		
Dr Fiona Taukulis		
CHECKED BY		
Dr Fiona Taukulis		
REVIEWED BY		
Dr David Jasper	…………………………………………	15/02/2018
APPROVED FOR ISSUE BY		
Dr Fiona Taukulis	…………………………………………	21/09/2018

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PERTH
41 Bishop Street, JOLIMONT, WA 6014
TEL +61 (08) 9388 8799

REVISION SCHEDULE

Rev No.	Date	Description	Signature or Typed Name (documentation on file)			
			Prepared by	Checked by	Reviewed by	Approved by
C	02/11/2017	Interim Draft For Review	Dr Fiona Taukulis			
D	12/02/2018	Final Draft For Review	Dr Fiona Taukulis			
E	19/02/2018	Final Report	Dr Fiona Taukulis	SIGMC	Dr David Jasper	Dr Fiona Taukulis
F	20/07/2018	Final Report (Revised)	Dr Fiona Taukulis	SIGMC	Dr David Jasper	Dr Fiona Taukulis
G	21/09/2018	Final Report (Revised)	Dr Fiona Taukulis	SIGMC	Dr David Jasper	Dr Fiona Taukulis

Executive Summary

Stantec Australia Pty Ltd (Stantec) was commissioned by St Ives Gold Mining Company Pty Limited (SIGMC; part of the Gold Fields Australia (GFA) group of companies, the ultimate parent company of which is Gold Fields Limited; GFL) to undertake a desktop assessment to summarise the ecology of Lake Lefroy and its peripheral wetlands (ecological assessment), in relation to the St Ives Gold Mine (St Ives). The ecological assessment aimed to, as far as practicable, address comments on knowledge gaps, according to the response of the Department of Water and Environmental Regulation (DWER) Environmental Protection Authority Services (EPAS), formerly the Office of the Environmental Protection Authority (EPA). These comments were provided to SIGMC, on their Beyond 2018 (B2018) Project Environmental Scoping Document (ESD). The purpose of the ESD is to define the form, content, timing and procedure of the Environmental Review Document (ERD), which includes characterising the lake environment and peripheral wetlands, as part of the objective of "maintaining the quality of groundwater and surface water to protect environmental values".

Stantec have previously assisted St Ives with streamlining a range of monitoring programs, to provide a useful insight into Lake Lefroy's overall function and ecological values, in relation to lake-based mining and dewatering discharge impacts. While existing information has been summarised for closure purposes, several knowledge gaps remain, particularly in relation to the peripheral wetlands and potential impacts associated with the B2018 Project. Therefore, the objectives of this ecological assessment were two-fold, comprising:

- Update the existing ecological summary report (St Ives Gold Mine - Closure of Lake-Based Dewatering Points: Desktop Assessment), following assessment of the peripheral wetlands, the scope of which comprised:
  - water and sediment quality
  - aquatic biota; and
  - riparian vegetation.
- Determine the ecological values of Lake Lefroy's peripheral wetlands, addressing current knowledge gaps and including key findings in the ecological assessment, by analysing the following components:
  - sediment quality, providing comparisons to the available trigger values;
  - resting stage community structure in the sediment;
  - algae (including diatoms) and macrophyte community structure (based on laboratory re-wetting trials); and
  - aquatic invertebrate community structure (based on laboratory re-wetting trials).

Following a review of more than 50 literature sources relating to lake-based ecological studies, it is apparent that a substantial amount of data collection and research has been completed, contributing to the understanding of Lake Lefroy's chemical, physical and biological attributes. However, many of these studies, while being survey intensive, have not necessarily targeted useful ecological indicators, or have widely varying methodology and taxonomic resolution, preventing meaningful spatial and/or temporal comparisons. In addition, there is limited information on the lake's peripheral wetlands, which have higher ecological value in comparison to the playa, with the latter characterised by a depauperate biological assemblage. The relationship between biodiversity, mining impacts, and historic impacts pre-SIGMC is also unknown, with no baseline data available prior to the construction of the causeway. It is known that the B2018 Project will discharge increased volumes of hypersaline water to the lake, increasing salt loads, which will potentially decrease the ecological value of the lake further. There is also potential that within the development envelope of the B2018 Project, there may be direct and indirect impacts to the peripheral wetlands, which are of greater ecological significance. A summary of the ecological components of the lake and peripheral wetlands is provided in subsequent sections, in relation to potential concerns for the B2018 Project.

Surface Water and Sediment Quality

The dataset for water and sediment quality from Lake Lefroy and the peripheral wetlands is considered patchy, with limited opportunities to sample during flooded conditions. In addition, water quality has mostly been analysed from discharge sites on the lake.

For water quality, the trends can be summarised as follows:

- Lake Lefroy – circumneutral (pH<7.5), extremely hypersaline (>300,000 mg/L), variable nutrients, and elevated concentrations of metals at discharge sites (copper, manganese, lead and zinc), compared to reference sites (except for manganese); and
- Peripheral wetlands – alkaline (>7.5), freshwater to mesosaline conditions (<32,000 mg/L), low nutrients and typically low metals (except for aluminium and copper).

For sediment, the trends can be summarised as follows:

- Lake Lefroy –acidic to alkaline (pH <6.5 to >7.5), elevated salinity at discharge sites (>500,000 mg/kg; salt crust up to 60 cm) compared to reference sites (<100,000 mg/kg; salt crust up to 8 cm), variable nutrients, and elevated concentrations of metals at the discharge sites (copper, cobalt, manganese, and zinc), compared to reference sites (except for manganese); and
- Peripheral wetlands – acidic to alkaline (pH <5.0 to >8.5), low to moderate salinity (<60,000 mg/kg), variable nutrients, and typically low concentrations of metals (except for chromium and nickel).

Discharging mine water on the lake has contributed to elevated concentrations of salts and metals in surface water and sediment, although the most obvious visual impact is the presence of a thick salt crust that covers an extensive area of the playa. However, high salinity and the sediment characteristics of the lake also suggest that metals are likely to be adsorbed to ions and fine clay particles, remaining biologically unavailable. Specific to the B2018 Project, while surface water salinities are unlikely to change at the discharge sites as concentrations are already close to saturation levels, there is likely to be less potential for dilution during major flood events. Conditions throughout the lake (including at reference sites) may increasingly reflect those at discharge sites, regardless of the magnitude of a flood event. A larger area of the lake may also be impacted by salt crusting, in addition to the predicted increase in salt crust thickness across the playa. The latter may be further exacerbated by the construction of new causeways within the development envelope.

In contrast to the lake playa, freshwater or low salinity conditions prevail at the peripheral wetlands, although studies are limited, with some evidence of natural mineralisation. These waterbodies are not at risk from discharge water, however the B2018 Project has the potential to cause increases in salinity and/or metal concentrations above background levels. This may occur via direct or indirect impacts such as surface water runoff or seepage, which contain contaminants. This is of particular concern for freshwater wetlands with strongly acidic or alkaline pH, as some metals may be more readily mobilised, posing a potential ecotoxicity risk to aquatic biota and riparian vegetation.

Aquatic Biota

The diversity and productivity of the Lake Lefroy is low due to the extreme salinity, in comparison to the freshwater and low salinity peripheral wetlands (**Table ES1**). The algal assemblage of the playa is characterised by cyanobacterial benthic communities (including *Schizothrix* mats), with diatoms occurring to a lesser extent, while phytoplankton productivity is almost negligible. In addition, macrophytes have only been recorded in the form of charophytes oospores (dormant propagules). Long-term monitoring of diatoms in the lake sediment has also shown localised impacts at discharge sites, with reference sites supporting a diatom population of mostly *Amphora*, *Hantzschia* and *Navicula* genera.

It has been suggested that the aquatic invertebrate assemblage of Lake Lefroy may be depauperate, in comparison to other saline playas in the Goldfields, likely attributed to the lack of a low salinity phase during flooding. To date, the most commonly recorded taxa include dipteran larvae (ceratopogonids), together with low numbers of copepods (*Calamoecia* cf. *salina* and *Meridiecyclops baylyi*) and the anostracan (brine shrimp) *Parartemia*. Few differences in aquatic invertebrate assemblages have been observed between discharge and reference sites on the lake, although surface water salinities are likely to be prohibitive. Limited flood event sampling, to provide regional context, also means that it is difficult to discern the relationship of aquatic invertebrate communities to the potential impacts of the dewatering discharge.

It is not known if the current environmental status of Lake Lefroy is due to dewatering discharge, or to the presence of the causeway restricting water flow, or alternatively, is the natural state of the lake. Regardless, reduced productivity of aquatic biota may be a consequence of the proposed increase in discharge volumes and salt loads associated with the B2018 Project. This is of particular concern for areas in the northern and southern extremities of the lake, which currently have not been impacted. Increased surface water salinities are likely to prevent the emergence of aquatic biota during flooding, decreasing propagule and egg replenishment opportunities.

In contrast to the lake playa, the more diverse and highly productive peripheral wetlands have been subject to minimal impacts from mining activities historically. These waterbodies support an abundant algal assemblage, including phytoplankton and benthic communities. Algal taxa mostly comprise chlorophytes (including *Oedogonium*), while cyanobacteria (such as *Microcoleus*) are known to form extensive mats. Diatoms include a range of freshwater and low salinity species such as *Nitzschia palea*. Macrophytes, represented by several charophytes and other taxa, have also been documented, and provide an important habitat and food source for aquatic invertebrates and waterbirds.

Aquatic invertebrate taxa recorded from the peripheral wetlands consist of a diverse community of crustaceans and insects. Crustaceans include anostracans (brine shrimp), ostracods (seed shrimp), copepods, notostracans (shied shrimp) and spinicaudatans (clam shrimp). Insect groups such as dipterans (fly larvae), coleopterans (beetle larvae), hemipterans (true bugs) and odonatans (dragonfly larvae) have also been recorded. Up to five potentially conservation significant aquatic invertebrate taxa have been identified from the peripheral wetlands (**Table ES-1**). These taxa are considered new or undescribed, and have a potentially restricted distribution to the Lake Lefroy area, although further investigation is required to verify their occurrence and distribution, due to limited studies completed during flood events. Regardless, the ecological value of the peripheral wetlands is considered high, and potential direct and indirect impacts associated with the B2018 Project should be minimised, in order to maintain the ecological integrity of these waterbodies.

Riparian Vegetation

Studies on the riparian vegetation zone of Lake Lefroy have indicated the presence of three main riparian communities:

- *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;
- *Melaleuca thyoides* and *Jacksonia arida* mid to tall open shrubland over *Darwinia* sp. Karonie low sparse to open shrubland; and
- *Darwinia* sp. Karonie and *Tecticornia* spp. low sparse shrubland.

Annual monitoring of the Lake Lefroy riparian zone indicates that the most frequently recorded plant taxa comprise *Darwinia* sp. Karonie, *Tecticornia indica*, *Jacksonia arida*, and *Melaleuca thyoides*. The findings of this monitoring have also been consistent over time, with no differences between discharge and reference sites in relation to species diversity, plant health and vegetation condition, and no evidence of impact from the dewatering discharge. However, increased discharge and salt loading from the B2018 Project and subsequent wind-blown salts, have the potential to adversely affect the riparian zone of the lake and nearby peripheral wetlands. Clearing for development and infrastructure, contamination associated with runoff and seepage, and changes in groundwater levels may also influence vegetation communities on the margins of the lake and within the riparian zone of the peripheral wetlands.

There may be up to six priority listed species within the riparian zone of the Lake Lefroy area (**Table ES1**), as well as several locally conservation significant and/or restricted communities. However, the riparian zone of the peripheral wetlands has not been studied in detail, and due to differences in the characteristics of these wetlands, they also have the potential to support conservation significant communities and/or taxa, requiring consideration in relation to potential direct and indirect impacts from the B2018 Project.

Table ES-1: Summary of the aquatic biota and riparian vegetation diversity (taxa numbers) recorded from Lake Lefroy and peripheral wetlands.

Ecological Component	Playa	Peripheral Wetlands	Total Taxa	Conservation Significant Taxa & Distribution
Phytoplankton	2	55	56	• None*
Benthic Algae	29	81	92	• None*
Diatoms	34	52	66	• None*
Macrophytes (incl. resting stages)	3	9	9	• None*
Aquatic Invertebrates	13	101	103	New taxa from peripheral wetlands, which are potentially restricted comprising: • *Calamoecia ampulla* var. B01 • *Eocyzicus* sp. MWH01 • *Ilyodromus* sp. BOS1031 • *Parartemia* nr *serventyi* MWH01 • *Parartemia* sp. (juvenile)
Riparian Vegetation	77	Unknown	294	Priority taxa and conservation significant communities and/or species comprising: • *Calandrinia* sp. Widgiemooltha (F. Obbens & E. Reid FO 9/05) (Priority 1) • *Tecticornia mellarium* (Priority 1); • *Tecticornia flabelliformis* (Priority 1) • *Ptilotus rigidus* (Priority 1) • *Pityrodia scabra* subsp. *dendrotricha* (Priority 3) • locally restricted conservation significant communities and/or species; and • potential groundwater dependent vegetation (GDEs)

*Note: most components are likely to have inflated taxa numbers due to poor taxonomic resolution historically (with the exception of the riparian vegetation); * due to limited taxonomic resolution of algae and macrophytes in Western Australia, with potential endemic taxa present.*

Risk Assessment & Recommendations

The outcomes of the ecological assessment of Lake Lefroy and peripheral wetlands indicate that the ecological values of the lake are "***low***", while the peripheral wetlands are of ***"high"*** ecological significance. Potentially sensitive environmental receptors were identified as water and sediment, aquatic biota and riparian zones. A range of direct and indirect impacts may be associated with the B2018 Project. These include habitat disturbance, increases in the concentrations of salt or metals (via discharge, runoff or seepage), and changes to surface hydrology and hydrogeology, which have the potential to adversely influence receptors, decreasing the biodiversity and productivity, as well as posing a potential ecotoxicity risk.

The existing salt loading on the lake associated with the dewatering discharge and/or the presence of the causeway, as well as its apparent low ecological value, led to a risk ranking of "***low to moderate***", in contrast to the relatively undisturbed peripheral wetlands, where a risk ranking of "***moderate to high***" was assigned. These environmental risks may be mitigated by addressing remaining knowledge gaps, and via ongoing monitoring to detect changes. However, impacts should primarily be minimised by avoiding areas currently not affected by mining activities, including the northern and southern extremities of Lake Lefroy and its surrounding waterbodies, which are of higher ecological significance.

Detailed recommendations are provided for consideration at the rear of this document (some of which have already been approved by SIGMC), in order to address any knowledge gaps, and progress with the collection of valuable, outcomes-based monitoring results for the B2018 Project, summarised as follows.

- review and revise the existing trigger values for Lake Lefroy water and sediment quality;
- assess the extent of the salt crust on Lake Lefroy, throughout the hydroperiod;
- locate any new discharge outfalls well onto the playa of Lake Lefroy, and ensure adequate engineering design and pre-treatment is in place to reduce erosion, flow, sedimentation and contaminants;
- continue to undertake annual monitoring of the Lake Lefroy environment and potentially the peripheral wetlands, and complete additional studies during major flood events;
- further investigation of the peripheral wetlands should be undertaken, in relation to the distribution of potentially conservation significant taxa;
- avoid construction of new causeways on Lake Lefroy, which may cause unnecessary, localised increases in salt crust thickness;
- ensure direct and indirect impacts are minimised to protect the northern and southern extremities of Lake Lefroy and the peripheral wetlands, due to their higher ecological value; and
- investigate the potential to form a Lake Lefroy catchment group with other mining companies, to coordinate environmental management of the lake and peripheral wetlands.

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1. Introduction

1.1 Purpose of the Ecological Assessment

Stantec Australia Pty Ltd (Stantec) was commissioned by St Ives Gold Mining Company Pty Limited (SIGMC; part of the Gold Fields Australia (GFA) group of companies, the ultimate parent company of which is Gold Fields Limited; GFL) to undertake a desktop assessment to summarise the ecology of Lake Lefroy and its peripheral wetlands (ecological assessment), in relation to the St Ives Gold Mine (St Ives). The ecological assessment will, as far as practicable, address comments on knowledge gaps, according to the response of the Department of Water and Environmental Regulation (DWER) Environmental Protection Authority Services (EPAS), formerly the Office of the Environmental Protection Authority (EPA).

These comments were provided to SIGMC in relation to their Beyond 2018 (B2018) Project Environmental Scoping Document (ESD). The ESD was endorsed by the EPAS on 6 October 2017, as providing an acceptable basis for the preparation of the Environmental Review Document (ERD) for the B2018 Project, which will be assessed under Part IV of the *Environmental Protection Act 1986* (EP Act). The purpose of the ESD is to define the form, content, timing and procedure of the ERD, required under section 40(3) of the EP Act. This includes characterising the lake environment and peripheral wetlands, as part of the objective of "maintaining the quality of groundwater and surface water to protect environmental values".

1.1.1 Background

In 2009, SIGMC referred the Beyond 2010 (B2010) Project proposal to the EPA, which was based on an increase in the mining area (totalling 1,713 ha of disturbance) and dewatering discharge volume (up to 30 GL/annum), with the latter discharged to Lake Lefroy. To date, there have been two modifications under section 45C of the EP Act to this proposal, approved under Ministerial Statement 879 (MS 879). The first change was for an increase of 348 ha to develop the Invincible Mine, resulting in a total disturbance area of 2,061 ha, approved in March 2014. The second change, referred to as the Beyond 2016 (B2016) Project, included an increase to the proposed development envelope, realignment of the layout of the approved disturbance area (with no increase in clearing), and additional dewatering discharge points on the lake. This change was approved in December 2016.

Currently, SIGMC requires further expansion of the disturbance area approved under MS 879; for the lake-based mining operations only. The revised proposal, which was also referred to the EPA, is for development of new lake-based and land-based gold mining areas for a ten year period (2018 to 2028), referred to as the B2018 Project (**Figure 1-1**). Following the referral, on 5 July 2017, SIGMC submitted an application for a change to proposal via section 43A of the EP Act. The proposed change was an alteration of the development envelope (with no increased impacts), and for an increase in dewatering discharge to 40 GL/annum. The EPA approved this proposal on 21 July 2017, prior to the approval and endorsement of the ESD.

1.1.2 Scope and Objectives

In 2015, Stantec assisted St Ives with streamlining several previously commissioned monitoring programs, in order to enhance the integration of information and provide a useful insight into Lake Lefroy's overall function and ecological values, in relation to lake-based mining and dewatering discharge impacts. As part of this, the *St Ives Gold Mine - Closure of Lake-Based Dewatering Points: Desktop Assessment* (MWH 2016c) was compiled to synthesize all available information on the ecology of the lake and associated environments. However, only limited information on Lake Lefroy's peripheral wetlands was included in the closure desktop assessment, due to a paucity of data. Therefore, the objectives of this ecological assessment were two-fold, comprising:

- Update the existing ecological summary report (St Ives Gold Mine - Closure of Lake-Based Dewatering Points: Desktop Assessment), following assessment of the peripheral wetlands, the scope of which comprised:
  - water and sediment quality
  - aquatic biota; and
  - riparian vegetation.

- Determine the ecological values of Lake Lefroy's peripheral wetlands, addressing current knowledge gaps and including key findings in the ecological assessment, by analysing the following components:
  - sediment quality, providing comparisons to available trigger values;
  - resting stage community structure in the sediment;
  - algae (including diatoms) and macrophyte community structure (based on laboratory re-wetting trials); and
  - aquatic invertebrate community structure (based on laboratory re-wetting trials).

While this report includes the latest, revised information on Lake Lefroy and peripheral wetlands, a regional flood study is also planned, following an adequate rainfall event, to further characterise the ecological values of these waterbodies during flooding. It is expected that information from the regional flood study may be used to refine this document in the future.

1.1.3 St Ives Gold Mine

St Ives is located in the Eastern Goldfields of Western Australia within the Shire of Coolgardie and is approximately 7 km south of Kambalda and 60 km south of Kalgoorlie. It has operations across more than 300 tenements, extending south from Kambalda, to the southern margins of Lake Lefroy (**Figure 1-2**). St Ives follows the strike of a main gold bearing deposit in excess of 30 km, and which is accessed via a number of separate satellite mining areas, comprising open pit and underground mines. Mining is carried out on the surface of Lake Lefroy; a large ephemeral salt lake, and on the lake surrounds. Operations comprise numerous open, partially-backfilled or backfilled pits, of which 16 are located on the playa of Lake Lefroy. There are 21 DWER-approved dewatering discharge points permitted to discharge excess mine water associated with mining operations, of which, 18 are located on Lake Lefroy.

1.1.4 Lake-Based Operations

Saline groundwater has been discharged to Lake Lefroy since 1965, prior to the establishment of St Ives (St Ives Gold Mining Company Pty Limited 2010). Dewatering discharge from St Ives to the lake is believed to have commenced between 1980 and 1981, during initial development of the Victory Leviathan gold deposits by Western Mining Corporation Limited (WMC). Other known approved, historic and active dewatering discharge to Lake Lefroy may have occurred from Mincor Operations Pty Ltd (Mariners Nickel Mine), Salt Lake Mining Pty Ltd (Beta Hunt Nickel Mine), Independence Group NL (Long Victor Nickel Complex), and Metals X Limited (South Kalgoorlie Gold Mine) (Department of Environment Regulation 2016; Outback Ecology 2004a).

Currently, dewatering of several St Ives' open pits and underground operations is required to maintain safe and dry conditions (**Plate 1-1**). Dewatering is undertaken from sumps; either within open pits, or from key points within underground operations. The bulk of mine dewatering from St Ives' operations is ultimately discharged to Lake Lefroy. Prior to discharge to the lake, pre-treatment takes the form of sediment settlement (using in-pit or underground sumps) and hydrocarbon capture. While St Ives have DWER approval to discharge from up to 18 lake-based points (**Figure 1-3**; **Table 1-1**), the dewatering regime is dynamic, and the discharge locations vary, and are dependent on operational requirements.

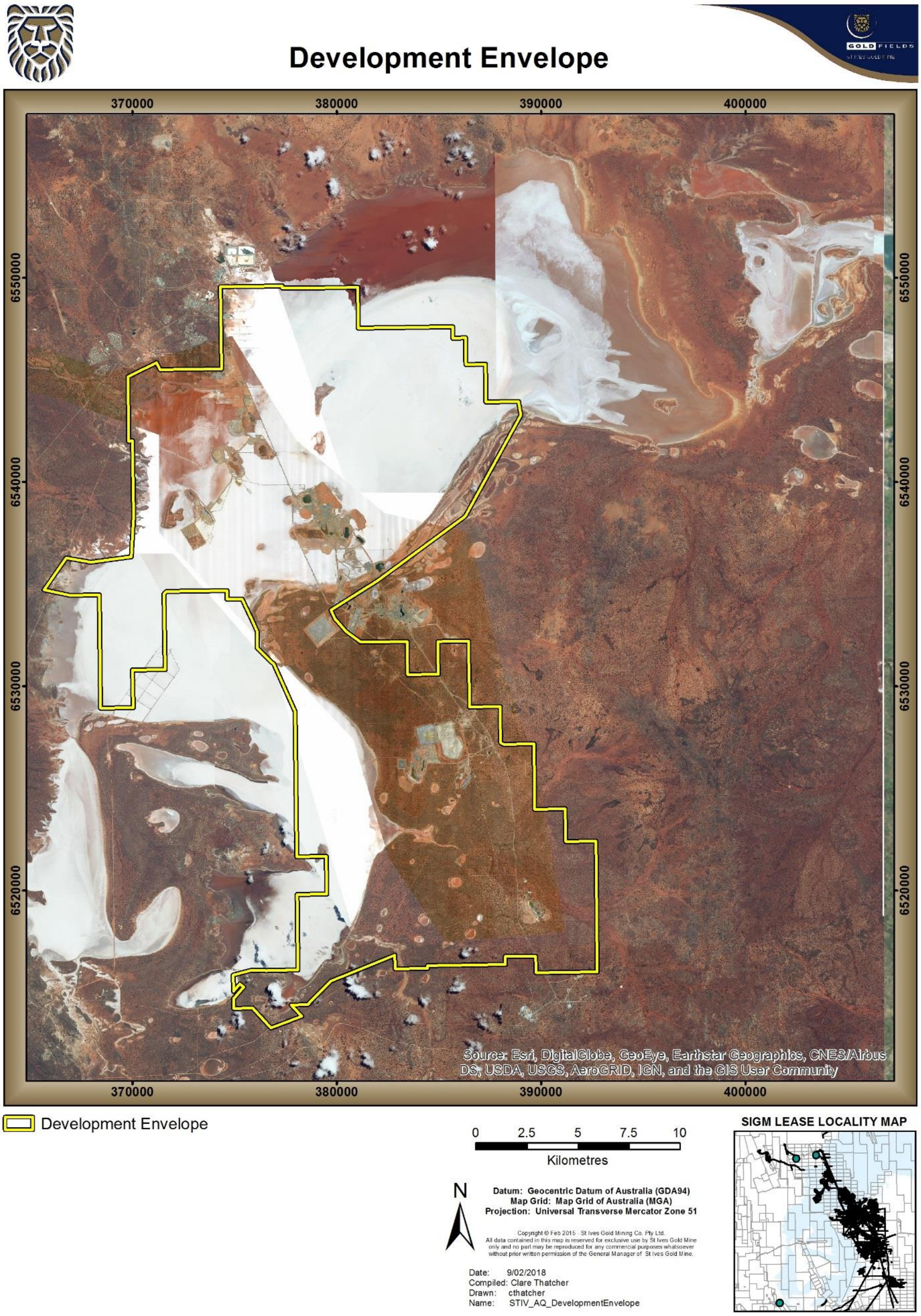

Figure 1-1: The proposed SIGMC B2018 Project development envelope for St Ives.

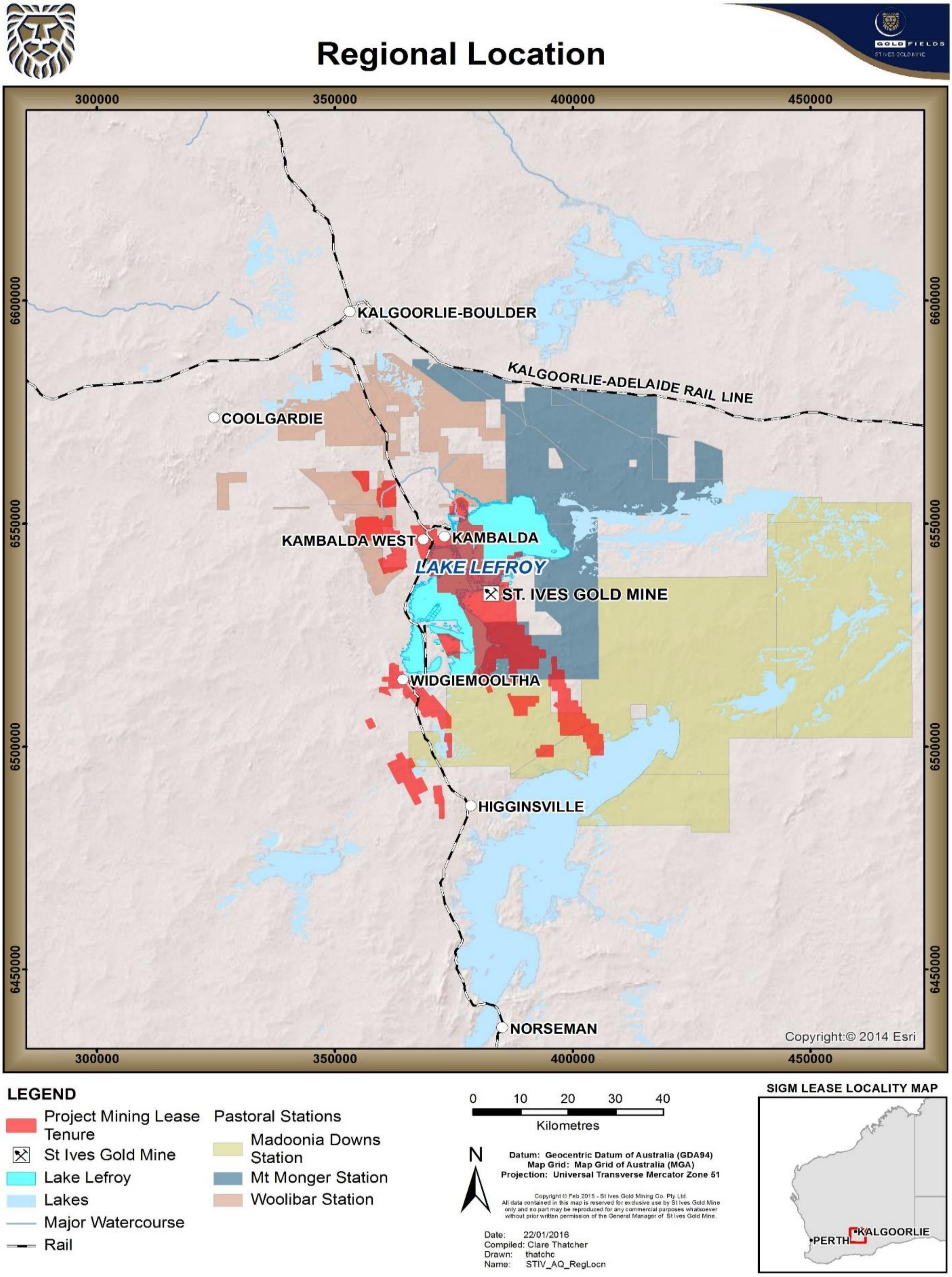

Figure 1-2: Location of St Ives and associated tenements in Western Australia, showing relevant localities.

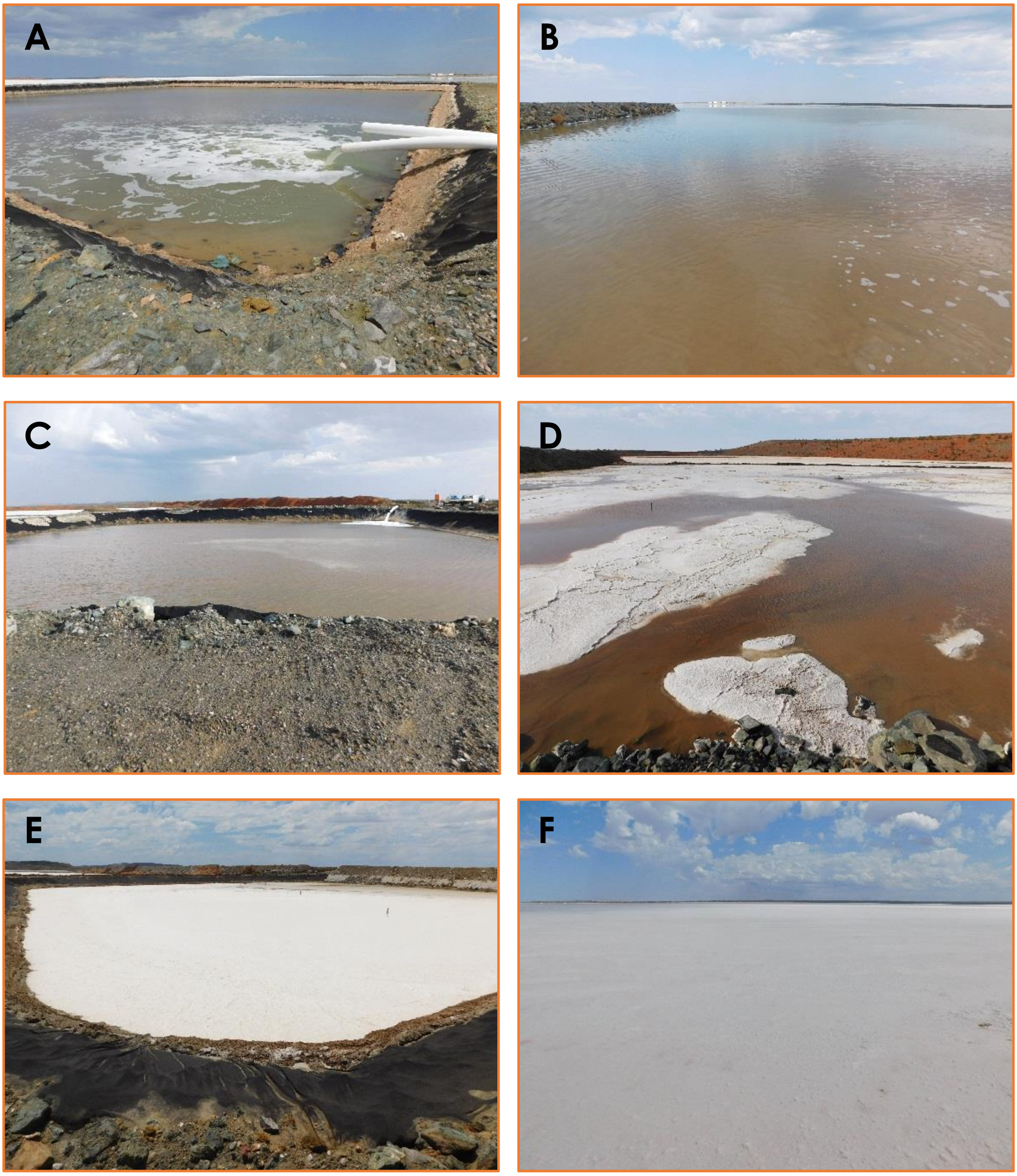

Plate 1-1: Discharge points on Lake Lefroy; (A-B) Invincible, (C-D) Revenge, and (E-F) Santa Ana.

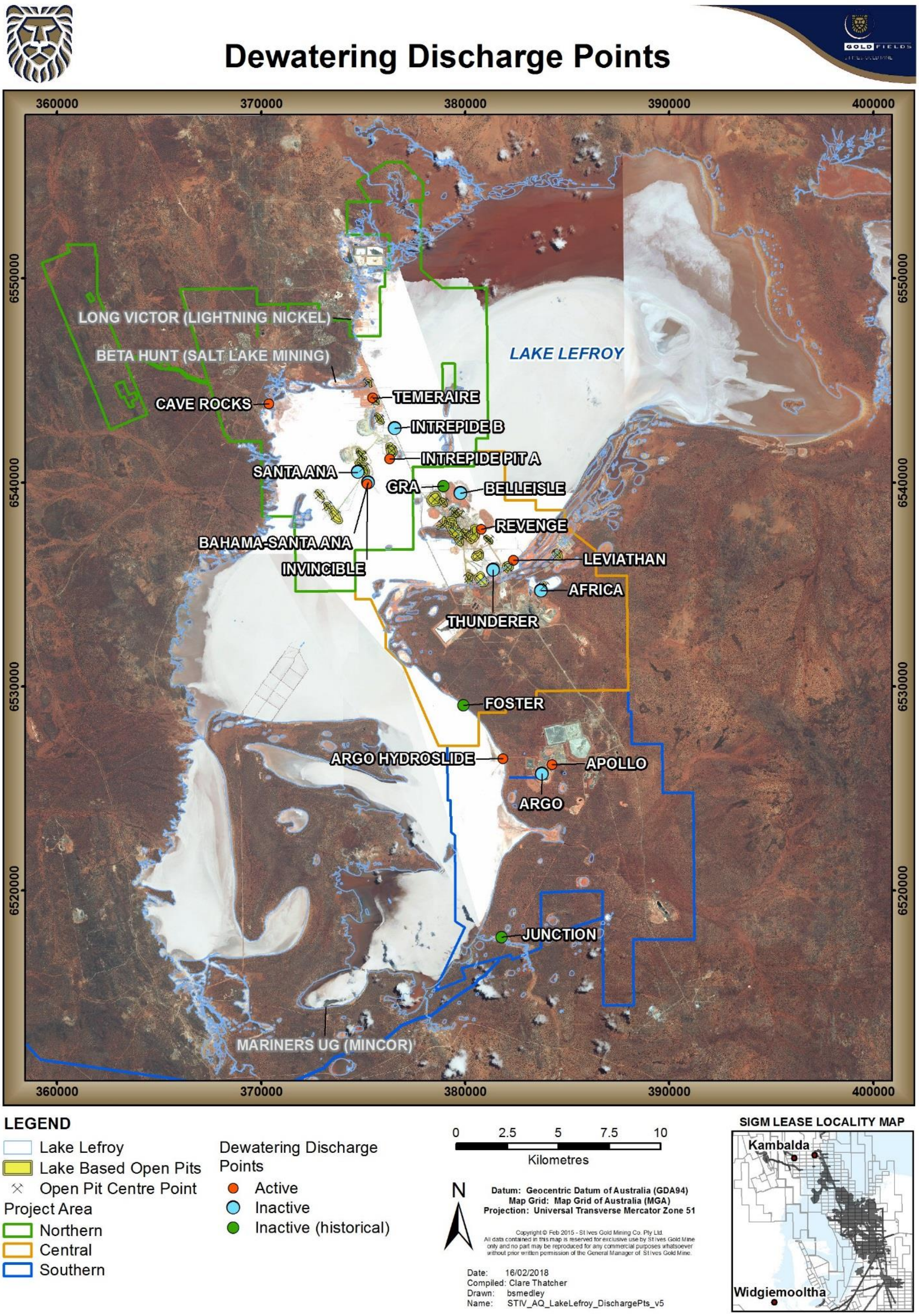

Figure 1-3: Location of DWER approved discharge points on Lake Lefroy.

Table 1-1: List of DWER approved and historic discharge points at St Ives, and their operational status (as at February 2018).

Dewatering Discharge Point	Approved by DWER	Approved by EPAS	Discharge Infrastructure	Discharge Point Location Code	SIGMC Operational	Location	Last Discharge Activity
Apollo	Yes	-	In-pit	-	Active	51 J 384258 6526172	(current)
Cave Rocks	Yes	-	Turkeys Nest	W1	Active	51 J 370384 6543866	(current)
Intrepide Pit A	Yes	-	In-pit	W2	Active	51 J 376250 6541585	(current)
Revenge (GRA)	Yes	Yes	Turkeys Nest	W4	Active	51 J 380784 6537706	(current)
Leviathan	Yes	Yes	Turkeys Nest	W5	Active	51 J 382360 6536194	(current)
Invincible (a)	Yes	-	Turkeys Nest	W10	Active	51 J 375201 6539936	(current)
Temeraire	Yes	-	In-pit	W12	Active	51 J 375462 6544150	(current)
Invincible (b)	Yes	-	Turkeys Nest	W18	Active	51 J 373876 6538563	(current)
Argo	-	-	In-pit	-	Inactive	51 J 383769 6525727	TBA
Belleisle	Yes	Yes	Turkeys Nest	W3	Inactive	51 J 379779 6539478	Jul-14
Thunderer	Yes	Yes	Turkeys Nest	W6	Inactive	51 J 381368 6535709	Sep-10
Africa	Yes	-	In-pit	W7	Inactive	51 J 383728 6534690	Dec-12
Argo Hydroslide	Yes	Yes	Turkeys Nest	W8	Inactive	51 J 381843 6526459	Apr-14
Santa Ana	Yes	Yes	Turkeys Nest	W9	Inactive	51 J 374749 6540504	Sep-15
Bahama-Santa Ana	Yes	-	Turkeys Nest	W11	Inactive	51 J 375239 6539992	Jun-15
Revenge (b)	Yes	-	Turkeys Nest	W16	Inactive	51 J 380785 6537699	TBA
Foster	Yes	-	Lake	W14	Inactive (historic)	51 J 379908 6529077	1990s
GRA	Yes	Yes	Turkeys Nest	W20	Inactive (historic)	51 J 378935 6539821	TBA
Junction	Yes	Yes	Creekline	W21	Inactive (historic)	51 J 381779 6517712	late 1990s
Intrepide B	Yes	-	TBD	W13	TBC	51 J 376553 6542656	Planned
Pistol Club	Yes	-	TBD	W15	TBC	51 J 373935 6543590	Planned
Grinder	Yes	-	TBD	W17	TBC	51 J 381250 6537308	Planned
Incredible	Yes	-	TBD	W19	TBC	51 J 379963 6523588	Planned

Note: DWER-approved discharge locations W13, W15, W17 and W19 are yet to be constructed; orange text indicates an active discharge point, blue text indicates an inactive discharge point, green text indicates an historic discharge point, black text indicates yet to be constructed/active discharge points; non-lake-based discharge point are indicated by "in-pit".

1.1.4.1 Regulation and Compliance

Environmental monitoring, associated with dewatering discharge to Lake Lefroy, is currently prescribed in MS 879 (**Appendix A**). The conditions outlined in MS 879 require monitoring of riparian vegetation, surface water quality, sediment quality, aquatic flora and fauna, terrestrial invertebrate fauna, migratory waterbirds, and lake hydrology and bathymetry, with the aim of reducing and / or mitigating impacts to the receiving environment, where possible.

St Ives is classified as a prescribed premise according to Schedule 1 of the Environmental Protection Regulations 1987 (EP Regulations), listed on their DWER EP Act Licence L8485/2010/2 (L8485/2010/2), Category 6–Mine Dewatering (**Appendix B**). This licence allows for the abstraction and discharge of up to 30,000,000 t per annum of mine water to Lake Lefroy (equivalent to 30 GL/annum), from numerous mines and pits. St Ives is also required to monitor surface water and sediment quality, relating to dewatering discharge on the lake. The most recent licence amendment was approved in October 2016, which included the dewatering of a new pit (A5), and the addition of five discharge locations. At the time of reporting, two underground mines (Hamlet and Invincible), and three open pits (A5, Neptune and Pistol Club), were in operation by SIGMC, with dewatering to five lake-based discharge points (**Figure 1-3**).

2. Existing Environment

2.1 Biogeographical Context and Land Use

Lake Lefroy is located in the Eastern Goldfields subregion (COO 3), within the Coolgardie bioregion, in Western Australia (**Figure 2-1**), as defined by the Interim Biogeographical Regionalisation for Australia (IBRA) classification system (Thackway and Cresswall 1995). Although the majority (98%) lies within the Rangelands, the western edge of the Coolgardie bioregion extends into agricultural zones. The subregion lies within the Yilgarn Craton, a granite basement characterised by Archaean Greenstone intrusions in parallel belts. The relief is subdued and comprises of 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 (Cowan 2001). Underlying geology consists of gneisses and granites eroded into a flat plane covered with tertiary soils and scattered bedrock. Calcareous earth is the dominant soil type. The western area of the subregion is characterised by several large salt lakes, the remnants of ancient major drainage lines.

Lake Lefroy lies within the Kalgoorlie Province, correlating with the majority of the Coolgardie botanical district (Beard 1990).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 (*Tecticornia*) shrubland dominates the fringing vegetation of salt lake systems.

The Eastern Goldfields subregion totals 5,102,428 ha, with primary land uses comprising Unallocated Crown Land, Crown reserves, grazing (37.8%), freehold (7.15%), and conservation and mining (**Figure 2-2**) (Cowan 2001). A total of 3.8% of the Eastern Goldfields subregion is located within a conservation estate (Bastin and ACRIS Management Committee 2008). Past and present land use in the area is summarised as follows:

- salt mining was conducted at the southern end of Lake Lefroy near Widgiemooltha during the 1940s, and subsequently 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 occurs periodically at the northern end of the Lake Lefroy Peninsula;
- pastoral land is located throughout the region, with SIGMC tenements located on and adjacent to the Woolibar, Madoonia Downs and Mt Monger pastoral stations (**Figure 2-2**); and
- recreational activities associated with the lake include wildlife photography, walking and hiking, motorbike riding, and land sailing.

Figure 2-1: Location of St Ives within the Coolgardie bioregion and Eastern Goldfields subregion.

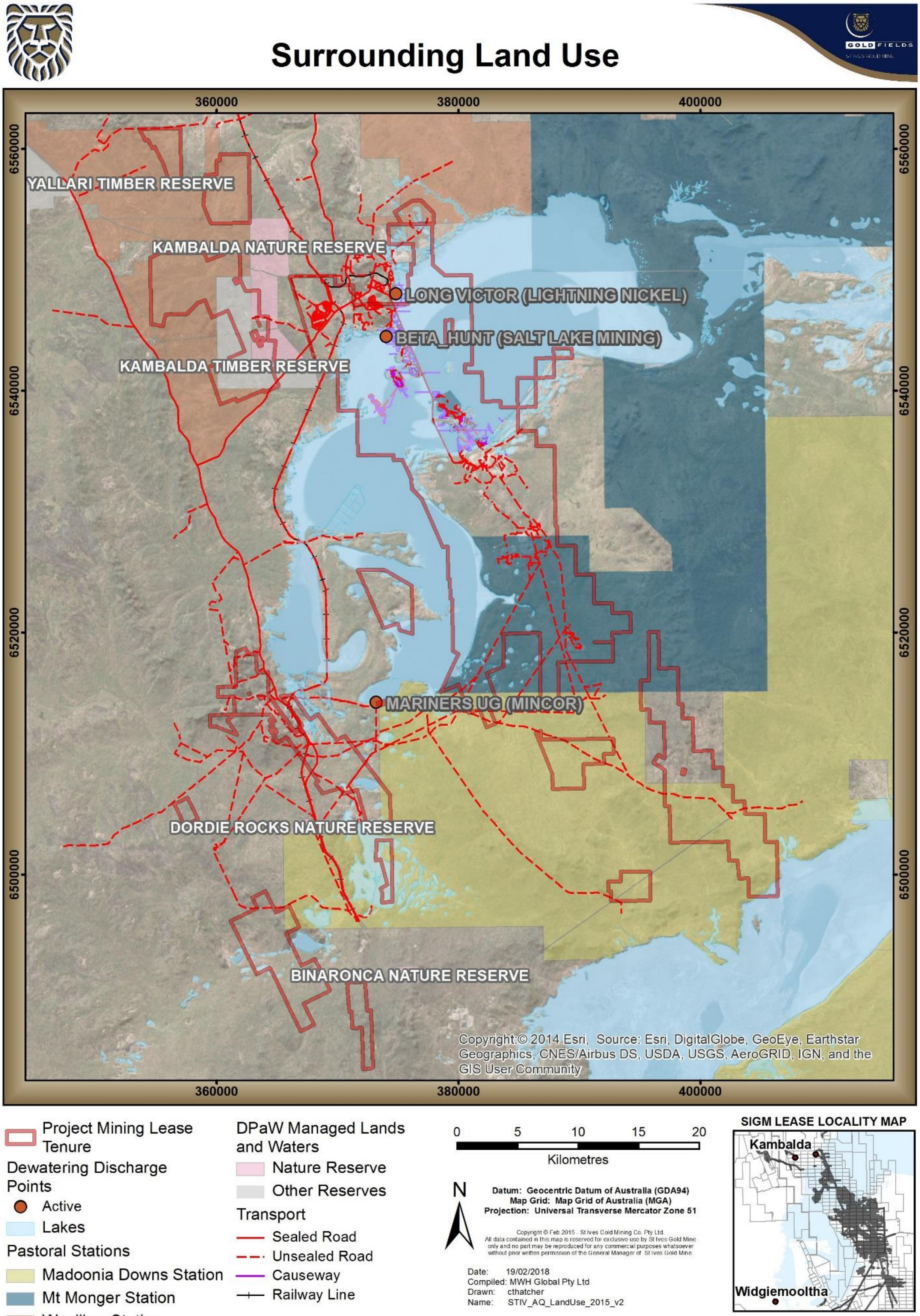

Figure 2-2: Land use surrounding St Ives and Lake Lefroy.

2.2 Climate

The climate of the Eastern Goldfields subregion is classified as arid to semi-arid, with an average rainfall of 250 to 300 mm per annum. The area has an average of 64 wet days per year and rainfall distribution is bi-modal, with peak mean monthly rainfall in February, generally resulting from ex-tropical cyclones or isolated thunderstorm activity. A secondary peak occurs in June, associated with the passage of cold fronts. During the summer months, prevailing winds are predominantly from the east in the mornings, tending southwest in the afternoon. During the winter months, prevailing winds are predominantly from the northeast in the morning, tending mildly west in the afternoon. The nearest Bureau of Meteorology weather station to St Ives is at Kambalda West (012117), approximately 12 km northwest. The long term average annual rainfall for Kambalda West is 299 mm (**Figure 2-3**) (Bureau of Meteorology 2017), with average annual evaporation ranging from approximately 2,700 mm to 3,000 mm throughout the area (Kern 1995). Potential evaporation on the playa of Lake Lefroy is approximately 1350 mm per year, due to the hypersaline conditions and the large size of the lake (URS Australia Pty Ltd 2010b).

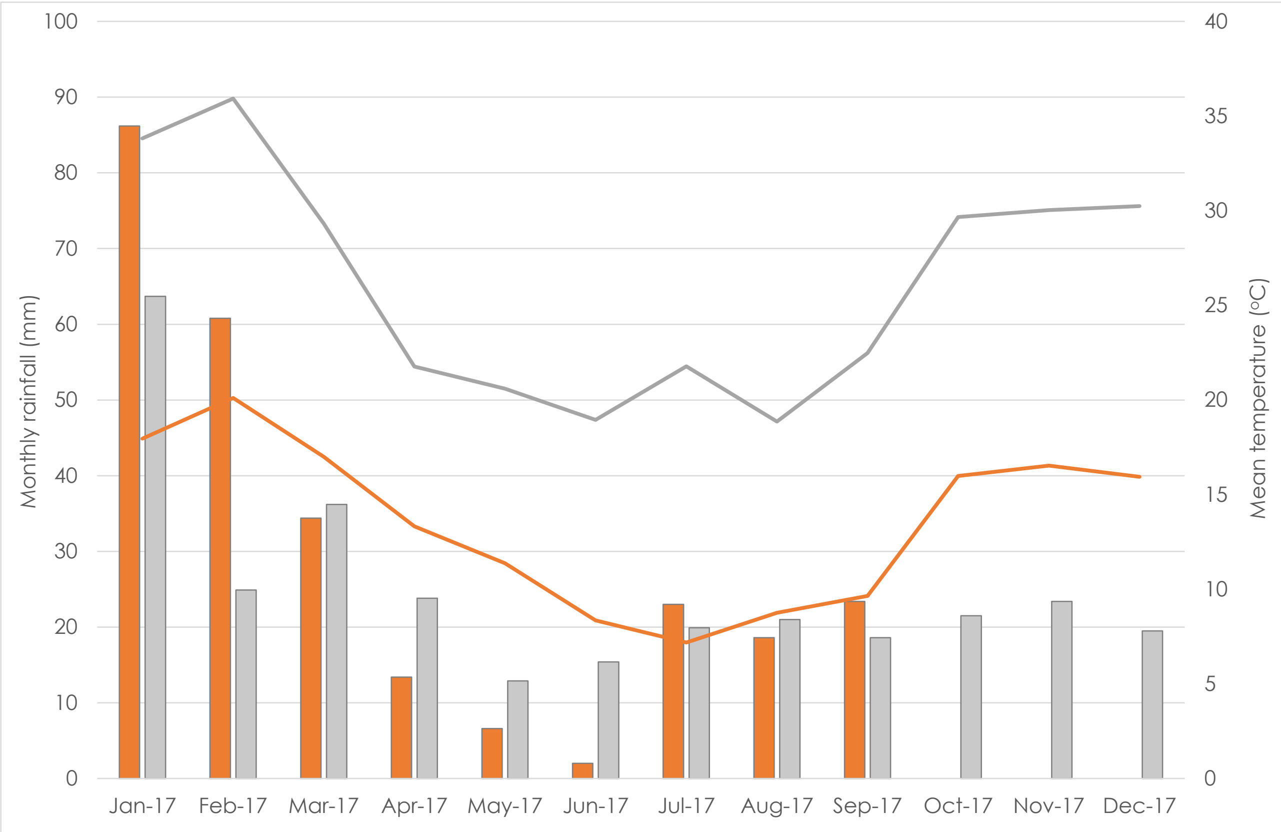

Figure 2-3: Total monthly rainfall (■) recorded at the Kambalda West weather station (012117) for 2017 to date, compared to long term average monthly rainfall (■); St Ives data presented for minimum temperature (—) and maximum temperature (—).

2.3 Physical Characteristics

2.3.1 Catchment and Topography

Lake Lefroy covers an area of 554 km^2 and is located within the Lake Lefroy catchment (**Figure 2-4**), which is approximately 4,528 km^2 in size (Clarke 1991). The lake appears to be a system in transition between an ephemeral lake and a salt pan, with continuing build-up of salts occurring via natural processes (Clarke 1994b), as well as dewatering discharge. It is estimated that approximately 2.4 million tonnes of salt is added to Lake Lefroy annually, as a result of mine discharges to the lake (Handley 2003; Vasey 2001). While the surface of Lake Lefroy varies in bathymetry, the playa is generally of low relief, at approximately 286 m above sea level.

2.3.2 Geology and Geomorphology

St Ives operations lie within the Kambalda Domain geological province, a subset of the Norseman-Wiluna Belt. The stratigraphic succession in the Kambalda domain comprises the Kalgoorlie group volcanic rocks and the Black Flag group felsic volcanic and sedimentary rocks, overlain by the post-tectonic Merougil beds unit. There are several styles of gold mineralisation at St Ives, including lode, supergene and palaeoplacer mineralisation. The interaction between structures and rock types has produced a large number of individual gold deposits, with at least 80 having been mined in the greater area. Mineralisation is controlled by the Boulder-Lefroy Fault and is generally associated with subsidiary structures such as quartz veins, brecciated zones and mylonitic sections of shear zones. The majority of known gold deposits follow the anticlinal axis, with the Playa shear diverting from the Boulder-Lefroy Fault shear zone for more than 10 km. With the exception of the Junction and Leviathan mines, operations generally centre within the Lefroy Palaeodrainage beneath a cover of Tertiary to Recent sediment.

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 (Payne 1998). Soils adjacent to Lake Lefroy comprise aeolian and alluvial material, with the more recent dunes comprising red, yellow and brown siliceous sands, of which gypsum may form part of the dune core. Red sand dunes containing weakly developed calcareous red earth and gypsum dunes form secondary dune systems, and silty sand with calcrete nodules, located furthest away, form the older Tertiary dune systems (Clarke 1991). The lake shore 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), with the playa occupying the lowest part of the landscape.

Figure 2-4: Location of St Ives operations, within the Lake Lefroy catchment area.

2.3.3 Hydrogeology

Lake Lefroy forms the headwater of the Lefroy Palaeodrainage, one of four main palaeodrainage systems in the area (**Figure 2-5**), which regionally flow eastwards towards the Eucla Basin (Clarke 1994a). The majority of operations at St Ives are located in or along the margins of Lake Lefroy, within the 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 area comprises a series of channelled, fine to coarse grained sand horizons representing in-filled palaeodrainage channels. In the Roe Palaeodrainage (west and north of Kalgoorlie), this unit is known formally as the Wollubar Sandstone. It is likely a lateral equivalent to the Hampton Sandstone, which is a shallow marine, estuarine and deltaic deposit commonly found around the margins of the western Eucla Basin (Clarke 1991; URS Australia Pty Ltd 2010a). The palaeodrainage channel sand unit of Lake Lefroy 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).

Fractured rock aquifers occupy the greater part of the Kalgoorlie area, generally containing only minor groundwater supplies. Fresh groundwater does not occur in the region, although some brackish groundwater exists in the upper reaches of some catchments. The regional water table ranges from less than 1 m below the ground, beneath and adjacent to Lake Lefroy, to more than 50 m below the ground in elevated areas. The natural groundwater flow is towards the Lefroy Palaeodrainage (**Figure 2-5**). Aquifer types identified within the local region include:

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

Recharge from the playa into underlying lacustrine sediment 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).

Operations at St Ives are located within the Lefroy Dundas sub-area of the Goldfields Groundwater Management Area, and groundwater in the broader area generally ranges from 50,000 to 300,000 mg/L total dissolved solids (TDS). Groundwater quality in the local vicinity of Lake Lefroy ranges between 274,000 and 423,000 mg/L TDS and metal concentrations reflect the mineralogy in the region (**Appendix B**).

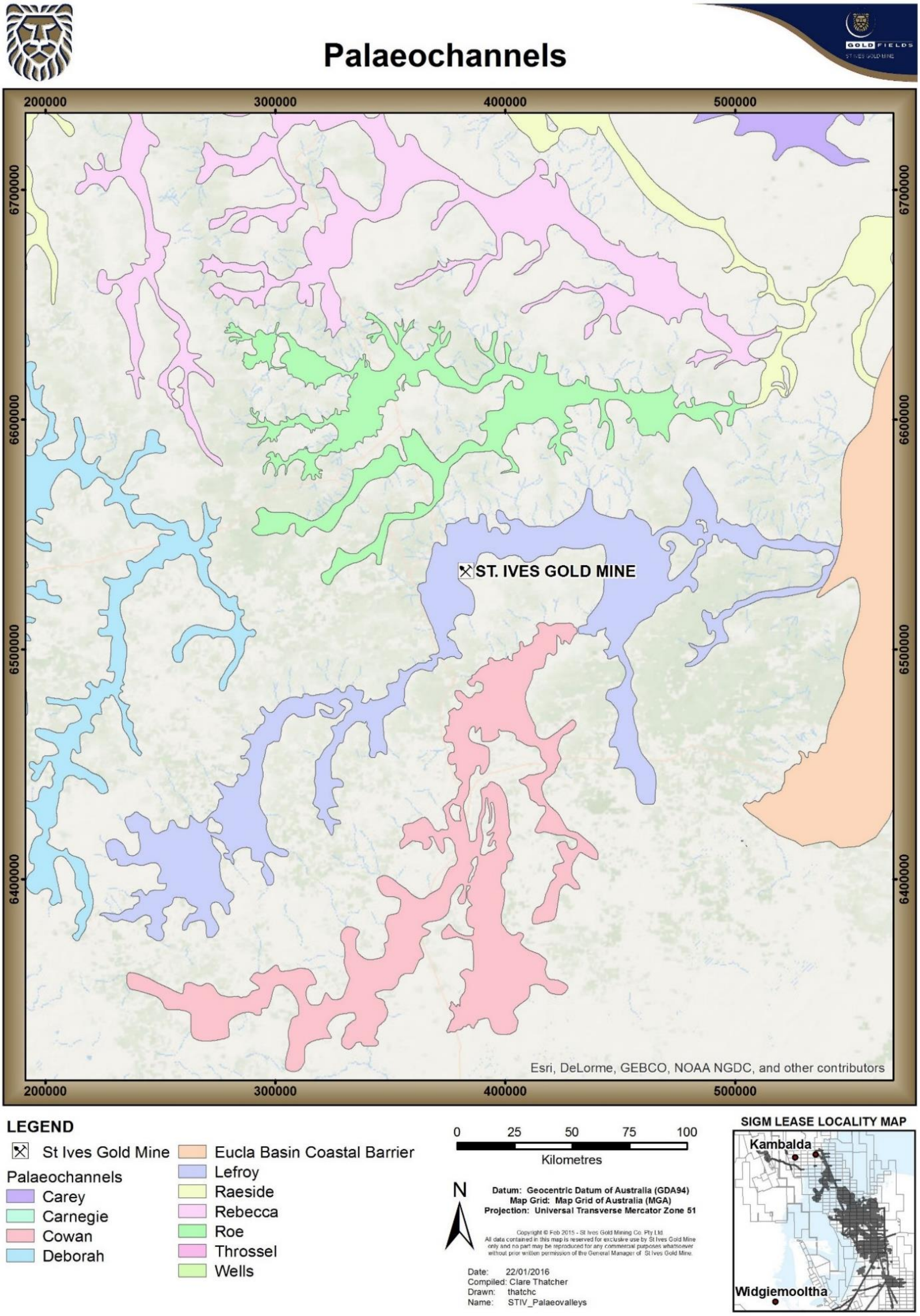

Figure 2-5: Location of St Ives operations within the Lefroy Palaeodrainage.

2.3.4 Surface Hydrology

Lake Lefroy is the major surface waterbody within the St Ives operational area, and is surrounded by numerous ephemeral drainage channels, creeklines and claypans (**Figure 2-6**). The hydrology of the lake has been substantially altered, due to the construction of the primary causeway in the late 1960s (St Ives Gold Mining Company Pty Limited 2010), which 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.

While the bathymetry of the lake is generally flat, there are two shallow water accumulation areas in the northeast and central southern areas (URS Australia Pty Ltd 2010b). Rainfall typically generates minimal lake surface flows, with runoff tending to infiltrate surrounding soils, before entering the playa (Handley 1991). The high infiltration capacity of the area, coupled with high evaporation rates, also appear to contribute to the limited residence time of surface water on the lake (URS Australia Pty Ltd 2010b).

Lake Lefroy is subject to rare, major flood events (**Figure 2-7**) and, due to its large size, the playa can accommodate major inflows, often attributed to ex-tropical cyclones causing heavy rainfall during summer. In these instances, flooding occurs rapidly, and surface water may remain in the lake for long periods (CSIRO Land and Water 2003). This was demonstrated following Tropical Cyclone Vance in March 1999 (Bureau of Meteorology 2016a) and Tropical Cyclone Steve in February and March 2000 (Bureau of Meteorology 2016b), with surface water persisting on the lake for approximately nine months after each event. The last significant flood event occurred in late January 2014, following more than 150 mm of rain, over a three day period (Bureau of Meteorology 2015), as a result of local storm activity.

During flood, the lake exhibits substantial fluctuations in water depth and movement, due to 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 mining infrastructure, the lake does not necessarily fill uniformly across the playa (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).

The salinity of the lake's surface water has been recorded to range from 260,000 mg/L to 435,000 mg/L TDS (URS Australia Pty Ltd 2010b), and a low salinity phase appears to be absent (based on sampling undertaken to date), even after large influxes of freshwater (Phoenix Environmental Sciences 2014). This can be attributed to the presence of an extensive salt crust on the surface of the playa. In contrast, there are numerous peripheral wetlands and claypans surrounding the lake, which are typically less saline (<10,000 mg/L) or freshwater (<3,000 mg/L) (Phoenix Environmental Sciences 2014), although limited information is available on their hydrological characteristics.

Recent hydraulic modelling undertaken to support the B2018 Project proposal assessed potential groundwater and surface water management impacts associated with increased dewatering discharge (Stantec 2017b). The modelling showed that increased discharge volumes were unlikely to contribute to substantial changes in the surface water elevation across Lake Lefroy (predicted to be <0.2 m), or inundation levels of the riparian zone and vegetation communities. However, the construction of causeways to support new operations associated with the B2018 Project was identified as likely to impact on local surface water elevation and salinity. In addition, the salt load on the lake was primarily found to be associated with historic and active dewatering discharge, with the salt crust on the playa's surface increasing in cover from an estimated 65% in 1991 (Clarke 1991) to 85% in 2017 (Stantec 2017b).

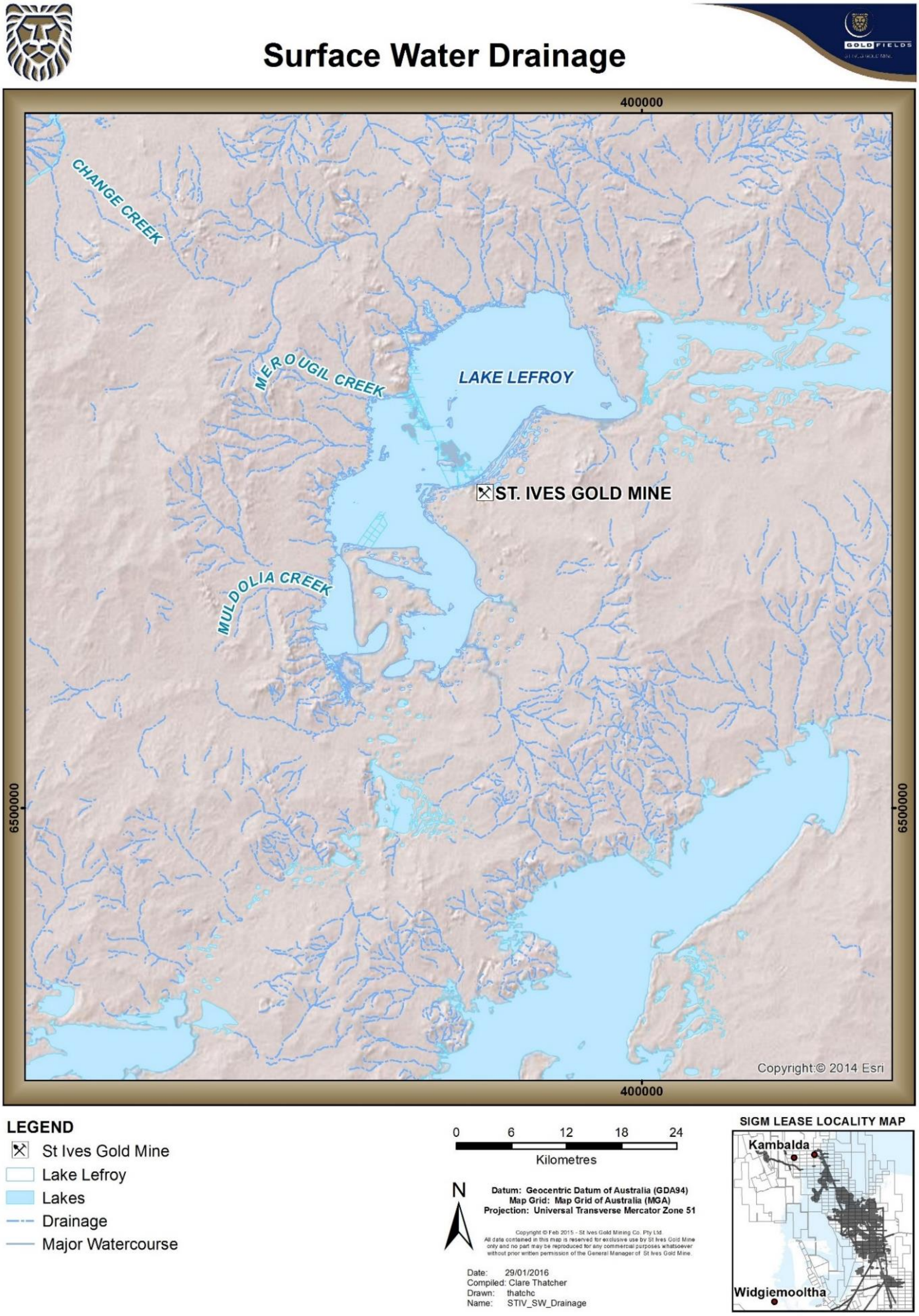

Figure 2-6: Surface drainage patterns surrounding Lake Lefroy.

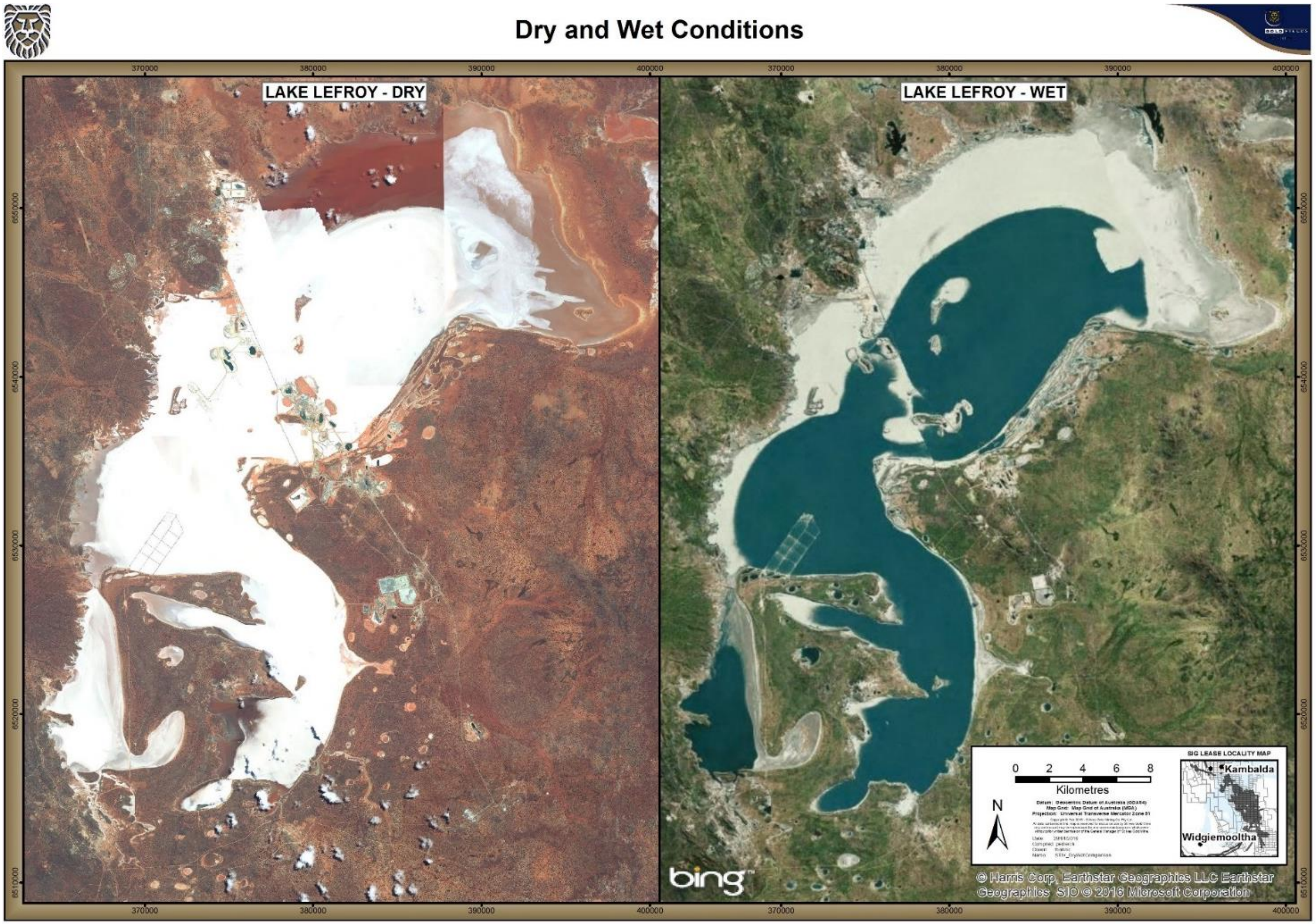

Figure 2-7: Comparison of Lake Lefroy in dry and flooded conditions.

2.4 Ecology

2.4.1 Database Searches and Conservation Significant Ecosystems

2.4.1.1 Wetlands

Database searches indicate that there is one wetland of national importance located in the Eastern Goldfields subregion; the Rowles Lagoon system (Department of the Environment 2010), situated more than 100 km northwest of Lake Lefroy in the Rowles Lagoon Conservation Park (**Figure 2-8**). It is the largest semi-permanent, freshwater wetland in the subregion (Department of Conservation and Land Management 2000), and following a major inundation event, comprises numerous ponds and marshes that provide a range of feeding, breeding and sheltering habitat for large numbers of waterbirds. While the subregion contains no Ramsar wetlands (Department of the Environment 2013), up to 41 species of waterbirds, including eight species protected under international agreements (JAMBA, CAMBA, ROKAMBA, Bonn Convention, etc.), have been recorded using Rowles Lagoon; more than any other Western Australian arid zone wetland south of the Kimberley region. A number of wetlands of subregional importance are known to occur within 200 km of St Ives, including Swan Lake (~100 km northeast), Lake Cowan (~50 km south) and Lake Arrow (~80 km north northwest) (Cowan 2001) (**Figure 2-8**).

2.4.1.2 Vegetation, Flora & Fauna

According to the database search results, there are no threatened ecological communities within the Eastern Goldfields subregion (**Appendix C**). The nearest priority ecological community are the vegetation complexes of the Woodline Hills (~100 km southeast of Lake Lefroy), Fraser Range vegetation complex (~140 km southeast) and Lake Giles (~200 km) (Department of Biodiversity, Conservation & Attractions 2017) (**Figure 2-8**; **Appendix C**). Flora and fauna records from the subregion also list 10 threatened fauna and more than 30 threatened flora species at a State level (Cowan 2001).

In the vicinity of Lake Lefroy, there are several C-Class reserves including the Kambalda Timber Reserve and Kambalda Nature Reserve (**Figure 2-2**). A halophytic community is also located on the southern margin of Lake Lefroy, adjacent to Madoonia Downs Station (**Figure 2-8**). This consists of an unusual combination of *Eucalyptus* woodland over a halophyte shrubland, on sandy loam (Australia's Virtual Herbarium 2010).

Figure 2-8: Location of conservation significant aquatic, flora and fauna ecosystems and species within 200 km of Lake Lefroy and St Ives.

2.4.2 Literature and Ecological Studies

There have been more than 50, predominantly lake-based, ecological studies, which have aimed to address knowledge gaps for Lake Lefroy and comply with regulatory conditions. Many of these have also attempted to quantify potential impacts associated with dewatering discharge to the lake, incorporating sampling sites (**Figure 2-9**) on the playa (**Plate 2-1A-F**) and peripheral wetlands (**Plate 2-2A-F**). Initial baseline studies of the lake were undertaken in 1999 during flooding, to determine the diversity of aquatic biota (Curtin University of Technology 1999a;b), based on commitments associated with St Ives' MS 548 (Environmental Protection Authority 2000). 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;2009). Intermittent ecological monitoring has also been completed as required, to ensure compliance and meet approvals requirements (Clarke 1991; CSIRO Land and Water 2003; Jim's Seeds Weeds & Trees 2006; Western Wildlife 2006).

In 2010, a number of comprehensive studies were commissioned by St Ives on the hydrology and ecology of Lake Lefroy, and the surrounding environment, to support the submission of the B2010 Project proposal (St Ives Gold Mining Company Pty Limited 2010). These included intensive lake studies investigating aquatic biota (Dalcon Environmental 2010a). Following on from this work, sampling during a major flood event was undertaken in 2014 (Phoenix Environmental Sciences 2014), while annual monitoring continued to assess mining impacts; primarily the influence of dewatering discharge (MWH 2016a;2017). This ensures compliance with St Ives MS 879, issued after the B2010 PER submission in late 2011, and the DWER's L8485/2010/2, both of which are still current. A limited number of studies have also been undertaken on the ecological values of Lake Lefroy's peripheral wetlands (Curtin University of Technology 1999a;b; Phoenix Environmental Sciences 2014). However, due to the proposed B2018 Project, these waterbodies have recently had greater focus, with increased investigation (**Appendix D**).

Despite the numerous studies completed to date, there are still substantial knowledge gaps, particularly within a regional context and relating to ecological values during flood events. In addition, the historic impacts on the lake's ecology, prior to the construction of the causeway is unknown, due to limited baseline information. As SIGMC progress with developing the ERD for the B2018 Project, some of these knowledge gaps aim to be addressed. The following sections provide a synthesis of available ecological information on Lake Lefroy and the peripheral wetlands that is known to date.

For the purposes of data comparison over time, sampling sites (**Figure 2-9**), which have incorporated the assessment of aquatic biota and riparian vegetation on the Lake Lefroy (**Plate 2-2A-F**), have been classified as the following:

- discharge site – a lake-based discharge point that is receiving dewatering discharge (active);
- historic discharge – a lake-based discharge point that no longer receives discharge (inactive); and
- reference site – a lake-based sampling site that has not received discharge, although may still be affected by pastoral, anthropogenic or other exploration / mining impacts.

The term 'peripheral wetlands' also includes:

- freshwater claypans and low salinity waterbodies surrounding the lake; and
- creeklines and tributaries on the lake margins.

While the lake has been subject to mining impacts primarily in the form of dewatering discharge, the peripheral wetlands remain relatively undisturbed (with a few exceptions).

Plate 2-1: Lake Lefroy; (A-B) discharge sites, (C) historic discharge site, (D) riparian zone, and (E-F) reference sites.

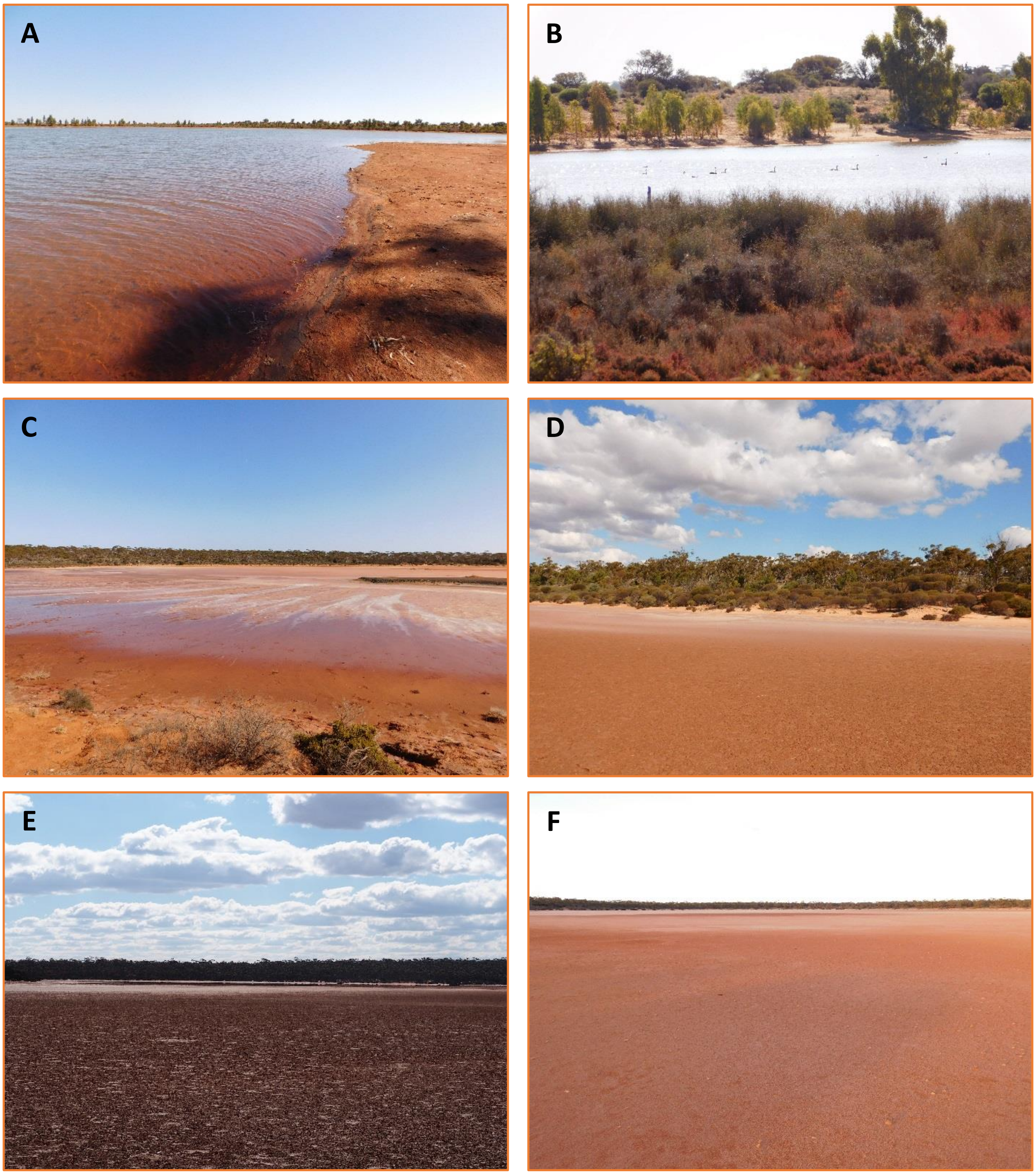

Plate 2-2: (A-B) Northern peripheral wetlands assessed in September 2017, and (C-F) regional peripheral wetlands, sampled in October 2017.

Figure 2-9: Aquatic sampling sites on Lake Lefroy and peripheral wetlands.

2.4.3 Surface Water Quality

Ephemeral salt lakes and their associated peripheral wetlands are common throughout the inland region of Western Australia and often exhibit substantial fluctuations in their chemical and physical properties. These are primarily influenced by their filling and drying phases, referred to as the hydroperiod (Boulton and Brock 1999). Changes in water quality affect aquatic biota, with adverse conditions often leading to reduced species diversity (Ghetti and Ravera 1994). Through consistent monitoring of water quality, contaminants associated with activities such as dewatering discharge can be readily detected, by assessing fluctuations outside the typical range (Meybeck *et al.* 1992).

With the exception of two studies conducted during flood events in 1999 and 2014 (Curtin University of Technology 1999a; Phoenix Environmental Sciences 2014), 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). During flooding, a limited number of peripheral wetlands have also been sampled. In 2010, preliminary water quality trigger values for the lake were developed by Dalcon Environmental (2010a) as part of the B2010 Project, referred to as St Ives upper reference range values (St Ives Gold Mining Company Pty Limited 2010). These were subsequently revised by Stantec (2018) for the B2018 Project (**Appendix E**), however are currently considered inadequate, as they are based on a limited number of samples from reference sites, and require further refinement to be applicable (Stantec 2018). Over time, the chemical analysis of samples is also likely to have been affected by high salt loads on the lake, which may have led to non-NATA accredited methods being employed, and potentially, erroneous laboratory results. In 2017, several flooded wetlands north of the lake were opportunistically sampled, while basic water quality parameters were also measured during laboratory-based re-wetting trials, from a larger, regional assessment of peripheral wetlands (**Appendix D**).

Since 1999, the pH of surface water at Lake Lefroy during predominantly dry and occasional flooded conditions has been classified as circumneutral, based on the classification system by Foged (1978), ranging from pH 6.5 to 7.5, with no substantial difference between discharge and reference sites (**Table 2-1**). 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 1994b; 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, and in the northern waterbodies greater than 9.0 (**Table 2-1; Appendix D**). This appears to be a characteristic of wetlands along the margins of large salt lakes in the Goldfields region (Timms *et al.* 2006).

Salinity (measured as TDS) of Lake Lefroy waters has been consistently classified as hypersaline (>50,000 mg/L), based on the classification system by Hammer (1986). Concentrations have exceeded 200,000 mg/L at the discharge sites and reference sites on the lake, in predominantly dry conditions (**Table 2-1**) (Curtin University of Technology 1999a; Dalcon Environmental 2010a; MWH 2015b; Outback Ecology 2009; Phoenix Environmental Sciences 2014). The salinity of the discharge water is characteristic of the underlying, hypersaline aquifer system that forms part of the Lefroy Palaeodrainage. Groundwater has relatively stable salt loads (*actis* Environmental Services 2003) which, along the margins of salt lakes is typically above 300,000 mg/L (Wright 2003). Salinity concentrations in excess of 350,000 mg/L have also regularly been recorded at the discharge sites (**Table 2-1**). At these concentrations, groundwater is considered saturated; the point at which salts begin to precipitate out of solution (McComb and Lake 1990).

Table 2-1: Summary of surface water characteristics of Lake Lefroy and peripheral wetlands.

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 (Northern)*	
		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 to mesosaline (<3,000-32,000 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.*

During flooded conditions on Lake Lefroy, surface water salinities decrease, although remain hypersaline (>150,000 mg/L) (**Table 2-1**) (Curtin University of Technology 1999a; Phoenix Environmental Sciences 2014), 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 2017b). The salt crust is thickest in the vicinity of discharge sites (**Plate 2-3 A-B**) (Clarke 1991), in comparison to historic discharge (**Plate 2-3 C**) and references sites (**Plate 2-3 D-F**). However, the limited data on reference sites also indicates extremely saline conditions of above 300,000 mg/L are known to occur (**Table 2-1**). In contrast, after flooding in 1999 and 2014, the peripheral wetlands of Lake Lefroy were characterised as freshwater to hyposaline (Curtin University of Technology 1999a; Hammer 1986; Phoenix Environmental Sciences 2014), while data from 2017 (**Appendix D**), suggests the upper limit of these waterbodies is in the mesosaline range (up to 32,000 mg/L) (**Table 2-1**). While freshwater and low salinity peripheral wetlands are typically associated with salt lakes, substantial variation occurs according to individual characteristics, 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 the groundwater (Talis 2015).

Nutrient concentrations have tended to fluctuate in the surface water of Lake Lefroy, with total nitrogen at discharge sites typically high (**Table 2-1**), exceeding 50 mg/L in some instances (MWH 2016b;2017). Previous studies on lakes in the Goldfields which receive dewatering discharge, have also shown comparatively higher concentrations of total nitrogen (MWH 2015a; Outback Ecology 2014). Surface water was also characterised by substantially lower concentrations of total phosphorous (generally below 0.1 mg/L), considered a feature of Goldfields salt lakes (Outback Ecology 2004b;2005;2009). However, following flooding of Lake Lefroy in 1999, total phosphorus levels rose rapidly and peaked at 0.23 mg/L (Curtin University of Technology 1999a); often the case during the initial stages of inundation (Boulton and Brock 1999), due to an influx of organic matter from the surrounding catchment (Gregory 2008). While data is limited, the lake's peripheral wetlands in the north appear to have comparatively lower nutrient concentrations than the playa (**Table 2-1; Appendix D**), although this is likely to fluctuate over the course of the hydroperiod.

A number of metals have typically exceeded the St Ives upper reference range values in surface water across Lake Lefroy, most commonly manganese, lead and zinc conditions (**Table 2-2**), during predominantly dry. However, concentrations generally have not exceeded the ANZECC & ARMCANZ (2000) trigger values, with some exceptions. Historically, the discharge sites have tended to show elevated concentrations of copper, lead and zinc (**Table 2-1**), which have exceeded their corresponding ANZECC & ARMCANZ (2000) guideline trigger values for protection of 80% of species in marine water; 0.008 mg/L, 0.012 mg/L, 0.043 mg/L, respectively (Dalcon Environmental 2010a; MWH 2017; Outback Ecology 2004b;2005;2006;2007;2009). 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). During flooding in 2014, metal concentrations decreased below ANZECC & ARMCANZ (2000) guideline trigger values (Phoenix Environmental Sciences 2014), attributed to dilution from rainfall, although were likely to have subsequently increased as the hydroperiod progressed, in response to evapoconcentration (Taukulis *et al.* 2012).

Data on metal concentrations within the peripheral wetlands of Lake Lefroy is limited, however concentrations appear to be comparatively lower than the playa. Exceptions include aluminium and copper in the northern waterbodies surrounding the lake (**Table 2-1**), with elevated concentrations above ANZECC & ARMCANZ (2000) trigger values for protection of 80% of species in freshwater in 2017; 0.15 mg/L and 0.0025 mg/L, respectively (**Appendix D**). For aluminium, the maximum exceedance was four times the ANZECC & ARMCANZ (2000) trigger value (0.64 mg/L), while copper was two times the respective trigger value (0.005 mg/L) (**Appendix D**). Elevated concentrations of both metals have also been observed from creeklines and claypans in the north-eastern Goldfields region (Taukulis et al. 2012).

2.4.3.1 Potential Concerns in relation to the B2018 Project

The primary concern relating to the surface water quality of Lake Lefroy in relation to the B2018 Project is increased discharge volumes and associated salt loads. The characteristics of the lake suggest that the majority of metals will readily adsorb to fine clay sediment and ions, becoming immobilised and biologically unavailable (Reddy and DeLaune 2008). In addition, aluminium, lead and manganese oxides within mineralised sediment such as that in Lake Lefroy, will effectively complex or occlude dissolved metal ions, forming highly stable and insoluble compounds (Reddy and DeLaune 2008). Therefore, metals are unlikely to pose an ecotoxicity risk to aquatic biota.

With increased discharge volumes on the lake, in predominantly dry conditions, surface water salinities are unlikely to change at the discharge sites, as salinity is already approaching saturation levels in some parts of the lake. However, during major flood events, limited dilution occurs. Therefore, it is likely that with increased discharge volumes, the salinity of surface water also increase, and the degree of dilution during flood events will be less. Over time, the properties of the surface water of the lake are likely to more closely reflect those of the discharge water, creating an even more hostile environment for aquatic biota.

For the peripheral wetlands, development and infrastructure for the B2018 Project may have potential to influence surface water quality; predominantly salinity and/or metal concentrations. Impacts may be direct or indirect, such as runoff of contaminants, or hydrogeological changes. For example, recently, seepage from a tailings storage facilities appears to be altering the natural hydrostatic pressure in its immediate vicinity, causing groundwater discharge to a nearby claypan, and potentially altering surface water quality (Stantec 2017a). The lower salinity of the peripheral wetlands and potentially strong alkaline conditions may also affect metal concentrations (such as copper and zinc), with the relationship to toxicity becoming complex at higher pH (ANZECC & ARMCANZ 2000).

Table 2-2: Summary of metal concentrations in surface water exceeding the upper reference site range values for SIGMC at Lake Lefroy.

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	-	-

Data sources: (Dalcon Environmental 2010a; MWH 2016b;2017)

Plate 2-3: Lake Lefroy surface showing salt crust at discharge sites; (A) Santa Ana, and (B) Belleisle, (C) historic discharge site; Junction, (D) reference sites; Location 170, (E) North East, and (F) West Dune.

2.4.4 Sediment Quality

Sediment is an important component of lake ecosystems, supporting a wide range of organisms (Pulford and Flowers 2006). However sediment also serves as a sink for contaminants entering a waterbody (Simpson *et al.* 2005). For this reason, understanding and interpreting sediment properties is vital (Hazelton and Murphy 2007), with chemical analysis a common tool, often used in conjunction with biological monitoring (Connell 2005). Lake sediment properties vary laterally and vertically (McKenzie *et al.* 2004), in association with the hydroperiod (Boulton and Brock 1999; McComb and Qui 1998). Sediment may be particularly heterogeneous in larger salt lakes subject to discharge (Simpson *et al.* 2005), due to differences in geomorphology and hydrogeochemical processes across the playa (URS Australia Pty Ltd 2013).

In contrast to water quality, there is a wealth of data 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 2016b;2017). In addition, during the B2010 PER, trigger values for metals in sediment were derived for Lake Lefroy (Dalcon Environmental 2010b), including low and high values based on 95th percentile (low) and the 2.5 x 95th percentile (high) of data from the reference sites; referred to as the St Ives upper reference range values (St Ives Gold Mining Company Pty Limited 2010). These trigger values have recently been revised for the B2018 Project (Stantec 2018) and are presented in **Appendix E**. However, the presence of the extensive salt crust and high salinities in sediment may have influenced the chemical analysis of samples from the lake over time, resulting in non-NATA accredited methods being employed, or erroneous laboratory data. For the peripheral wetlands, sediment quality data is limited to the recent regional assessment and opportunistic sampling in 2017 (**Appendix D**).

Sediment pH at Lake Lefroy has generally ranged from moderately acidic (<6.0) to moderately alkaline (>7.9), based on the classification system by Hazelton and Murphy (2007), with the discharge and reference sites being comparable (**Table 2-3**). 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 2-3**; **Appendix D**). 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 2013). The high salinity of the lake also promotes settling of sediment mantled with salts, hardening to form a halite crust (URS Australia Pty Ltd 2013). This salt crust is thickest at discharge sites; up to 60 cm in some areas (**Table 2-3**), and prohibitive to the emergence of aquatic biota. The salt crust also appears to prevent a low salinity surface water phase during flooding, which restricts the productivity of aquatic biota (Taukulis 2016).

At several historic discharge sites (inactive), a thick salt crust is present (MWH 2017), while at other historic discharge sites, there is little to no salt crust. In comparison, reference sites have little to no salt crust (zero to 8 cm; with the latter related to the potential influence of migrating discharge salts), and this is considered to reflect the natural condition of the lake surface (**Table 2-3**). Sediment salinities at the discharge sites have been shown to be significantly higher (based on statistical analysis) than reference sites. In some instances, concentrations in excess of 500,000 mg/kg have been recorded, in comparison to <100,000 mg/kg at reference sites. Due to the substantial existing salt loads, there is also concerns regarding the migration of salts from affected areas in the central parts of the lake, to the eastern and southern extremities that are currently not impacted (MWH 2017). In contrast, the sediment salinity of the peripheral wetlands (**Table 2-3**) is much lower (<60,000 mg/kg), particularly to the north of the playa (<500 mg/kg) (**Appendix D**), likely associated with drainage patterns and geomorphology (Stantec 2017b).

Table 2-3: Summary of sediment characteristics of Lake Lefroy and peripheral wetlands.

<table>
<tr><th colspan="2">Hydroperiod</th><th>Discharge Sites</th><th>Reference Sites</th></tr>
<tr><td rowspan="7">Lake Lefroy</td><td rowspan="5">Predominantly dry conditions</td><td>moderately acidic (pH<6.5) to moderately alkaline (pH>8.5)</td><td>moderately acidic (pH<6.5) to moderately alkaline (pH>8.5)</td></tr>
<tr><td>extremely saline (up to 500,000 mg/kg)</td><td>saline (<100,000 mg/kg)</td></tr>
<tr><td>salt crust up to 60 cm</td><td>salt crust up to 8 cm^</td></tr>
<tr><td>variable nutrients</td><td>variable nutrients</td></tr>
<tr><td>high metals (Cu, Co, Mn, Zn >triggers[#])</td><td>high metals (Mn >high triggers[#])</td></tr>
<tr><td rowspan="2">Flooded conditions</td><th colspan="2">Discharge and Reference Sites*</th></tr>
<tr><td colspan="2">Not available</td></tr>
<tr><td rowspan="10">Peripheral Wetlands</td><td rowspan="5">Predominantly dry conditions</td><th colspan="2">Peripheral Wetlands (Regional)</th></tr>
<tr><td colspan="2">strongly acidic (pH<5.0) to strongly alkaline (pH>8.5)</td></tr>
<tr><td colspan="2">low to moderate salinity (<15,000-57,000 mg/kg)</td></tr>
<tr><td colspan="2">variable nutrients</td></tr>
<tr><td colspan="2">low metals (Cr[#], Ni[#] >triggers)</td></tr>
<tr><td rowspan="5">Flooded conditions</td><th colspan="2">Peripheral Wetlands (Northern)*</th></tr>
<tr><td colspan="2">alkaline (pH>8.0)</td></tr>
<tr><td colspan="2">low salinity (<500 mg/kg)</td></tr>
<tr><td colspan="2">variable nutrients</td></tr>
<tr><td colspan="2">low metals (Cr[+], Ni[#] >triggers)</td></tr>
</table>

*Note: * based on limited data; # exceeding ANZECC & ARMCANZ (2000) 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.*

Concentrations of total nitrogen and total phosphorus have been variable in the sediment of Lake Lefroy and the peripheral wetlands (**Table 2-3; Appendix D**), with fluctuations related to changes in sediment properties over the course of the hydroperiod (Boulton and Brock 1999). However, a characteristic of most inland salt lakes and wetlands in the Goldfields region (Gregory 2008), consistent with trends observed at Lake Lefroy, is that the concentrations of total nitrogen generally always exceed total phosphorus. In the lake, concentrations of total nitrogen have exceeded 950 mg/kg, while total phosphorus levels have been typically below 250 mg/kg (MWH 2017). The lake generally contains limited organic matter, reflecting the predominantly dry environment and sparsely vegetated catchment (Bunn *et al.* 2006), although major drainage lines may transport allocthonous material into the system. Within the peripheral wetlands, the presence and abundance of algae and macrophytes, and subsequent decomposition and microbial activity, is likely to have a stronger influence on nutrient dynamics (Boulton and Brock 1999). In addition, when in flood, nutrients can be released into overlying surface water, reducing concentrations in the sediment. 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 direct impacts relating to dewatering discharge, with elevated concentrations of one or more metals above the ANZECC & ARMCANZ (2000) interim sediment quality guidelines (ISQG) low and high trigger values (**Table 2-3**). For the latter (ISQG-High trigger values), this has typically been for cobalt, copper, manganese and zinc (Palaris 2014a; URS Australia Pty Ltd 2013). Several other metals, including arsenic and barium, have also regularly exceeded the upper low reference range values for SIGMC (**Table 2-4**). Most recently, any exceedances have generally been in the order of two to three times higher than corresponding trigger values (MWH 2016b;2017).

At the discharge sites with lower discharge volumes, sediment has naturally elevated or variable metal concentrations (MWH 2016b;2017). This is consistent with the historic discharge and reference sites, where exceedances of the upper low reference range values (**Table 2-4**), appear to reflect natural sediment properties (particularly in relation to elevated concentrations of manganese), or catchment mineralisation and subsequent runoff (MWH 2016b;2017; Palaris 2014a). There have also been a number of isolated 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).

In contrast to the lake sediment, the peripheral wetlands appear to have mostly low concentrations of metals, with natural mineralisation of chromium and nickel attributed to the geological setting. In particular nickel has been recorded at elevated concentrations (96 mg/kg), almost twice that of the ANZECC & ARMCANZ (2000) high trigger value (52 mg/kg) (**Appendix D**). However, this is considered characteristic of lake sediment in some parts of the Goldfields (Förstner 1977).

2.4.4.1 Potential Concerns in relation to the B2018 Project

The proposed increase in salt loads to the lake for the B2018 Project from dewatering discharge is predicted to cause an increase in the existing salt crust thickness of between 20 mmm to 160 mm, in addition to the existing halite crust (Stantec 2017b). This will be most evident in areas where the discharge water is constrained by causeways (Stantec 2017b), although salt crust extent and distribution remains a key knowledge gap. While salts will effectively immobilise metals from the discharge water, increased salt crust thickness and extent will result in a larger area of Lake Lefroy being impacted, and reduce the potential for natural mitigation via dilution in major flood events. The additional salts, together with the substantial existing salt loads, are likely to be even more prohibitive to the emergence and maintenance of aquatic biota over the long-term.

In the peripheral wetlands, sediment quality may be influenced by changes to surface hydrology, due to infrastructure associated with the B2018 Project, which, similar to water quality, has potential alter salinity and/or metal concentrations. Changes to sediment quality, also have the potential to impact on surface water quality during flood events. While there appears to be natural mineralisation of wetlands in this region, potential increases in salinity and metals above background levels may adversely affect aquatic biota. This is particularly relevant for freshwater wetlands with strongly acidic pH, where some metals (such as copper, manganese, nickel and zinc) may be more readily mobilised, posing a potential ecotoxicity risk for aquatic biota (ANZECC & ARMCANZ 2000).

Table 2-4: Summary of metal concentrations in sediment exceeding the upper low and high reference site range values for SIGMC at Lake Lefroy.

Sediment Quality Site	Upper Reference Site Range Value*	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, 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

Sediment Quality Site	Upper Reference Site Range Value*	2011	2012	2013	2014	2015	2016	2017
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
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

Data Sources: (MWH 2016a;b; Palaris 2014a.)

2.4.5 Aquatic Biota

2.4.5.1 Algae and Macrophytes

Algae are widespread in aquatic environments, where they have a fundamental role as primary producers, occurring as either free-floating phytoplankton or benthic organisms (Bellinger and Sigee 2010). In shallow ephemeral water, including salt lakes, salinity is a major determinant of community structure (Smith *et al.* 2004). In hypersaline conditions, the diversity of true phytoplankton (free-floating algae) are often restricted (Borowitzka 1981; John 2001) and productivity may be confined to the benthic (bottom-dwelling) algae (Handley 2003). Macrophytes (larger aquatic plants and algae) are also of considerable ecological importance in ephemeral water and may have either a submerged, free-floating or emergent habit. They are vital in nutrient cycling and fulfil several key roles for aquatic invertebrate and vertebrate fauna (Bunn *et al.* 2006; Porter *et al.* 2007; Sainty and Jacobs 2003).

Previous studies of algae and macrophytes at Lake Lefroy, during flood events, are limited to 1999 (Curtin University of Technology 1999a) and 2014 (Phoenix Environmental Sciences 2014). Other assessments of the lake have been completed during mostly dry conditions. However, laboratory-based re-wetting trials have also been undertaken to simulate flood events on the playa, with the aim of determining algal species diversity and abundance (**Appendix D**) (Dalcon Environmental 2010a). While the range of studies completed over time is extensive, the dataset for algae and macrophytes is patchy, with discrepancies between methodology, results and taxonomic resolution. There is however, a broad consensus that typically primary producers may be limited within the lake, in comparison to the more productive and diverse peripheral wetlands (**Appendix D**) (Curtin University of Technology 1999a; Phoenix Environmental Sciences 2014).

There are no conservation significant algal or macrophyte taxa known from the lake or peripheral wetlands (Department of Biodiversity, Conservation & Attractions 2017; Department of the Environment & Energy 2017). This is likely to be a reflection of the lack of survey effort and specialists in this field, with taxonomic resolution to genera indicating algae and macrophytes mostly comprise ubiquitous taxa widespread throughout Australia. However, while not typically considered to be rare or restricted, there may be local endemism at the species level.

2.4.5.1.1 Phytoplankton and Benthic Algae

In salt lake environments, algae are often the predominant group responsible for primary production (Williams 1998). In total, 56 phytoplankton taxa have been recorded from Lake Lefroy and the peripheral wetlands (**Table 2-5**; **Appendix F**), 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 (**Table 2-5**; **Appendix F**). Of these, the chlorophyte *Dunaliella* sp., was prevalent (Phoenix Environmental Sciences 2014). 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 north of the playa in 2017 (**Appendix D**). 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. (**Plate 2-4A**). 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 (**Table 2-5**). The higher diversity of phytoplankton in the surface water of peripheral wetlands is likely to reflect the freshwater and low salinity conditions, which are conducive to an abundant algal assemblage (Hammer 1986).

Algal productivity appears to be high in both the surface water and benthos of the peripheral wetlands, while being mostly 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 2-5; Appendix F**). 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). Encysted forms of the chlorophyte *Dunaliella* sp. (**Plate 2-4 C**), also occur as part of the benthic community (**Appendix F**).

In the peripheral wetlands, cyanobacterial mats of *Phormidium* sp. and *Microcoleus* sp. (**Plate 2-4 D**) have been identified (**Appendix F**), and are typical of benthic communities throughout waterbodies in the wheatbelt and Pilbara regions of Western Australia (Paling 1989). Desmids, which are single-celled chlorophytes (such as *Cosmarium* sp.) were also prevalent in the northern wetlands in 2017 (**Appendix F**). This group of algae are found exclusively in freshwaters (John 2002), and are common throughout Australia (Entwisle *et al.* 1997) (**Plate 2-4B**). Diatoms (**Plate 2-4 E-F**), 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 (**Table 2-5**; **Appendix F**). Similar to phytoplankton, benthic algae in the playa were not as diverse as waterbodies on the margins of Lake Lefroy, however productivity may still be high, supporting higher order consumers including aquatic invertebrates and waterbirds (Curtin University of Technology 1999a).

Table 2-5: Summary of algal taxa per phyla recorded from Lake Lefroy and peripheral wetlands.

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	

Data Sources: (Curtin University of Technology 1999a; Dalcon Environmental 2010a; Outback Ecology 2004b; Phoenix Environmental Sciences 2014); Stantec unpublished data 2017.

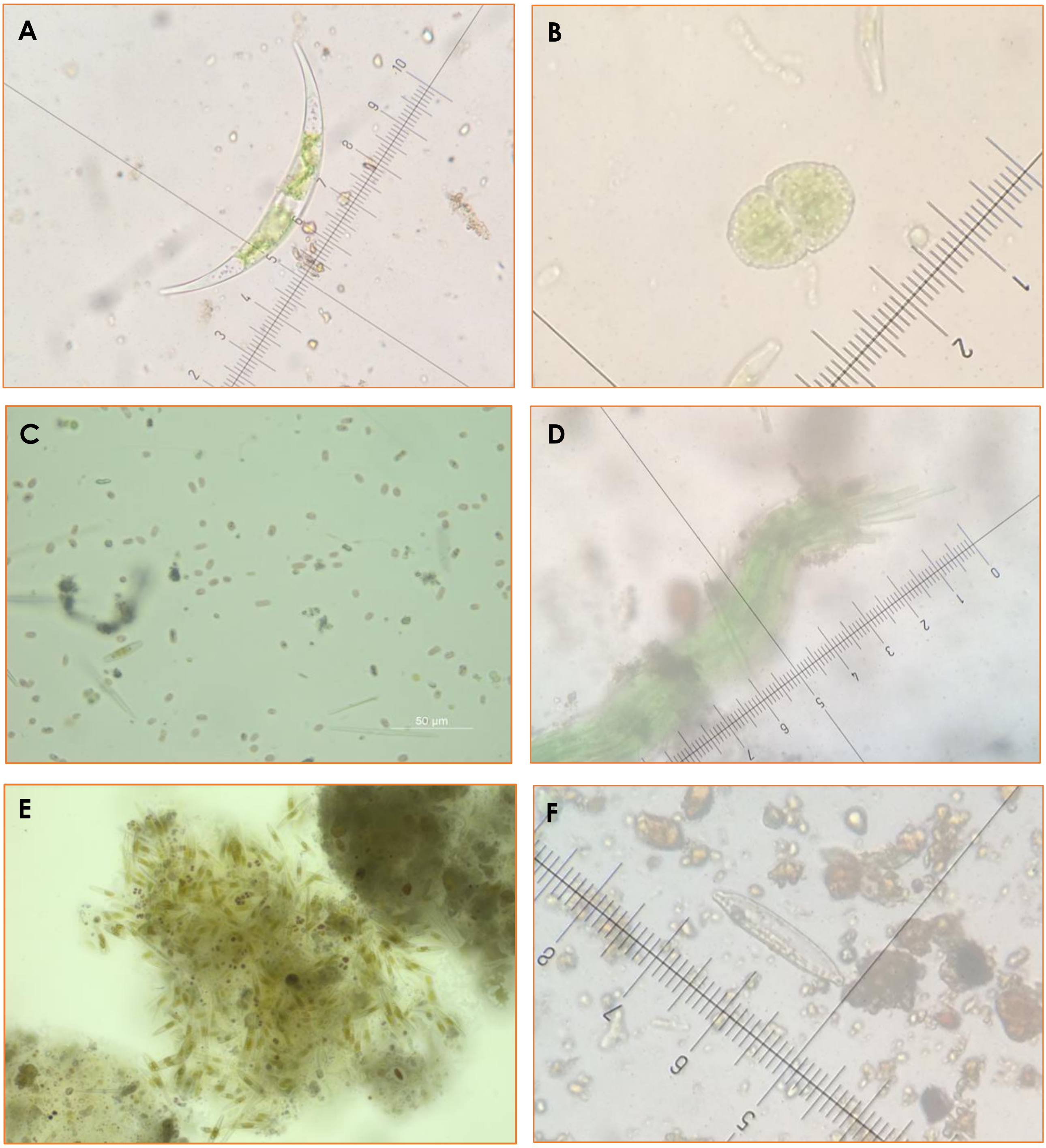

Plate 2-4: Planktonic and benthic algae of Lake Lefroy and peripheral wetlands; (A) *Closterium* sp., (B) *Cosmarium* sp., (C) *Dunaliella* (pink cells), (D) *Microcoleus* sp., and (E-F) diatoms.

2.4.5.1.2 Diatoms

Diatoms, which can persist in the moist sediment of salt lakes in dry conditions, may be treated in acid to allow for greater taxonomic resolution. In conjunction with their well-documented water quality tolerance limits, they are considered excellent biological indicator organisms (John 1998; Smith *et al.* 2004). They are important contributors to primary production in waterbodies and are the predominant food for many aquatic invertebrates (Padhi *et al.* 2010). At Lake Lefroy, they are also one of the few groups of biota that have been consistently assessed since 2004 during annual monitoring; however, in several instances, identification to species level has not occurred. In total, 66 species have been recorded from the lake and peripheral wetlands, not taking into account unidentified taxa (**Appendix F**). Of the total, 34 taxa were considered representative of the salt lake environment, and 52 taxa were associated with the surrounding waterbodies (**Table 2-6**).

In dry conditions, the diversity of diatoms on the playa generally ranges from 10 to 15 taxa (MWH 2017), comprising *Amphora*, *Hantzschia* and *Navicula* representatives (**Table 2-9**; **Plate 2-5A-D**), 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 ($\geq$10 records) (**Table 2-9**). 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 (**Appendix F**), 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 (**Appendix D**), with some overlap of taxa found in the lake. This included *Amphora coffeaeformis*, which appears to be dominant throughout the lake and surrounding waterbodies (**Appendix D**). However, species known from freshwater environments, such as *Hantzschia distinctepunctata* and *Nitzschia palea* (Joh 2014; John 2000) were also commonly recorded in the peripheral wetlands. 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 2-6: Summary of diatom taxa by per genera recorded from Lake Lefroy and peripheral wetlands.

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	

Data Sources: (MWH 2016b;2017; Outback Ecology 2004b;2005;2006;2007;2009).

Note: Dalcon Environmental 2010a data source removed due to limited taxonomic resolution.

Table 2-7: Common diatom taxa (≥10 records) from Lake Lefroy (playa only).

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

Data Sources: Data Sources: (MWH 2016b;2017; Outback Ecology 2004b;2005;2006;2007;2009).

A record comprises occurrence per site, per assessment, from available data sources (includes Navicula duerrenbergiana).*

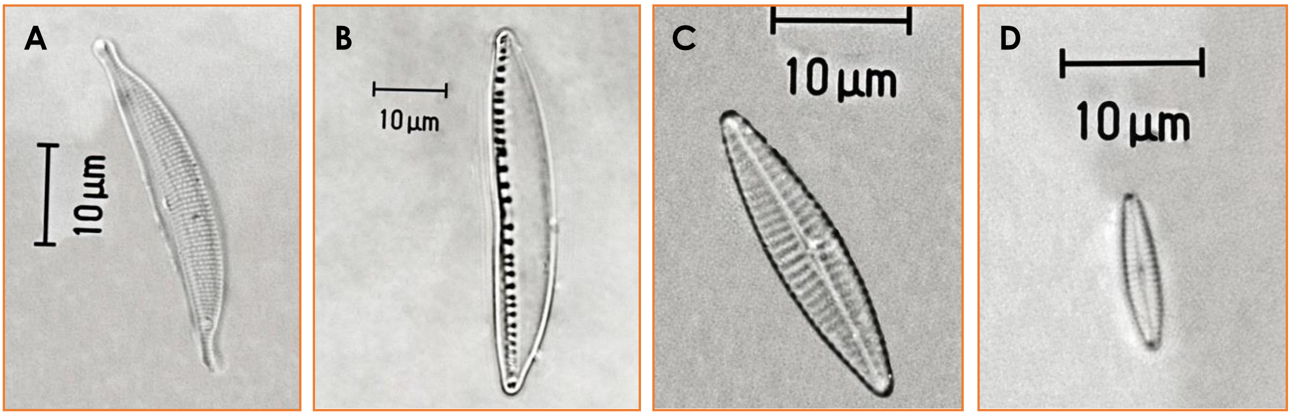

Plate 2-5: Diatom taxa of Lake Lefroy; (A) *Amphora coffeaeformis*, (B) *Hantzschia* sp. aff. *baltica*, (C) *Navicula* sp. aff. *incertata*, and (D) *Navicula* sp. aff. *salinicola*.

Typically, the previous studies have suggested that the dewatering discharge is 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 2009). 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).

2.4.5.1.3 Macrophytes

To date, a total of nine macrophyte taxa have been identified from Lake Lefroy and the peripheral wetlands (**Table 2-8**). However, only dormant propagules (resting stages) have been recorded 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) (**Table 2-8**). 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 (**Appendix F**).

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. (**Plate 2-6A**), have been found in the sediment of Lake Lefroy and the peripheral wetlands (**Table 2-8**), with the latter commonly associated with saline waters throughout Australia (Porter 2007). The propagules (oospores) belonging to another charophyte; *Chara* sp., were also identified from the peripheral wetlands (**Table 2-8**). In addition, mature specimens of *Chara* sp. and *Nitella* sp. (**Plate 2-6B-C**) were recorded from waterbodies to the north of the lake in 2017 (**Appendix D**). 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. (**Plate 2-6D**) (Porter 2007), the seeds of which were identified in the lake sediment (**Table 2-8**). 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 the taxon most commonly associated with inland waterbodies in the Goldfields region (Taukulis *et al.* 2014).

Table 2-8: Dormant propagules of 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	

Data Sources: (Dalcon Environmental 2010a; MWH 2016b;2017; Outback Ecology 2005;2009); Stantec unpublished data 2017.

Macrophytes have several important functions within inland waters and are utilised for a range of purposes including protection, oviposition (egg-laying) and as a food source; primarily by aquatic invertebrates and waterbirds (Davis and Christidis 1999; Dvorak and Best 1982; Rogers and Paton 2009). In Lake Lefroy, it appears they are either 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, growth and development. In addition, 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 germination and growth, as well as providing a source of biological material for the playa.

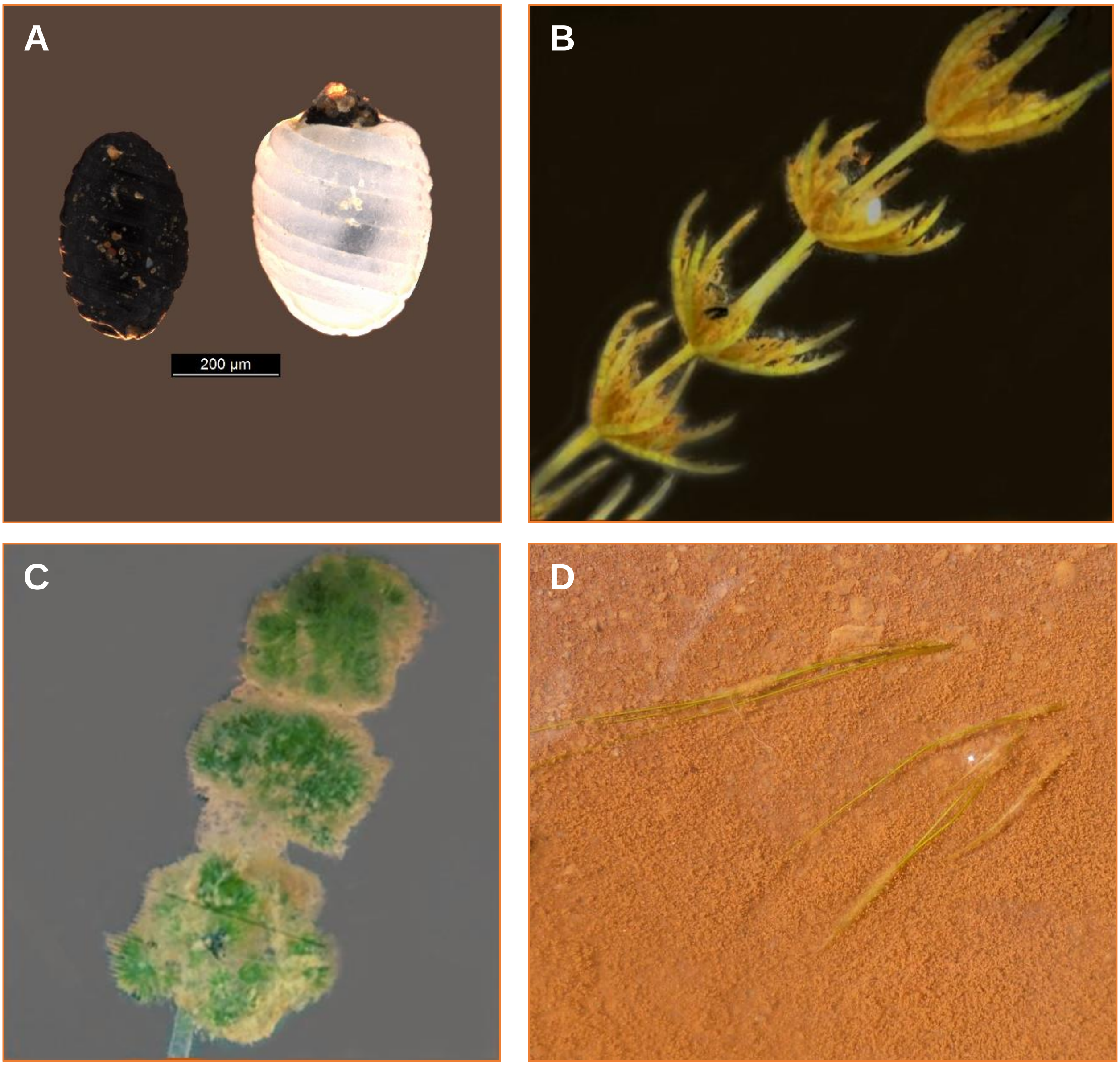

Plate 2-6: Macrophytes of Lake Lefroy and peripheral wetlands; (A) *Lamprothamnium* oospores, (B) *Chara* sp. SIGM01 (Stantec), (C) *Nitella* sp.SIGM01 (Stantec) , and (D) *Ruppia* sp SIGM01 (Stantec).

2.4.5.1.4 Potential Concerns in relation to the B2018 Project

The productivity (diversity and abundance) of algae and macrophytes in Lake Lefroy is low in comparison to the peripheral wetlands. This is a trend considered typical of large inland salt lakes, as the lower salinity of surrounding waterbodies is more favourable for a greater diversity and abundance of taxa (Taukulis *et al.* 2014; Taukulis *et al.* 2012). However, a suitable, comprehensive monitoring program that systematically records these groups has yet to be completed during flooded conditions. In addition, inconsistencies and discrepancies in methodology and taxonomy have led to patchy datasets, which likely contain artificially inflated numbers of algal taxa in particular. Therefore limited differences have been detected between discharge and reference sites for macrophytes, phytoplankton and benthic algae over time. In contrast, diatoms, which have been assessed on a regular basis, have consistently shown localised impacts from the discharge water. However, it is not known if the presence of the salt crust, which appears to be one of the key factors influencing primary productivity (and the dormant propagule bank), is wholly associated with salts from the discharge water, or is related to historic anthropogenic effects (such as the construction of the causeway restricting water flow), or alternatively, is the natural state of the lake. Regardless, the increased discharge volumes and salt loading expected with the B2018 Project is unlikely to have any additional impact on algae and macrophytes at discharge sites.

Areas currently not impacted by discharge water; primarily the northern and southern extremities of the lake may be subject to adverse impacts if the salt crust extent increases with development of the B2018 Project. The productivity of algae and macrophytes contributes to aiding the recovery of a wetland during flooding (Boulton and Brock 1999). Typically, productivity increases rapidly during major flood events (Taukulis *et al.* 2012), however this does not appear to be the case at Lake Lefroy (noting that some knowledge gaps remain, particularly within a regional context). Possible increases in surface water salinities during flooding may also reduce replenishment opportunities for algae and macrophytes, reducing the propagule bank in the lake sediment over time. As primary producers are vital for supporting higher trophic levels (Bunn *et al.* 2006; Porter *et al.* 2007; Sainty and Jacobs 2003), including aquatic invertebrates and waterbirds, this may further reduce the ecological value of the lake.

In contrast, the peripheral wetlands have a higher ecological value, with increased productivity of algae and macrophytes to support higher order consumers. These groups are sensitive to changes in water quality, particularly salinity, and other factors including hydroperiod, water depth and temperature and light (Casanova and Brock 1990;1996; Porter 2007). Therefore direct impacts on these waterbodies for the B2018 Project should be minimised, including habitat disturbance for development and infrastructure, which may alter hydrology and/or water quality. In addition, surface water runoff and seepage should also be managed, to avoid potential contaminants such as salts and metals posing an ecotoxicity risk to primary producers within the peripheral wetlands.

2.4.5.2 Aquatic Invertebrates

Aquatic invertebrates represent an important component of aquatic ecosystems and occupy a range of submerged habitats. They have numerous roles ranging from consumers and detritivores through to predators, while also providing an important food source for vertebrate fauna, including waterbirds (Jones *et al.* 2009). In ephemeral water, salinity is a key factor influencing the invertebrate assemblage, however hydroperiod, predation, food availability, competition, and biological and chemical interactions are also important (Williams 1998). Aquatic invertebrates inhabiting these environments employ various mechanisms for survival during dry conditions and can typically be divided into two groups. These comprise resident invertebrate fauna (crustaceans), which persist in sediment as desiccation-resistant eggs (resting stages), breaking dormancy with the onset of favourable conditions. Others, such as insects, are generally transient during their mobile adult phases, and are able to opportunistically colonise newly created waterbodies (King *et al.* 1996).

Several studies have investigated the aquatic invertebrate communities of Lake Lefroy and the peripheral wetlands during flooding, including the baseline study in 1999, 2014 major flood event, and opportunistic sampling of northern wetlands in 2017 (**Appendix D**) (Curtin University of Technology 1999a; Dalcon Environmental 2010a; Phoenix Environmental Sciences 2014). There is also limited data available from discharge sites in 2010 (Dalcon Environmental 2010a), and annual monitoring data from recent years (MWH 2016b;2017). Re-wetting trials undertaken in 1999 (Curtin University of Technology 1999a;b) and 2017 (**Appendix D**), have also contributed to the taxa known from the playa and surrounding waterbodies. These studies have yielded a total of 103 taxa; predominantly crustaceans and insects, the majority of which have been recorded from the freshwater and low salinity peripheral wetlands (101 taxa), in comparison to the playa (13 taxa) (**Table 2-9**; **Appendix F**). Although the level of taxonomic resolution has improved over time, 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 Environmental Sciences 2014). During flooding, the lake has been dominated by dipterans and specifically ceratopogonids; biting midge larvae (**Table 2-10**; **Appendix F**) (Curtin University of Technology 1999a;b; Dalcon Environmental 2010a; Phoenix Environmental Sciences 2014). 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 2-9: 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	

Data Sources: (Curtin University of Technology 1999a;b; Dalcon Environmental 2010a; MWH 2016b;2017; Phoenix Environmental Sciences 2014); Stantec unpublished data 2017.

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*' (**Plate 2-7A**). The latter species has also been recorded from the peripheral wetlands (**Table 2-10**; **Appendix F**) (Dalcon Environmental 2010a; Phoenix Environmental Sciences 2014). 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, which potentially represents *Parartemia serventyi* (**Plate 2-7B**), 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 (**Appendix F**). This species is commonly associated with waterbodies 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 Environmental Sciences 2014), likely due to the extremely hypersaline conditions that appear to characterise the lake, even during major flood events.

Table 2-10: Common aquatic invertebrate taxa (records ≥2) of 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

Data Sources: (Chaplin and John 1999a; Dalcon Environmental 2010a; MWH 2016b; Phoenix Environmental Sciences 2014).

Note: a record comprises occurrence per site, per assessment, from available data sources.

Both *Parartemia* and ostracod eggs have been recorded in the sediment of Lake Lefroy (**Plate 2-7 C-D**) (Curtin University of Technology 1999a; MWH 2017; Outback Ecology 2009), and form part of the dormant egg bank (**Appendix F**), 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). In addition, 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 flooding (**Appendix D**) (Chaplin and John 1999b; Dalcon Environmental 2010a; Phoenix Environmental Sciences 2014). 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 2-9; Appendix F**).

In the wetlands north of the lake, 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, with dipterans (*Polypedilum nubifer*) also prevalent (**Appendix D**). Elsewhere, peripheral wetlands 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, of which the ostracod '*Dragoncypris outbacki*' was the most abundant (**Appendix D**). The presence of this taxon, and several others in both Lake Lefroy and surrounding waterbodies, demonstrates there is some degree of overlap between aquatic invertebrate assemblages (**Appendix F**). This reflects propagule exchange throughout the area during flooding, and reflects the higher salinity of some of the wetlands along the lake margins.

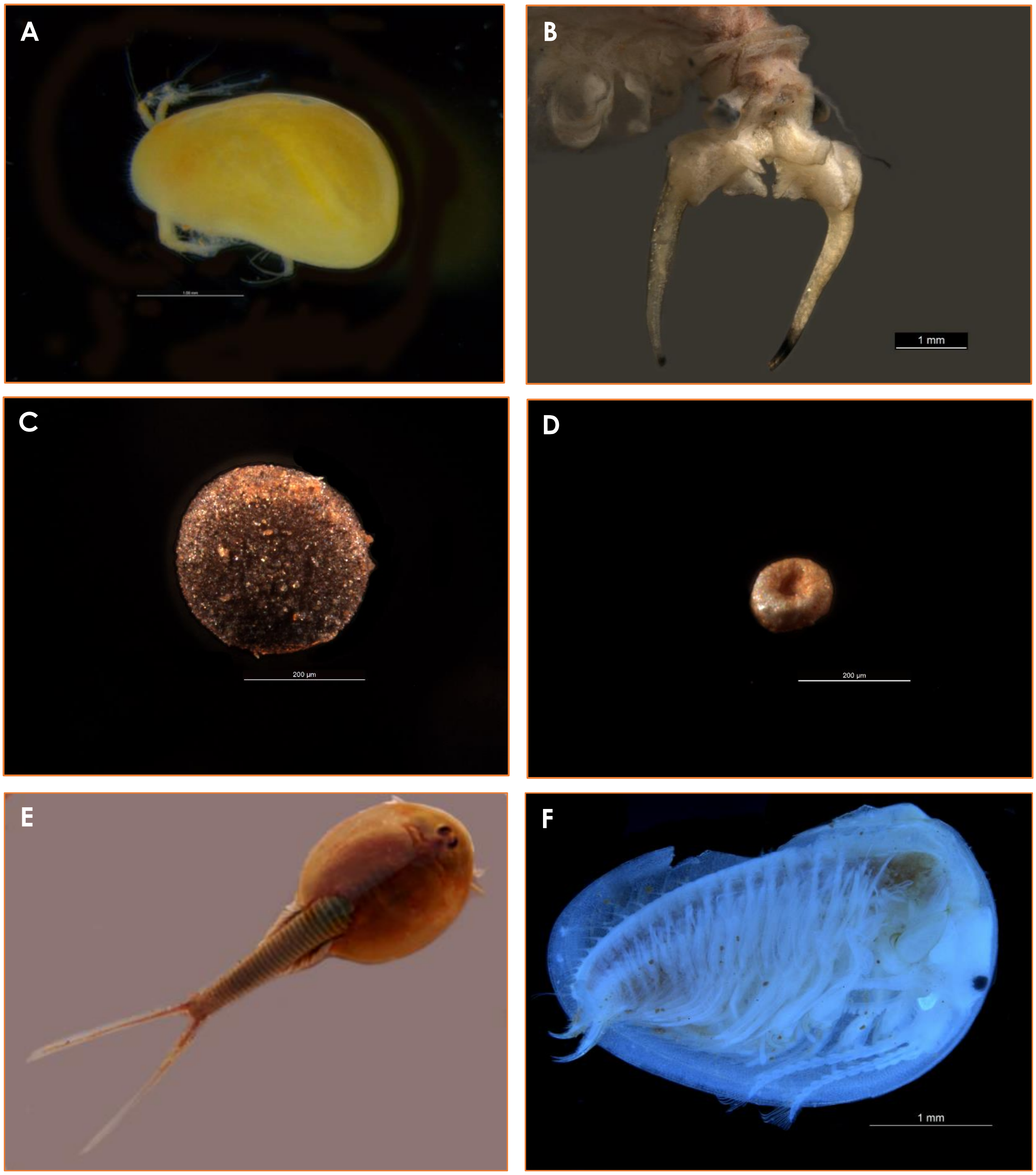

Plate 2-7: Aquatic invertebrates of Lake Lefroy and peripheral wetlands; (A) *Parartemia serventyi*, (B) '*Dragoncypris outbacki*', (C) *Parartemia* egg, (D) ostracod egg, (E) *Triops australiensis*, and (F) *Eocyzicus* sp. MWH01.

2.4.5.2.1 Conservation Significant Taxa

A review of the current threatened and priority fauna rankings (Department of Biodiversity, Conservation & Attractions 2017) and Wildlife Conservation (Specially Protected Fauna) Notice (Department of Biodiversity, Conservation & Attractions 2017) indicated that there are three Priority 1 *Branchinella* taxa (fairy shrimp) known from the Goldfields region*; Branchinella apophysata*, *Branchinella denticulata* and *Branchinella simplex* (**Appendix C**). While specific records are not available, the studies to date suggest that these species do not occur within Lake Lefroy or the peripheral wetlands. *Branchinella apophysata* has currently only been recorded from one location more than 200 km northeast of the lake (Timms 2012), while *Branchinella denticulata* and *Branchinella simplex* are widely distributed in the Goldfields (Timms 2002). Database searches also indicated there are no taxa of conservation significance that have been recorded from Lake Lefroy. However, this is likely to be attributed to a lack of survey effort, or delays in the time taken for database lists to be updated with new information as it becomes available.

Studies of the lake and peripheral wetlands indicate that while the aquatic invertebrates recorded are typically considered widespread throughout the Goldfields region or more broadly across Australia, there are five potentially conservation significant taxa that have been identified over time. These comprise new and/or undescribed taxa that have only been recorded from the peripheral wetlands of Lake Lefroy (**Appendix D**), and are potentially restricted to the area including:

- *Calamoecia ampulla* var. B01 – copepod recorded (in abundance) from northern and south eastern peripheral wetlands;
- *Eocyzicus* sp. MWH01 – clam shrimp (single specimen) recorded from north eastern wetland, also known from wetlands throughout the Goldfields (based on morphology);
- *Ilyodromus* sp. BOS1031 – copepod recorded (in abundance) from northern peripheral wetlands;
- *Parartemia* nr *serventyi* MWH01 – recorded (in limited numbers) from central western peripheral wetland; and
- *Parartemia* sp. (juvenile) – recorded (in limited numbers) from southern peripheral wetland.

Of these, the clam shrimp *Eocyzicus* sp. MWH01 was the only taxon recorded from within the development envelope of the B2018 Project (**Figure 2-10**), however is also known from freshwater wetlands throughout the Goldfields (Taukulis *et al.* 2012). The copepods *Calamoecia ampulla* var. B01 and *Ilyodromus* sp. BOS1031 were relatively common in the northern wetlands of Lake Lefroy, while only limited specimens of the remaining *Parartemia* taxa have been recorded from the peripheral wetlands. Therefore further investigation is required to determine the distribution and occurrence of these taxa within a regional context.

2.4.5.2.2 Potential Concerns in relation to the B2018 Project

It has been suggested that the aquatic invertebrates of Lake Lefroy may be depauperate in comparison to other salt lakes in the region (Curtin University of Technology 1999b), such as Lake Carey (Taukulis *et al.* 2012). However, it has not been established if this low diversity is natural, or due to the influence of historic and active mining operations, such as the dewatering discharge, or the hydrological impacts from the causeway. It may also be related to limited sampling of the broader lake system during flooded conditions. It is therefore difficult to discern the relationship between the dewatering discharge and aquatic invertebrate populations, although the 2014 flood study indicated few differences between discharge and reference sites (Phoenix Environmental Sciences 2014).

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). This may be amplified with the proposed increase in discharge volumes and salt loads for the B2018 Project. Similar to algae and macrophytes, high surface water salinities in major flood events are likely to prevent the emergence of aquatic invertebrates, which in turn will decrease egg replenishment opportunities. Over time, this will potentially reduce the dormant egg bank in the sediment, and subsequent productivity of aquatic invertebrates, further decreasing the ecological value of the lake.

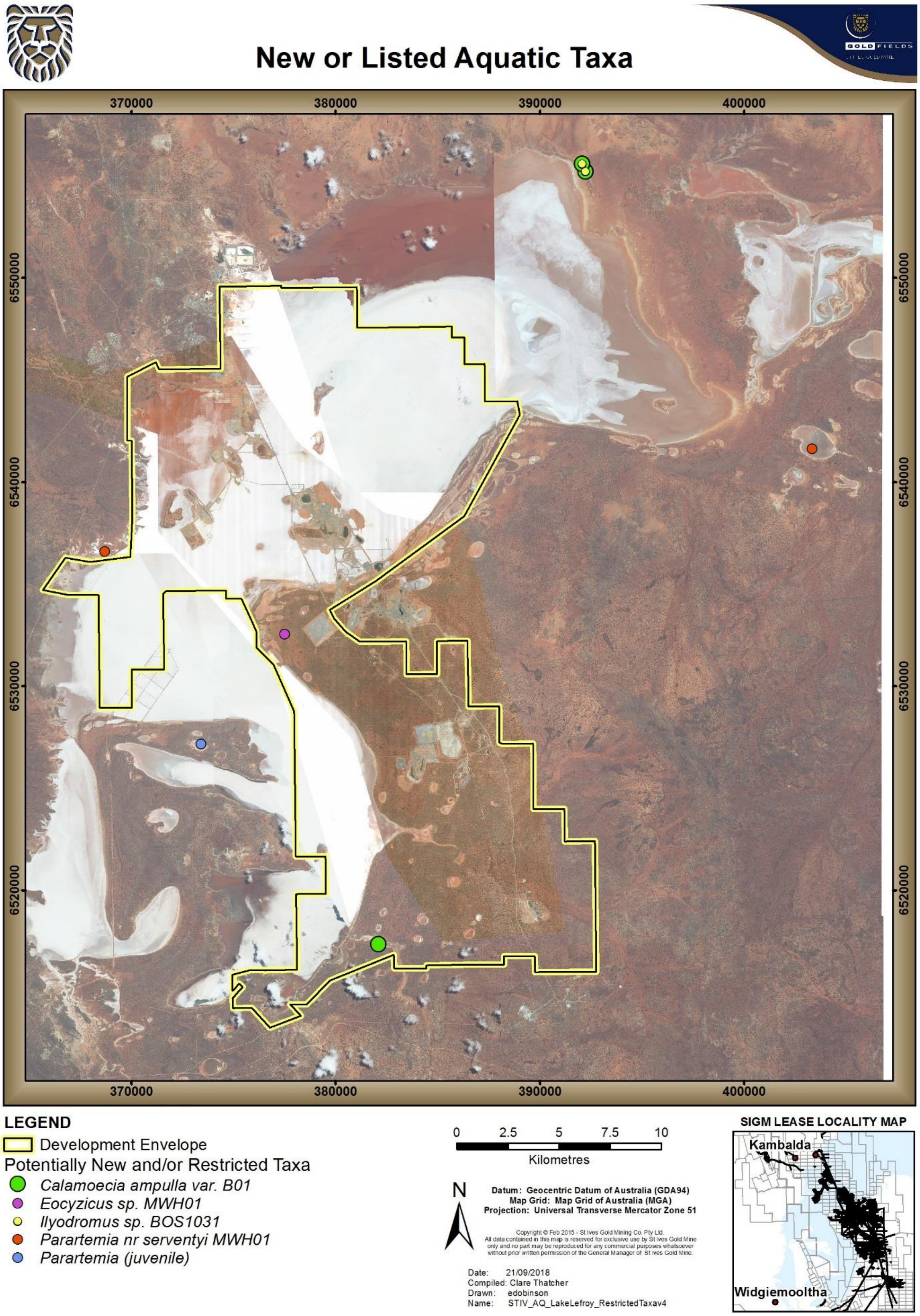

Figure 2-10: Taxa of potential conservation significance recorded from the peripheral wetlands of Lake Lefroy, in relation to the B2018 Project development envelope.

In addition to discharge impacts, there is also the potential for indirect and direct impacts on the peripheral wetlands from infrastructure associated with the B2018 Project, predominantly from habitat disturbance. Contaminants, contained in surface water runoff or seepage, also pose a potential ecotoxicity risk to aquatic biota (Stantec 2017a), particularly in freshwater wetlands with either acidic or alkaline pH (ANZECC & ARMCANZ 2000). While it is evident that the waterbodies surrounding Lake Lefroy are ecologically significant, and are likely to provide a pathway for the migration and dispersal of biological propagules onto the lake during major flood events, knowledge gaps remain. Specifically, these are in relation to the occurrence and distribution of conservation significant taxa.

2.4.6 Riparian Vegetation

Salt lakes, eucalypt woodlands and shrub thickets cover most of the Eastern Goldfield subregion, with eucalypt woodlands dominated by species from the Myrtaceae, Asteraceae, Chenopodiaceae and Poaceae families. Changes in vegetation communities reflect underlying geology, with close associations between plant species and soil type (Beard 1990). While the surface of salt lakes in the subregion are typically devoid of vegetation, the riparian zone comprises halophytic communities, often dominated by *Tecticornia*, due to their ability to withstand waterlogging and elevated salinities (Datson 2002).

Baseline studies of the riparian zone of Lake Lefroy were first completed in 1999 (Curtin University of Technology 1999a), with larger, regional flora studies completed in 2011 (Botanica Consulting 2012) and 2017 (Phoenix Environmental Sciences 2015) (Phoenix Environmental Sciences 2018). Annual monitoring of the lake's riparian zone has also been undertaken, using standardised methodology, since 2010 (Botanica Consulting 2010;2013;2014; MWH 2016a;2017; Native Vegetation Solutions 2014; Outback Ecology 2006;2007;2009).

A total of 294 flora species and subspecies representing 44 families and 120 genera have been recorded from the broader area over time (Phoenix Environmental Sciences 2018). The majority of the vegetation communities are also well-represented at a regional level, with some exceptions. Vegetation health is considered to be pristine to excellent (Phoenix Environmental Sciences 2018). Specific to the riparian zone, three riparian communities have been identified comprising:

- *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;
- *Melaleuca thyoides* and *Jacksonia arida* mid to tall open shrubland over *Darwinia* sp. Karonie low sparse to open shrubland; and
- *Darwinia* sp. Karonie and *Tecticornia* spp. low sparse shrubland.

During annual monitoring of the lake's riparian zone, 77 confirmed plant taxa have been identified (**Appendix F**). The most frequently recorded taxon has been *Darwinia* sp. Karonie (524 occurrences), followed by *Tecticornia indica* (283 occurrences), *Jacksonia arida* (249 occurrences), and *Melaleuca thyoides* (205 occurrences) (**Table 2-11**). The findings of annual monitoring have been consistent, indicating there are no differences between the discharge and reference sites in relation to species diversity, plant health and vegetation condition, with no evidence of impact from the dewatering discharge on the lake (**Plate 2-8**) (Botanica Consulting 2010;2014; Minesite Environmental Pty Ltd 2009; Native Vegetation Solutions 2014). Instead, changes appear to be more strongly influenced by climate, and in particular rainfall (Botanica Consulting 2013; Outback Ecology 2006;2007;2009).

Table 2-11: Common plant taxa recorded from the riparian zone of Lake Lefroy.

Riparian Vegetation Taxa	Number of Records
Aizoaceae	
Gunniopsis quadrifida	81
Chenopodiaceae	
Maireana glomerifolia	96
Tecticornia halocnemoides subsp. *catenulata*	59
Tecticornia indica	283
Fabaceae	
Jacksonia arida	249
Frankeniaceae	
Frankenia interioris	90
Frankenia pauciflora	98
Goodeniaceae	
Scaevola spinescens	72
Myrtaceae	
Darwinia sp. Karonie	524
Melaleuca thyoides	205

Data Sources: (Botanica Consulting 2010;2013;2014; MWH 2016b;2017; Native Vegetation Solutions 2014).

Note: a record comprises occurrence per site, per assessment, from available data sources.

2.4.6.1.1 Conservation Significant Taxa

To date, there have been no vegetation communities in the vicinity of Lake Lefroy that are considered representative of a Commonwealth or State-listed TEC, or State-listed PEC (Phoenix Environmental Sciences 2018). However, there are several priority flora that have been recorded from the riparian zone of the lake and peripheral wetlands, or have the potential to occur, based on the findings of recent studies (Botanica Consulting 2012; MWH 2016b;2017; Phoenix Environmental Sciences 2018) and/or database searches (**Appendix C; Appendix G**). These include:

- *Calandrinia* sp. Widgiemooltha (F. Obbens & E. Reid FO 9/05)(Priority 1) – from the Monitaceae family, collected from a creekline northwest of Lake Lefroy, and from Lake Cowan, and known from a limited number of specimens within the Widgiemooltha area;
- *Ptilotus rigidus* (Priority 1) – from the Amaranthaceae family, collected from the southwest of Lake Lefroy, and also known from a limited number of specimens within the Goldfields region;
- *Pityrodia scabra* subsp. *dendrotricha* (Priority 3) species, formerly known as Pityrodia sp. Yilgarn (A.P. Brown 2679) – from the Lamiaceae family, collected from the southern area of Lake Lefroy, also known from a limited number of specimens within the Goldfields region;
- *Tecticornia mellarium* (Priority 1) – from the Chenopodiaceae family, collected from the western, eastern and southern shoreline of Lake Lefroy, and previously only known from Lake Carey; and
- *Tecticornia flabelliformis* (Priority 1) – from the Chenopodiaceae family, collected from the southwest of Lake Lefroy, and also known from the southwest of Lake Yindarlgooda, and known from a limited number of specimens within the Goldfields region.

Several vegetation types may also be considered locally significant, as they represent habitat for conservation significant species and/or have a restricted local distribution. In particular, shrublands on the playa, foreshore and dune systems of Lake Lefroy have been identified as potentially representing habitat for conservation significant species (Phoenix Environmental Sciences 2018). There are also several vegetation types associated with the riparian zone of the lake and peripheral wetlands, which support potentially groundwater dependent species including *Melaleuca* spp. and/or *Eucalyptus* spp., and *Tecticornia* spp., although the groundwater dependence of the latter is unknown (Phoenix Environmental Sciences 2018).

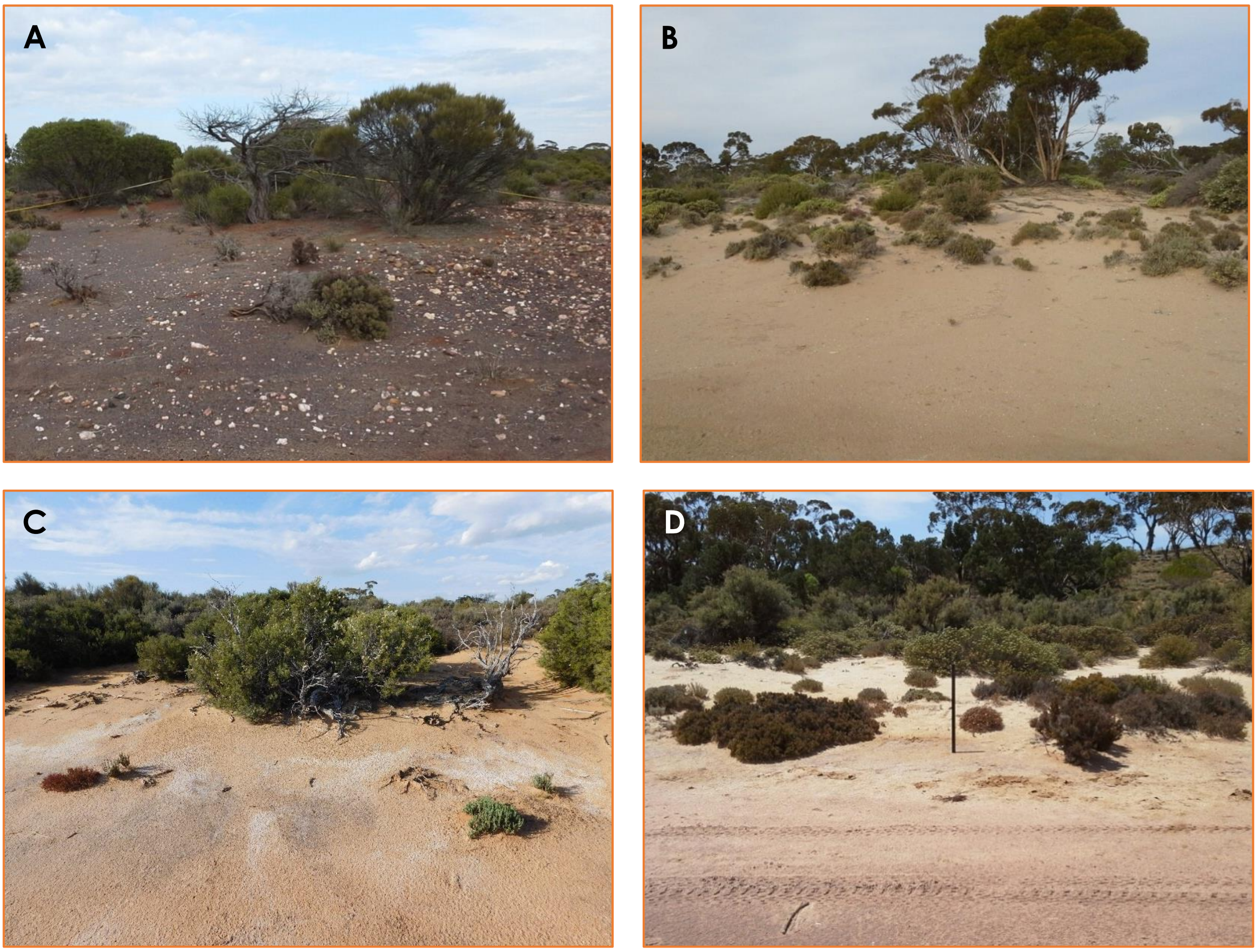

Plate 2-8: Riparian vegetation of Lake Lefroy; (A-B) discharge, (C) historic discharge, and (D) reference sites.

2.4.6.2 Potential Concerns in relation to the B2018 Project

The riparian vegetation of Lake Lefroy and peripheral wetlands may be subject to direct impacts from the B2018 Project; primarily clearing for development and infrastructure. Vegetation types containing potentially groundwater dependent species may also be susceptible to changes in groundwater levels associated with mining activities (Phoenix Environmental Sciences 2018). In addition, potential contaminants contained in surface water runoff or seepage may adversely affect riparian zones, posing an ecotoxicity risk.

Specific to the lake, bathymetry studies and hydraulic modelling has shown that typically, the discharge water does not directly influence the riparian zone (Clarke 1991; Stantec 2017b; URS Australia Pty Ltd 2010b), except during major flood events. However, the most recent modelling indicates that under flooded conditions, surface water containing discharge would be most likely to affect the south eastern margin of the lake, within the B2018 Project development envelope (Stantec 2017b). While plants in the riparian zone are adapted to naturally saline conditions, they can typically only persist in waterlogged conditions for short periods (Datson 2002). A potential increase in the inundation regime, together with predicted increases in salt loading and salt crust extent, may be detrimental to plant health. Wind-blown salts from the playa may also impact on the riparian zone of the lake and nearby peripheral wetlands, posing an ecotoxicity risk to plants (James *et al.* 2003), and conservation significant taxa. Therefore consideration should be given to the location of discharge points, to minimise impacts to the riparian zone of the lake.

While extensive regional mapping of vegetation has been completed for the broader Lake Lefroy area, the riparian zone of the peripheral wetlands has not been surveyed in detail (Phoenix Environmental Sciences 2018). Due to substantial differences in the characteristics of these wetlands there is potential for conservation significant taxa or communities, which are of high ecological value, to occur. The riparian zone of these wetlands requires adequate surveying prior to any potential disturbance associated with the B2018 Project.

3. Potential Impacts and Risk Assessment

The outcomes of the ecological assessment of Lake Lefroy and peripheral wetlands indicate that the ecological values of the lake are "***low***", while the peripheral wetlands are of "***high***" ecological significance. Based on the findings, a broad risk assessment has been developed, in relation to potential impacts associated with the B2018 Project (**Table 3-1**). As part of this, potentially sensitive environmental receptors were identified for the lake and peripheral wetlands and include:

- water and sediment;
- aquatic biota (such as algae, macrophytes, aquatic invertebrates and waterbirds), including dormant propagules in sediment; and
- plants inhabiting riparian zones.

There are a range of potential direct and indirect impacts that may result from the B2018 Project development envelope, adversely influencing receptors and potentially decreasing the biodiversity and productivity of the lake and peripheral wetlands, summarised as follows:

- Direct impacts:
  - potential removal and/or disturbance of aquatic and riparian habitat on the playa and peripheral wetlands;
  - increased salt loads within the playa (above existing current loads), resulting in increased thickness and extent of the salt crust (particularly where new causeways are constructed);
  - surface water runoff into the playa and peripheral wetlands, containing potential contaminants (elevated concentrations of salts and metals), which may pose an ecotoxicity risk to aquatic biota and riparian vegetation;
  - seepage of potential contaminants into groundwater, which may be subsequently discharged to the surface of the playa and peripheral wetlands, or riparian zones, posing an ecotoxicity risk to aquatic biota and riparian vegetation; and
  - changes in groundwater levels due to abstraction, which may affect groundwater dependent vegetation.
- Indirect impacts:
  - adverse effects on the aquatic biota on the playa, including reduced emergence and propagule and egg replenishment opportunities, due to the presence of a thick salt crust (forming a physical barrier);
  - wind-blown salts from the playa adversely affecting aquatic biota and riparian plants of peripheral wetlands (particularly those in close proximity to the playa); and
  - changes to surface hydrology, hydrogeology and/or water quality, influencing the playa and peripheral wetlands, which may adversely affect aquatic biota and riparian plants.

The risk to potentially sensitive environmental receptors from the various potential impacts of the B2018 Project was assessed in the context of the current ecological status of the lake and peripheral wetlands (**Table 3-1**). As existing salt loads on the playa are already considered substantial, additional contributions may not cause any further adverse effects, due to the low ecological value of the lake. However, there are some areas of the playa that may be of greater ecological significance. These include the northern and southern extremities, which are currently not impacted by a salt crust, and have limited information available on their ecology, particularly during flooding. The freshwater and low salinity peripheral wetlands are also considered relatively undisturbed by mining activities (with some exceptions), which corresponds to their comparatively higher ecological value, and the presence of several conservation significant taxa.

Based on this, a risk ranking of "***low to moderate***" was applied to the environmental receptors, in relation to potential impacts from the B2018 Project (**Table 3-1**). In contrast, for the peripheral wetlands, a risk ranking of "***moderate to high***" was assigned. These environmental risk rankings may be mitigated by addressing remaining knowledge gaps for the lake and peripheral wetlands in the future, and via ongoing monitoring to detect changes; recommended on an annual basis, as well as during flooding (**Table 3-1**). However, the primary aim should be to minimise impacts by avoiding areas currently not affected by mining activities, or that are considered to have higher ecological significance.

Table 3-1: Summary of risk to environmental receptors on Lake Lefroy and peripheral wetlands, in relation to the B2018 Project (based on current conditions).

Environmental Receptors	Conservation Significant / Restricted Habitat or Species	Potential Impacts	Risk	Risk Justification / Knowledge Gaps	Recc. Monitoring	
					Annual	Flood Event
Lake Lefroy: Surface Water and Sediment	• NA	• Elevated salts and metals in water and sediment from discharge • Increased salt crust on the playa from discharge • Elevated surface water salinities in major floods	Low to Moderate	Currently, dewatering discharge contributes to salt and metal loading on the playa. Additional predicted impacts for the B2018 Project are for increased salt loading and salt crusting. Metals are likely to remain biologically unavailable. Knowledge gaps remain, including understanding salt crust thickness and distribution over the hydroperiod, and characterising ecological values within a regional context during flooding.	✓	✓
Peripheral Wetlands: Surface Water and Sediment	• NA	• Elevated salinities and metals in water and sediment due to runoff or seepage • Changes to surface hydrology or hydrogeology that affect water and sediment quality	Moderate to High	Currently, the peripheral wetlands remain relatively undisturbed and are associated with low salinity or freshwater conditions. Therefore any change to water quality from the B2018 Project may result in significant ecological changes. Knowledge gaps remain, including characterising ecological values within a regional context during flooding.	✓	✓
Lake Lefroy: Algae / Macrophytes and Aquatic Invertebrates	• None	• Reduced productivity and biodiversity due to increased salinity • Reduced replenishment of propagule bank due to salt crust • Ecotoxicity risk to aquatic biota from increased salts and metals • Impacts to potentially conservation significant taxa	Low to Moderate	The ecological value of the lake appears to be low, with no additional change to impacted areas from the B2018 Project. Knowledge gaps remain, including characterising ecological values within a regional context during flooding.	✓	✓

Environmental Receptors	Conservation Significant / Restricted Habitat or Species	Potential Impacts	Risk	Risk Justification / Knowledge Gaps	Recc. Monitoring	
					Annual	Flood Event
Peripheral Wetlands: Algae / Macrophytes and Aquatic Invertebrates	• *Calamoecia ampulla* var. B01 • *Eocyzicus* sp. MWH01 • *Ilyodromus* sp. BOS1031 • *Parartemia nr serventyi MWH01* • *Parartemia* (juvenile)	• Reduced biodiversity of peripheral wetlands due to habitat disturbance or increased salts and metals • Ecotoxicity risk to aquatic biota from increased salts and metals • Impacts to potentially conservation significant taxa	Moderate to High	The ecological value of the peripheral wetlands is high, requiring consideration for the B2018 Project. Knowledge gaps remain, including verification of status and distribution of potentially conservation significant taxa, and characterising ecological values within a regional context during flooding.	✓	✓
Lake Lefroy: Riparian Vegetation	• *Calandrinia* sp. Widgiemooltha (F. Obbens & E. Reid FO 9/05)(P1) • *Tecticornia mellarium* (P1); • *Tecticornia flabelliformis* (P1) • *Ptilotus rigidus* (P1) • *Pityrodia scabra* subsp. *dendrotricha* (P3)	• Reduced plant diversity and cover from clearing • Degradation from wind-blown salts or salts in floodwaters • Ecotoxicity risk to plants from increased salts • Changes in groundwater levels affecting GDEs • Impacts to potentially conservation significant taxa	Low to Moderate	Currently, discharge water does not impact on riparian vegetation during dry conditions, with no change expected from the B2018 Project. However, with increased salt loading there is potential for wind-blown salts from discharge water, or floodwater containing discharge salts to impact riparian vegetation.	✓	✓
Peripheral Wetlands: Riparian Vegetation	• Unknown, although possible locally restricted conservation significant communities and/or species • Potential GDEs	• Reduced diversity and cover from clearing • Wind-blown salts from the playa causing degradation • Ecotoxicity risk to plants from increased salts • Changes in groundwater levels affecting GDEs • Impacts to potentially conservation significant taxa	Moderate to High	The main risk to riparian vegetation of peripheral wetlands may be clearing for the B2018 Project, which may indirectly impact aquatic biota and ecological values.	✓	✓

Risk rating: Low risk indicates negligible risk, or no risk due to current conditions and/or existing impacts; Moderate risk indicates potential loss of some ecological values and/or taxa in previously undisturbed areas; High risk indicates potential loss of significant ecological values and/or taxa in previously undisturbed areas.

4. Summary

Following a review of more than 50 literature sources on lake-based ecological studies, it is apparent that a substantial amount of data collection and research has been completed, contributing to the understanding of Lake Lefroy's chemical, physical and biological attributes. However, many of these studies, while being survey intensive, have not necessarily targeted useful ecological indicators, or have widely varying methodology and taxonomic resolution, preventing meaningful spatial and/or temporal comparisons. In addition, there is limited information on the lake's peripheral wetlands, which have higher ecological value than the playa. The relationship between biodiversity, mining impacts, including historic impacts pre-SIGMC, is also unknown, with no baseline data available prior to the construction of the causeway.

The B2018 Project will discharge increased volumes of hypersaline water to the lake, increasing salt loads, which will potentially reduce the current ecological values of the lake. There is also the potential that within the development envelope of the B2018 Project, there may be direct and indirect impacts to the peripheral wetlands, which are of greater ecological significance. A summary of the ecological components is provided in subsequent sections, in relation to potential concerns for the B2018 Project.

4.1 Surface Water and Sediment Quality

The dataset for water and sediment quality from Lake Lefroy and the peripheral wetlands is considered patchy, with limited opportunities to sample during flooded conditions. In addition, water quality has mostly been analysed from discharge sites on the lake.

For water quality, the trends can be summarised as follows:

- Lake Lefroy – circumneutral (pH<7.5), extremely hypersaline (>300,000 mg/L), variable nutrients, and elevated concentrations of metals at discharge sites (copper, manganese, lead and zinc), compared to reference sites (except for manganese); and
- Peripheral wetlands – alkaline (>7.5), freshwater to mesosaline conditions (<32,000 mg/L), low nutrients and typically low metals (except for aluminium and copper).

For sediment, the trends can be summarised as follows:

- Lake Lefroy –acidic to alkaline (pH <6.5 to >7.5), elevated salinity at discharge sites (>500,000 mg/kg; salt crust up to 60 cm) compared to reference sites (<100,000 mg/kg; salt crust up to 8 cm), variable nutrients, and elevated concentrations of metals at the discharge sites (copper, cobalt, manganese, and zinc), compared to reference sites (except for manganese); and
- Peripheral wetlands – acidic to alkaline (pH <5.0 to >8.5), low to moderate salinity (<60,000 mg/kg), variable nutrients, and typically low concentrations of metals (except for chromium and nickel).

Discharging mine water on the lake has contributed to elevated concentrations of salts and metals in surface water and sediment, although the most obvious visual impact is the presence of a thick salt crust that covers an extensive area of the playa. However, high salinity and the sediment characteristics of the lake also suggest that metals are likely to be adsorbed to ions and fine clay particles, remaining biologically unavailable. Specific to the B2018 Project, while surface water salinities are unlikely to change at the discharge sites as concentrations are already close to saturation levels, there is likely to be less potential for dilution during major flood events. Conditions throughout the lake (including at reference sites) may increasingly reflect those at discharge sites, regardless of the magnitude of a flood event. A larger area of the lake may also be impacted by salt crusting, in addition to the predicted increase in salt crust thickness across the playa. The latter may be further exacerbated by the construction of new causeways within the development envelope.

In contrast to the lake playa, freshwater or low salinity conditions prevail at the peripheral wetlands, although studies are limited, with some evidence of natural mineralisation. These waterbodies are not at risk from discharge water, however the B2018 Project has the potential to cause increases in salinity and/or metal concentrations above background levels. This may occur via direct or indirect impacts such as surface water runoff or seepage, which contain contaminants. This is of particular concern for freshwater wetlands with strongly acidic or alkaline pH, as some metals may be more readily mobilised, posing a potential ecotoxicity risk to aquatic biota and riparian vegetation.

4.2 Aquatic Biota

The diversity and productivity of the Lake Lefroy is low due to the extreme salinity, in comparison to the freshwater and low salinity peripheral wetlands (**Table 4-1**). The algal assemblage of the playa is characterised by cyanobacterial benthic communities (including *Schizothrix* mats), with diatoms occurring to a lesser extent, while phytoplankton productivity is almost negligible. In addition, macrophytes have only been recorded in the form of charophytes oospores (dormant propagules). Long-term monitoring of diatoms in the lake sediment has also shown localised impacts at discharge sites, with reference sites supporting a diatom population of mostly *Amphora*, *Hantzschia* and *Navicula* genera.

It has been suggested that the aquatic invertebrate assemblage of Lake Lefroy may be depauperate, in comparison to other saline playas in the Goldfields, likely attributed to the lack of a low salinity phase during flooding. To date, the most commonly recorded taxa include dipteran larvae (ceratopogonids), together with low numbers of copepods (*Calamoecia* cf. *salina* and *Meridiecyclops baylyi*) and the anostracan (brine shrimp) *Parartemia*. Few differences in aquatic invertebrate assemblages have been observed between discharge and reference sites on the lake, although surface water salinities are likely to be prohibitive. Limited flood event sampling, to provide regional context, also means that it is difficult to discern the relationship of aquatic invertebrate communities to the potential impacts of the dewatering discharge.

It is not known if the current environmental status of Lake Lefroy is due to dewatering discharge, or to the presence of the causeway restricting water flow, or alternatively, is the natural state of the lake. Regardless, reduced productivity of aquatic biota may be a consequence of the proposed increase in discharge volumes and salt loads associated with the B2018 Project. This is of particular concern for areas in the northern and southern extremities of the lake, which currently have not been impacted. Increased surface water salinities are likely to prevent the emergence of aquatic biota during flooding, decreasing propagule and egg replenishment opportunities.

In contrast to the lake playa, the more diverse and highly productive peripheral wetlands have been subject to minimal impacts from mining activities historically. These waterbodies support an abundant algal assemblage, including phytoplankton and benthic communities. Algal taxa mostly comprise chlorophytes (including *Oedogonium*), while cyanobacteria (such as *Microcoleus*) are known to form extensive mats. Diatoms include a range of freshwater and low salinity species such as *Nitzschia palea*. Macrophytes, represented by several charophytes and other taxa, have also been documented, and provide an important habitat and food source for aquatic invertebrates and waterbirds.

Aquatic invertebrate taxa recorded from the peripheral wetlands consist of a diverse community of crustaceans and insects. Crustaceans include anostracans (brine shrimp), ostracods (seed shrimp), copepods, notostracans (shied shrimp) and spinicaudatans (clam shrimp). Insect groups such as dipterans (fly larvae), coleopterans (beetle larvae), hemipterans (true bugs) and odonatans (dragonfly larvae) have also been recorded. Up to five potentially conservation significant aquatic invertebrate taxa have been identified from the peripheral wetlands (**Table 4-1**). These taxa are considered new or undescribed, and have a potentially restricted distribution to the Lake Lefroy area, although further investigation is required to verify their occurrence and distribution, due to limited studies completed during flood events. Regardless, the ecological value of the peripheral wetlands is considered high, and potential direct and indirect impacts associated with the B2018 Project should be minimised, in order to maintain the ecological integrity of these waterbodies.

4.3 Riparian Vegetation

Studies on the riparian vegetation zone of Lake Lefroy have indicated the presence of three main riparian communities:

- *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;
- *Melaleuca thyoides* and *Jacksonia arida* mid to tall open shrubland over *Darwinia* sp. Karonie low sparse to open shrubland; and
- *Darwinia* sp. Karonie and *Tecticornia* spp. low sparse shrubland.

Annual monitoring of the Lake Lefroy riparian zone indicates that the most frequently recorded plant taxa comprise *Darwinia* sp. Karonie, *Tecticornia indica*, *Jacksonia arida*, and *Melaleuca thyoides*. The findings of this monitoring have also been consistent over time, with no differences between discharge and reference sites in relation to species diversity, plant health and vegetation condition, and no evidence of impact from the dewatering discharge. However, increased discharge and salt loading from the B2018 Project and subsequent wind-blown salts, have the potential to adversely affect the riparian zone of the lake and nearby peripheral wetlands. Clearing for development and infrastructure, contamination associated with runoff and seepage, and changes in groundwater levels may also influence vegetation communities on the margins of the lake and within the riparian zone of the peripheral wetlands.

There may be up to six priority listed species within the riparian zone of the Lake Lefroy area (**Table 4-1**), as well as several locally conservation significant and/or restricted communities. However, the riparian zone of the peripheral wetlands has not been studied in detail, and due to differences in the characteristics of these wetlands, they also have the potential to support conservation significant communities and/or taxa, requiring consideration in relation to potential direct and indirect impacts from the B2018 Project.

Table 4-1: Summary of the aquatic biota and riparian vegetation diversity (taxa numbers) recorded from Lake Lefroy and peripheral wetlands.

Ecological Component	Playa	Peripheral Wetlands	Total Taxa	Conservation Significant Taxa & Distribution
Phytoplankton	2	55	56	• None*
Benthic Algae	29	81	92	• None*
Diatoms	34	52	66	• None*
Macrophytes (incl. resting stages)	3	9	9	• None*
Aquatic Invertebrates	13	101	103	New taxa from peripheral wetlands, which are potentially restricted comprising: • *Calamoecia ampulla* var. B01 • *Eocyzicus* sp. MWH01 • *Ilyodromus* sp. BOS1031 • *Parartemia* nr *serventyi* MWH01 • *Parartemia* sp. (juvenile)
Riparian Vegetation	77	Unknown	294	Priority taxa and conservation significant communities and/or species comprising: • *Calandrinia* sp. Widgiemooltha (F. Obbens & E. Reid FO 9/05) (Priority 1) • *Tecticornia mellarium* (Priority 1); • *Tecticornia flabelliformis* (Priority 1) • *Ptilotus rigidus* (Priority 1) • *Pityrodia scabra* subsp. *dendrotricha* (Priority 3) • locally restricted conservation significant communities and/or species; and • potential groundwater dependent vegetation (GDEs)

*Note: most components are likely to have inflated taxa numbers due to poor taxonomic resolution historically (with the exception of the riparian vegetation); * due to limited taxonomic resolution of algae and macrophytes in Western Australia, with potential endemic taxa present.*

5. Recommendations

Recommendations are provided for consideration by SIGMC (some of which are already in the process of being implemented), in order to minimise impacts to potentially sensitive environmental receptors, address remaining knowledge gaps, and progress with valuable, outcomes-based monitoring for the B2018 Project. These include:

- Revise the existing Lake Lefroy trigger values for water and sediment quality, due to limitations within the existing datasets. These should be developed using all available reference data (historic and annual monitoring data), and should also be refined on a regular basis incorporating any new data that becomes available. This will allow for a more accurate comparison of potential discharge impacts, in relation to background levels, and enable the management (for example pre-treatment) of discharge water to be refined if necessary.
- Assess the extent of the salt crust on Lake Lefroy throughout the hydroperiod. Several new mapping techniques (involving aerial imaging) are available to assess the surface extent and thickness of the salt crust on the lake. The results of salt crust mapping and subsequent salt modelling (if deemed appropriate) may be used to gain a better understanding of the associated risk to aquatic biota and riparian vegetation. This may need to be undertaken on an annual basis.
- Ensure that discharge outfalls on Lake Lefroy are situated well onto the playa and away from the lake margins, minimising potential backflow along creeklines or into riparian zones. Also ensure that adequate engineering design and pre-treatment is in place to minimise the influence on the lake from erosion, flow, sedimentation and contaminants.
- Continue to undertake annual monitoring of the Lake Lefroy environment, and complete additional studies during major flood events (1 in 20 year ARI rainfall event). Lake-based monitoring should comprise suitable ecological components (to align with current annual monitoring), and include water and sediment quality, algae (diatoms as a minimum), macrophytes (where present), aquatic invertebrates (where present), the dormant propagule bank and riparian vegetation. Discharge, historic discharge and reference sites should be assessed, with spatial (regional) and temporal comparisons across the lake, to determine potential mining impacts. It may also be pertinent to include peripheral wetlands within the annual lake-based monitoring program.
- Further investigation of the peripheral wetlands should also be undertaken during flooding, to assess productivity and biodiversity, potentially incorporating playa areas to the north of Lake Lefroy. Along with sampling of the main playa, this would provide additional regional context on ecological values, in relation to potential mining impacts. This would also increase understanding on the occurrence and distribution of potentially conservation significant aquatic invertebrate and riparian plant taxa.
- Minimise infrastructure such as causeways on the playa of Lake Lefroy, which may restricting water flow and movement, causing salts to accumulate, and increasing the thickness of the salt crust in localised areas. These effects are evident in the vicinity of the main causeway that bisects the lake, and appear to adversely affect the lake's natural hydrology and ecology.
- Ensure direct (such as habitat disturbance) and indirect impacts (such as surface water runoff and seepage that may contain contaminants) are minimised, to protect the northern and southern extremities of Lake Lefroy and the peripheral wetlands, which have higher ecological value. These areas remain relatively undisturbed, and have not been affected by mining activities.
- Investigate the potential to form a Lake Lefroy catchment group with other mining companies that actively discharge, or have historically discharged to the lake, or are mining on the periphery. This will allow for the coordination of environmental management, assessment of potential cumulative impacts, and streamline information sharing to improve the regional knowledge base. A catchment group could also share, and therefore reduce the costs associated with future lake-based monitoring studies.

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Appendices

Appendix A EPA Ministerial Statement 879

Published on: 16 November 2011 Statement No. 879

STATEMENT THAT A PROPOSAL MAY BE IMPLEMENTED
(PURSUANT TO THE PROVISIONS OF THE
***ENVIRONMENTAL PROTECTION ACT 1986*)**

GOLD MINE DEVELOPMENTS ON LAKE LEFROY

Proposal: The proposal is to expand existing open-cut and underground gold mining developments within a defined project area on the surface of Lake Lefroy, approximately 20 kilometres south east of Kambalda. The proposal includes the discharge of dewatering to the lake's surface and the construction of associated mining infrastructure (including open pits and waste rock dumps).

The proposal is further documented in schedule 1 of this statement.

Proponent: St Ives Gold Mining Company Pty Limited

Proponent Address: PO Box 359,
KAMBALDA WEST WA 6444

Assessment Number: 1809

Previous Assessment Number: 1250

Report of the Environmental Protection Authority: Report 1411

Previous Report of the Environmental Protection Authority: Report 976

Previous Statement Number: 548 (Published on 13 July 2000)

Appeal Determination: Appeal 90 of 2011

The proposal referred to in the above report of the Environmental Protection Authority may be implemented. The implementation of that proposal is subject to the following conditions and procedures:

1 Proposal Implementation

1-1 The proponent shall implement the proposal as documented and described in schedule 1 of this statement subject to the conditions and procedures of this statement.

2 Proponent Nomination and Contact Details

2-1 The proponent for the time being nominated by the Minister for Environment under sections 38(6) or 38(7) of the *Environmental Protection Act 1986* is responsible for the implementation of the proposal.

2-2 The proponent shall notify the Chief Executive Officer of the Office of the Environmental Protection Authority (CEO) of any change of the name and address of the proponent for the serving of notices or other correspondence within 30 days of such change.

3 Time Limit of Authorisation

3-1 The authorisation to implement the proposal to expand existing open-cut and underground gold mining developments within a defined project area on the surface of Lake Lefroy, approximately 20 kilometres south east of Kambalda provided for in this statement shall lapse and be void five years after the date of this statement if the proposal to which this statement relates is not substantially commenced.

3-2 The proponent shall provide the CEO with written evidence which demonstrates that the proposal has substantially commenced on or before the expiration of five years from the date of this statement.

4 Compliance Reporting

4-1 The proponent shall prepare and maintain a compliance assessment plan to the satisfaction of the CEO.

4-2 The proponent shall submit to the CEO the compliance assessment plan required by condition 4-1 at least six months prior to the first compliance report required by condition 4-6, or prior to implementation, whichever is sooner. The compliance assessment plan shall indicate:

1. the frequency of compliance reporting;
2. the approach and timing of compliance assessments;
3. the retention of compliance assessments;

4. the method of reporting of potential non-compliances and corrective actions taken;

5. the table of contents of compliance assessment reports; and

6. public availability of compliance assessment reports.

4-3 The proponent shall assess compliance with conditions in accordance with the compliance assessment plan required by condition 4-1.

4-4 The proponent shall retain reports of all compliance assessments described in the compliance assessment plan required by condition 4-1 and shall make those reports available when requested by the CEO.

4-5 The proponent shall advise the CEO of any potential non-compliance within seven days of that non-compliance being known.

4-6 The proponent shall submit to the CEO the first compliance assessment report by 31st March 2012 (to cover the period 1st July 2010 to 31st December 2011) and then annually by the 31st March each year to cover the previous 12 month calendar year period. The compliance assessment report shall:

1. be endorsed by the proponent's General Manager or a person delegated to sign on the General Manager's behalf;

2. include a statement as to whether the proponent has complied with the conditions;

3. identify all potential non-compliances and describe corrective and preventative actions taken;

4. be made publicly available in accordance with the approved compliance assessment plan; and

5. indicate any proposed changes to the compliance assessment plan required by condition 4-1.

5 Environmental Monitoring

5-1 Prior to ground disturbing activity, the proponent shall prepare and implement a monitoring plan to the satisfaction of the CEO. The plan shall include the monitoring of:

1. Riparian vegetation health at discharge and reference sites;

2. Surface water quality at discharge sites and points throughout the lake including the playas and clay pans adjacent to Lake Lefroy;

3. Sediment quality at discharge sites, including levels of heavy metals;

4. Aquatic flora and fauna following a 1:20 year (100 mm in 72 hours) rainfall event or greater;

5. Terrestrial invertebrate fauna; and

6. Migratory water bird populations.

5-2 The monitoring required under condition 5-1, shall be carried out in such a way that it allows confirmation that the observed impacts from the proposal documented in schedule 1 are not greater than those predicted in the Public Environmental Review for the proposal, which is titled Gold Mining Developments on Lake Lefroy Beyond 2010 (dated 3 December 2010).

5-3 The proponent shall submit annually, as part of the compliance plan, the results of the monitoring required by condition 5-1 to the CEO.

5-4 The proponent shall make the approved monitoring plan and the results of the monitoring required by condition 5-1 publicly available in a manner approved by the CEO.

5-5 Should the monitoring carried out under condition 5-1 indicate that the environmental impacts of the project are greater than those predicted in the Public Environmental Review the proponent will develop and implement a management plan, to the satisfaction of the CEO, that details how the impacts will be reduced or mitigated and any remedial work required.

6 Surface Water Discharge

6-1 The proponent shall restrict discharge to the discharge points shown in Figure 3 in Schedule 1 of this Statement.

6-2 The proponent shall visually monitor and record the size of the area of inundation of the Lake Lefroy riparian zone following rainfall of 100 mm or greater in any 72 hour period being recorded at two points in the Lake Lefroy catchment as agreed to with the CEO.

6-3 Should the area of inundation exceed that predicted in the surface water model presented in the Public Environmental Review the proponent shall:

1. report such findings to the CEO within 7 days of the exceedance being identified;

2. determine actions in consultation with the Department of Environment and Conservation to be taken to prevent future exceedences and to remediate any impact resulting from the exceedance;

3. submit actions to be taken to the CEO within 21 days of reporting the exceedance; and

4. implement actions identified above upon approval of the CEO.

6-4 The proponent shall make the results of monitoring required by condition 6-2 publicly available in a manner approved by the CEO.

6-5 The proponent shall make the records of the area of inundation monitoring available on request of the CEO.

6-6 The proponent shall use the actual area of inundation data gathered under monitoring for condition 6-2 to verify the surface water model presented in the Public Environmental Review within 3 months of the relevant rainfall event.

6-7 Should the verification carried out under condition 6-5 show that the model is not accurate the proponent shall recalibrate the surface water model presented in the Public Environmental Review.

6-8 On completing any work required under conditions 6-5 and 6-6, the proponent shall provide a report to the CEO detailing the results of the verification and the recalibration and the environmental implications of changes to the model for Lake Lefroy.

Notes

1. Where a condition states "on advice of the Office of the Environmental Protection Authority", the Office of the Environmental Protection Authority will provide that advice to the proponent.

2. The Office of the Environmental Protection Authority may seek advice from other agencies or organisations, as required, in order to provide its advice to the Department of Environment and Conservation.

3. The Minister for Environment will determine any dispute between the proponent and the Office of the Environmental Protection Authority over the fulfilment of the requirements of the conditions.

4. Mine closure and rehabilitation will be managed by the Department of Mines and Petroleum under the statutory requirements of *Mining Act 1978*.

5. The proponent is required to apply for a Works Approval and Licence for this project under the provisions of Part V of the *Environmental Protection Act 1986*.

[Signed 15 November 2011]

HON BILL MARMION MLA
MINISTER FOR ENVIRONMENT; WATER

Schedule 1

The Proposal (Assessment No. 1809)

The proposal is to expand existing open-pit and underground gold mining operations within a defined project area on Lake Lefroy, 20 kilometres south east of Kambalda, and includes dewatering discharge to the lake surface.

The proposal is described in the following document – *Gold Mining Developments on Lake Lefroy – Beyond 2010: Public Environmental Review*, December 2010.

Table 1: Summary of Key Proposal Characteristics

Element	Description
Area of disturbance	Up to 1713 ha (including 1273 ha of existing disturbance)
Area of direct riparian zone disturbance	Up to 90 ha (including 77 ha of existing disturbance)
Height of waste rock dumps	Up to 40 metres
Volume of waste rock used for backfilling	A minimum of approximately 95 million tonnes
Mining method	Open pit using conventional techniques, with some underground mining likely to be conducted at some deposits
Dewatering volume and discharge to Lake Lefroy	Up to 30 Gigalitres per annum whole of lake discharge

Figures

Figure 1 Regional location of mine site

Figure 2 Project footprint and location of key components – mine disturbance

Figure 3 Project footprint and location of key components – dewatering points

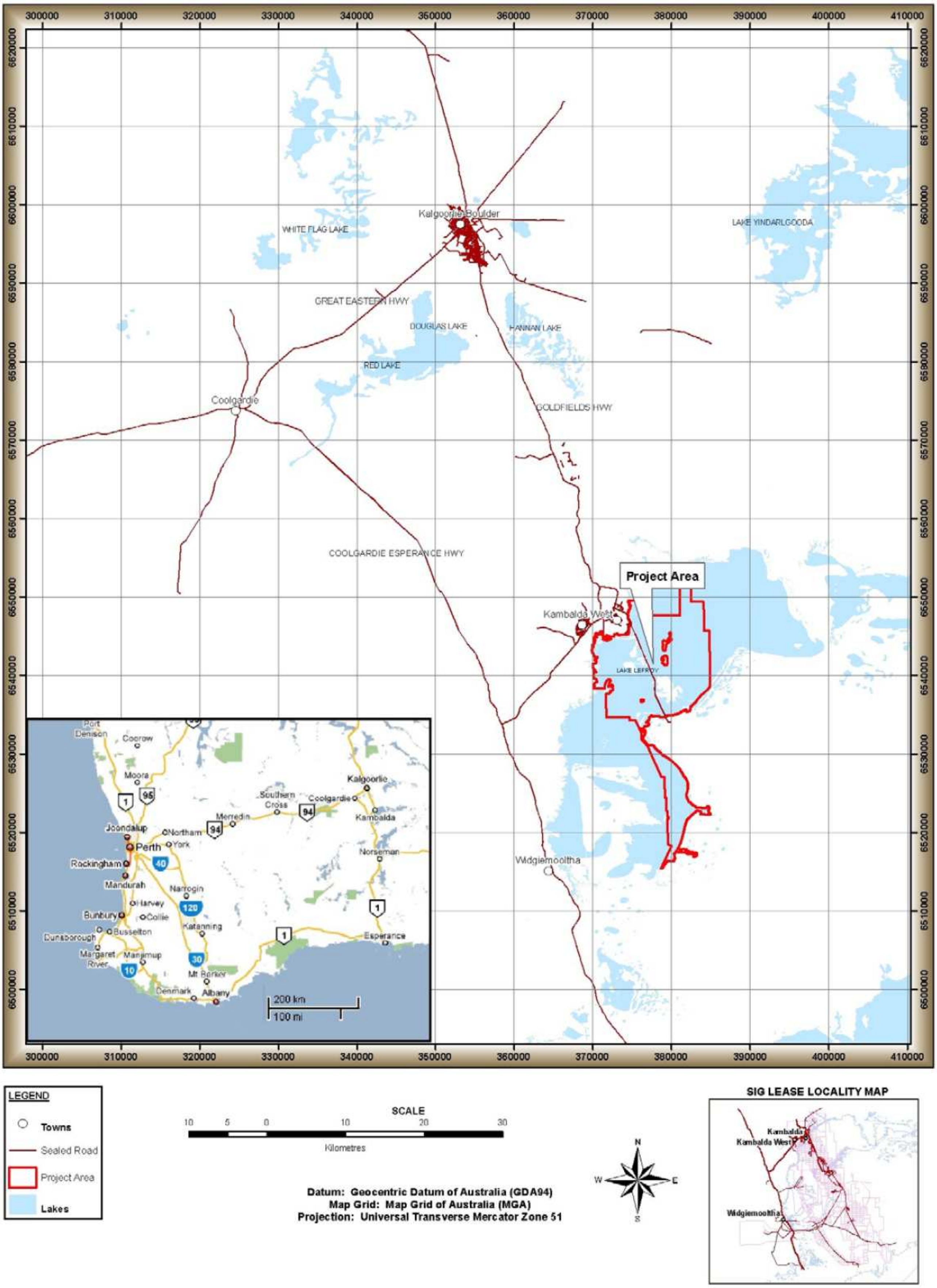


Figure 1 Regional location of mine site

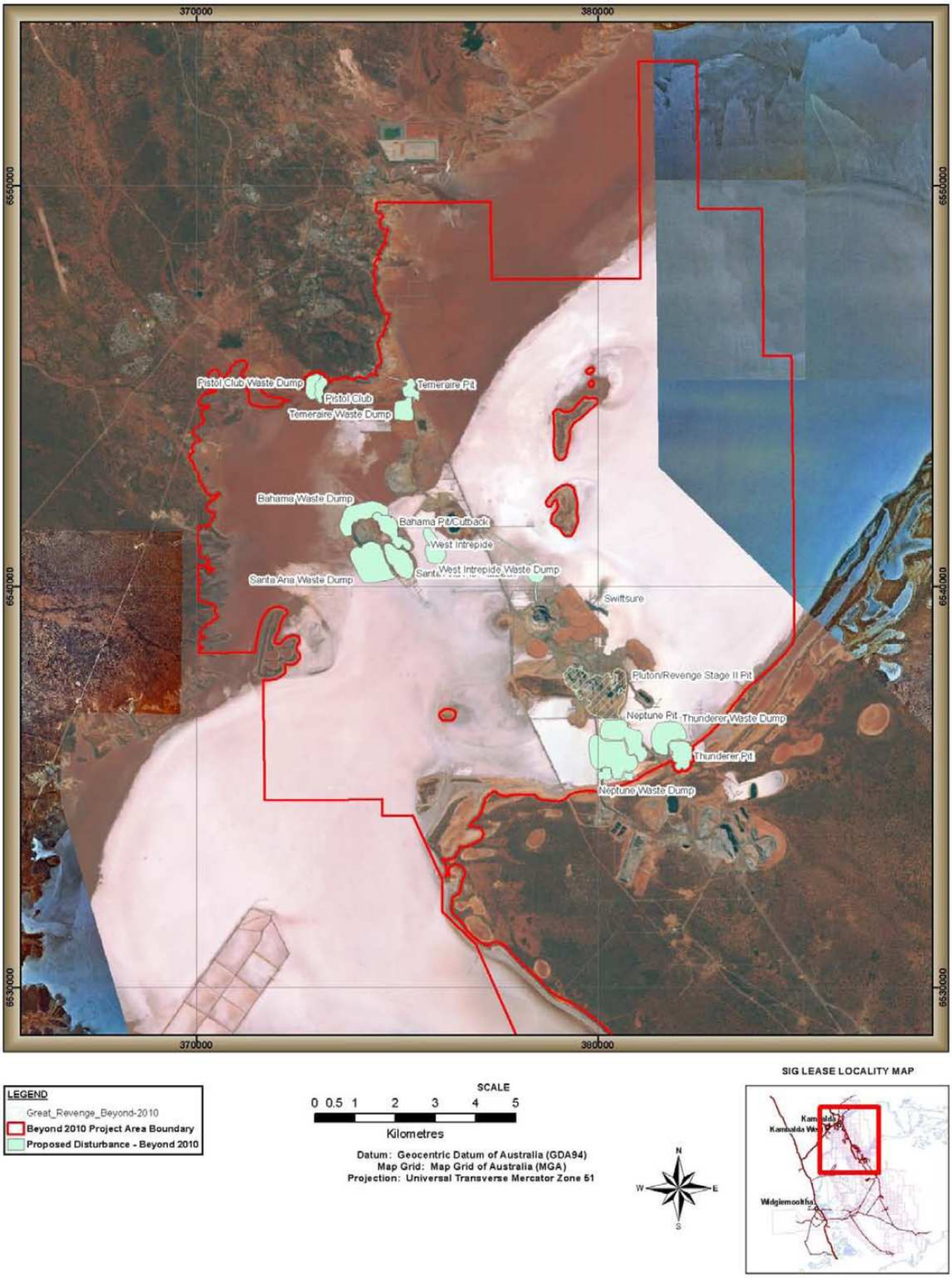


Figure 2 Project footprint and location of key components – mine disturbance

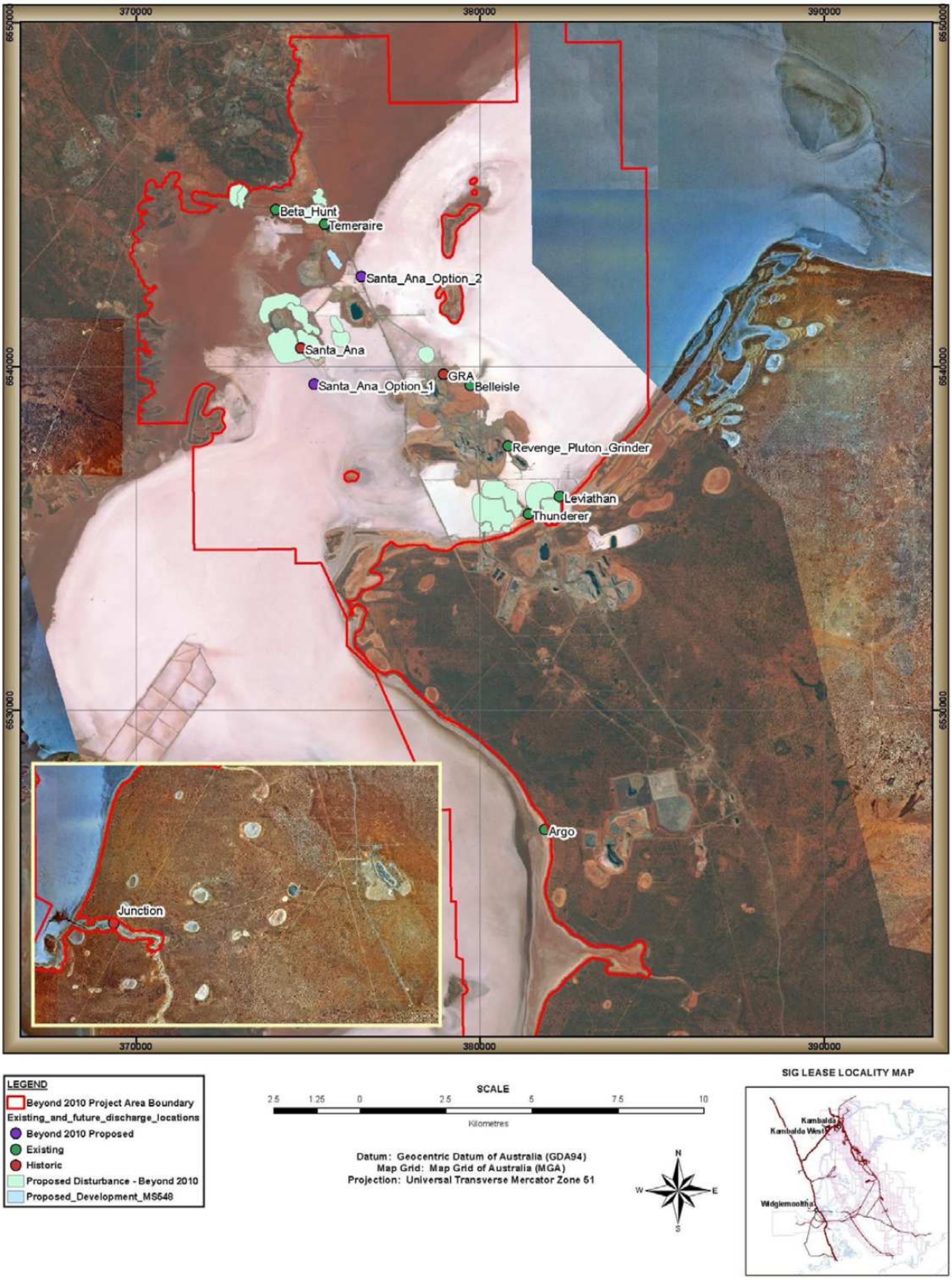


Figure 3 Project footprint and location of key components – dewatering points

Attachment 1 to Ministerial Statement 879

Change to proposal under s45C of the *Environmental Protection Act 1986*

This Attachment replaces Schedule 1 in Ministerial Statement 879, and Figures 1, 2 and 3 in Schedule 1 of Ministerial Statement 879.

Proposal: Gold Mine Developments on Lake Lefroy (Assessment No. 1809)

Proponent: St Ives Gold Mining Company Pty Limited

The Proposal (Assessment No. 1809)

The proposal is to expand existing open-cut and underground gold mining developments within a defined project area on the surface of Lake Lefroy, approximately 20 kilometres south east of Kambalda. The proposal includes the discharge of dewatering to the lake's surface and the construction of associated mining infrastructure (including open pits and waste rock dumps).

Change: - Increase of 348 hectares to the area of disturbance.

Summary Description

A summary of the key proposal characteristics is presented in Table 1.

Table 1 ï Summary of Key Proposal Characteristics

Element	Description	Approved change to Description
Area of disturbance	Up to 1713 ha (including 1273 ha of existing disturbance)	**Up to 2061 ha (including 1273 ha of existing disturbance).**
Area of direct riparian zone disturbance	Up to 90 ha (including 77 ha of existing disturbance)	Up to 90 ha (including 77 ha of existing disturbance)
Height of waste rock dumps	Up to 40 metres	Up to 40 metres
Volume of waste rock used for backfilling	A minimum of approximately 95 million tonnes	A minimum of approximately 95 million tonnes
Mining method	Open pit using conventional techniques, with some underground mining likely to be conducted at some deposits	Open pit using conventional techniques, with some underground mining likely to be conducted at some deposits
Dewatering volume and discharge to Lake Lefroy	Up to 30 Gigalitres per annum whole of lake discharge	Up to 30 Gigalitres per annum whole of lake discharge

Note: Text in **bold** in the Key Proposal Characteristics indicates change/s to the proposal.

List of Replacement Figures:

Figure 1 ï Regional Location of Minesite (replaces figure 1 in Schedule 1)

Figure 2 ï Project footprint and location of key components – mine disturbance (replaces figure 2 in Schedule 1)

Figure 3 ï Project footprint and location of key components – dewatering points (replaces figure 3 in Schedule 1)

[Signed 26 March 2014]

Dr Paul Vogel
CHAIRMAN
Environmental Protection Authority
under delegated authority

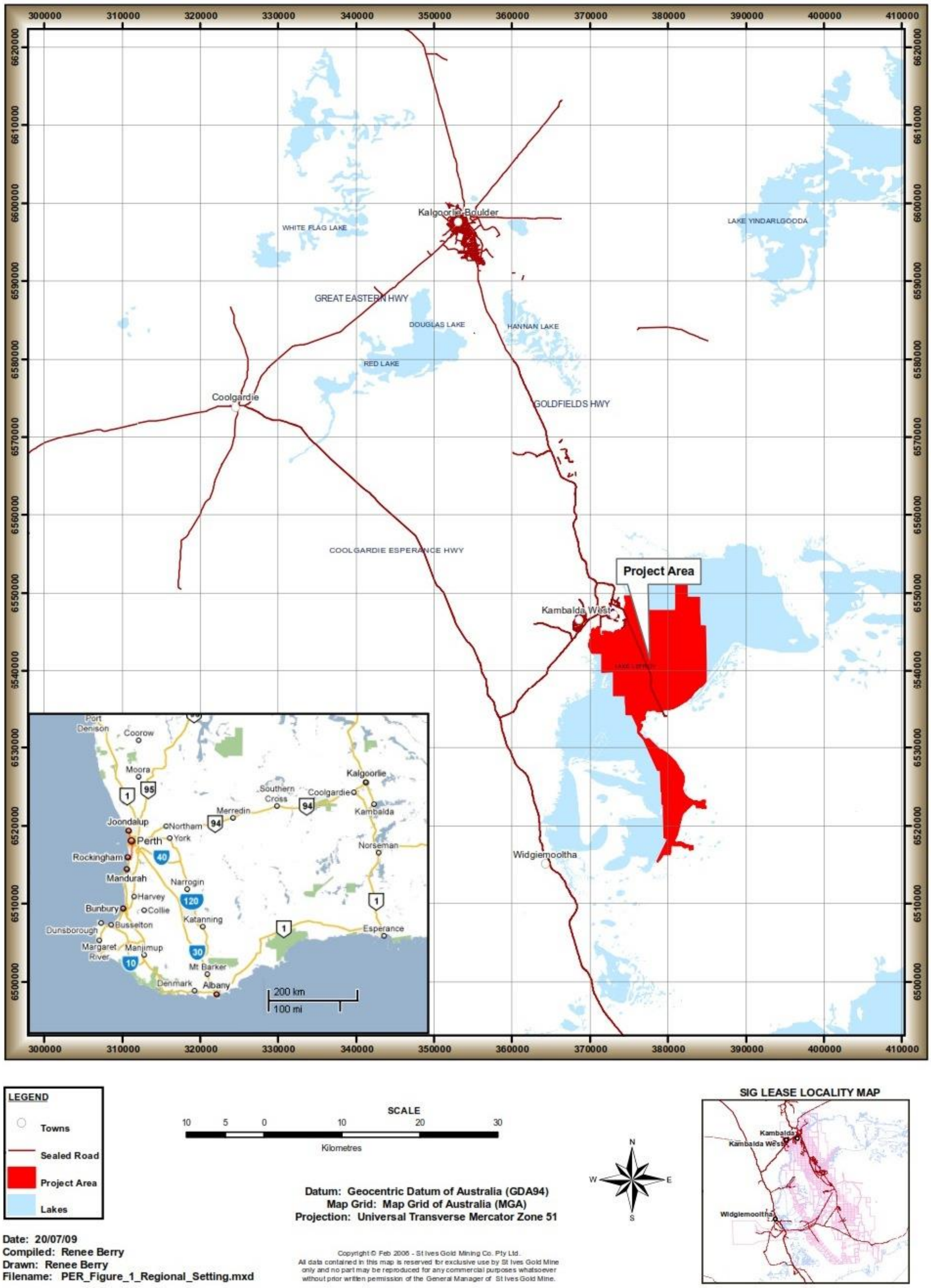


Figure 1 - Regional location of mine sites

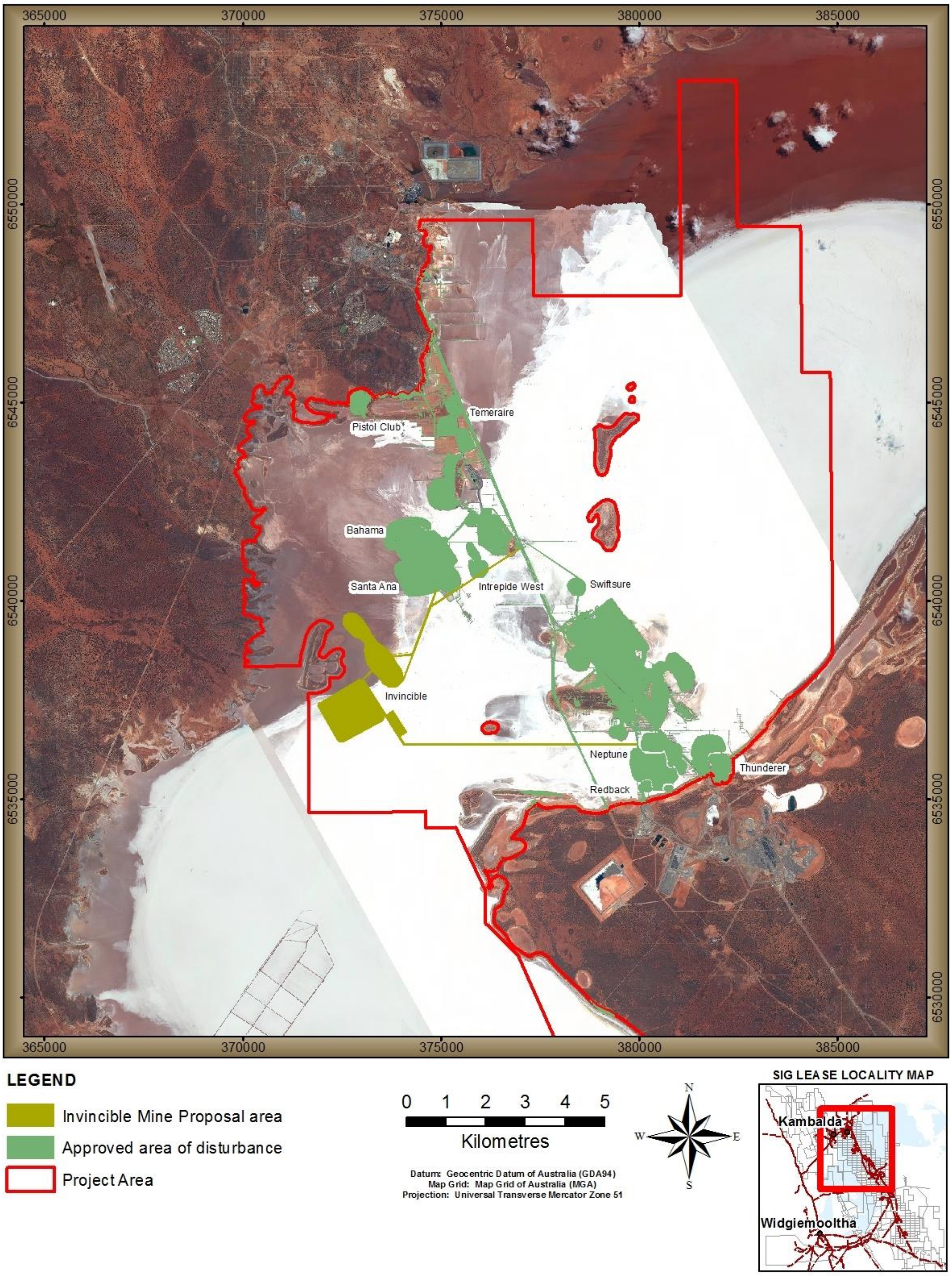


Figure 2 - Project footprint and location of key components – mine disturbance

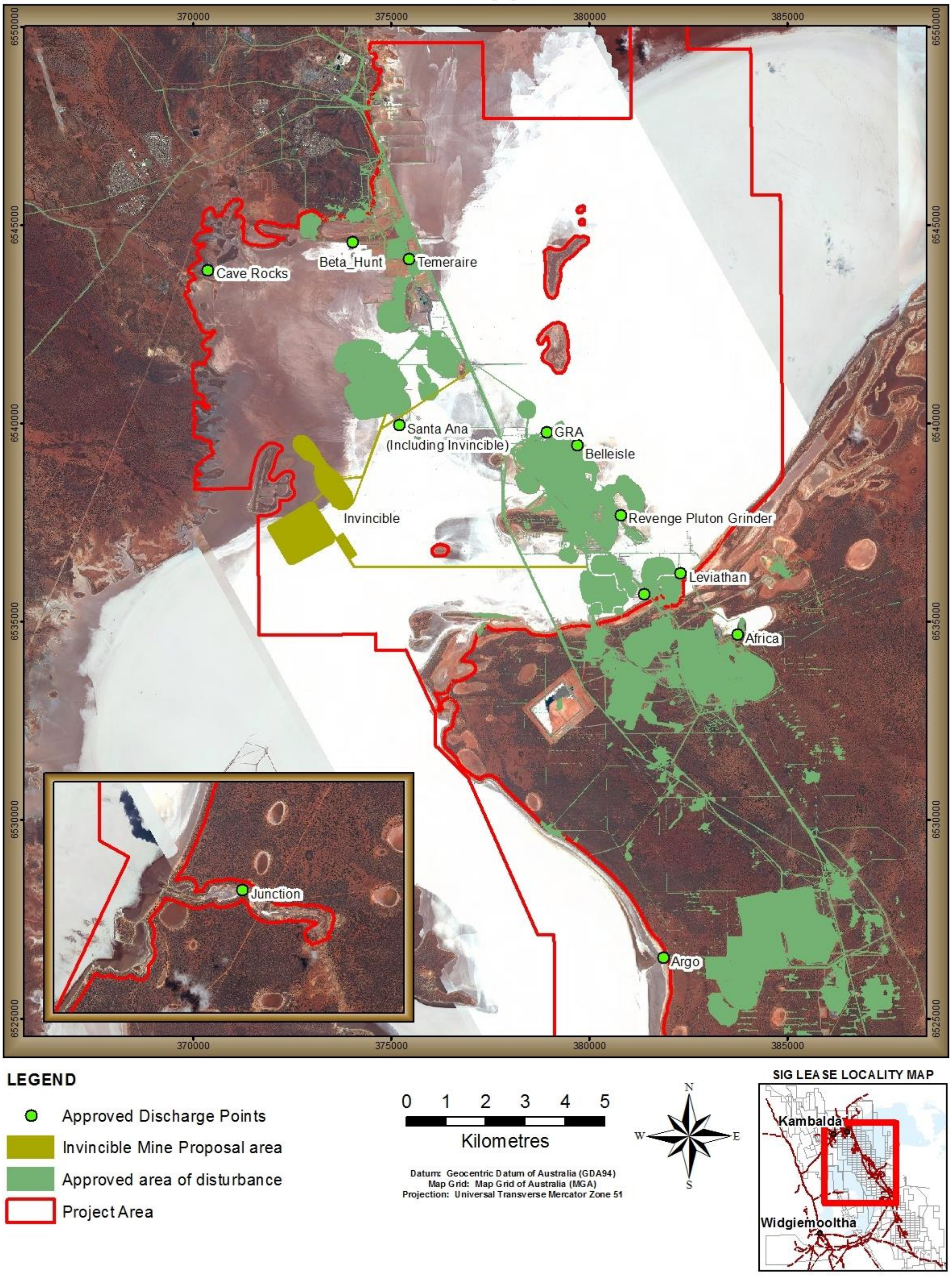


Figure 3 Project footprint and location of key components – dewatering points

Appendix B DWER EPA Act License (L8485/2010/2)

Government of **Western Australia**
Department of **Environment Regulation**

Licence

Environmental Protection Act 1986, Part V

Licensee: St Ives Gold Mining Company Pty Ltd

Licence: L8485/2010/2

Registered office: Level 5
50 Colin Street
WEST PERTH WA 6005

ACN: 098 386 273

Premises address: St Ives Gold Mine
Mining Tenements described in Schedule 1
KAMBALDA WEST WA 6442

Issue date: Thursday, 3 October 2013

Commencement date: Monday, 7 October 2013

Expiry date: Wednesday, 6 October 2021

Prescribed premises category
Schedule 1 of the *Environmental Protection Regulations 1987*

Category number	Category description	Category production or design capacity	Approved premises production or design capacity
05	Processing or beneficiation of metallic or non-metallic ore	50 000 tonnes or more per year	9 000 000 tonnes per annual period
06	Mine dewatering	50 000 tonnes or more per year	30 000 000 tonnes per annual period
07	Vat or in situ leaching of metal	5 000 tonnes or more per year	3 000 000 tonnes per annual period
54	Sewage facility	100 cubic metres or more per day	220 cubic metres per day
64	Class II or II putrescible landfill site	20 tonnes or more per year	1 000 tonnes per annual period

Conditions
This Licence is subject to the conditions set out in the attached pages.

Date signed: 14 October 2016
....
Tim Gentle
Manager Licensing – Industry Regulation (Resources Industries)
Officer delegated under section 20
of the *Environmental Protection Act 1986*

Contents

Introduction

This Introduction is not part of the Licence conditions.

DERõs industry licensing role
The Department of Environment Regulation (DER) is a government department for the state of Western Australia in the portfolio of the Minister for Environment. DER's purpose is to advise on and implement strategies for a healthy environment for the benefit of all current and future Western Australians.

DER has responsibilities under Part V of the *Environmental Protection Act 1986* (the Act) for the licensing of prescribed premises. Through this process DER regulates to prevent, control and abate pollution and environmental harm to conserve and protect the environment. DER also monitors and audits compliance with works approvals and licence conditions, takes enforcement action as appropriate and develops and implements licensing and industry regulation policy.

Licence requirements
This Licence is issued under Part V of the Act. Conditions contained within the Licence relate to the prevention, reduction or control of emissions and discharges to the environment and to the monitoring and reporting of them.

Where other statutory instruments impose obligations on the Premises/Licensee the intention is not to replicate them in the licence conditions. You should therefore ensure that you are aware of all your statutory obligations under the Act and any other statutory instrument. Legislation can be accessed through the State Law Publisher website using the following link:
http://www.slp.wa.gov.au/legislation/statutes.nsf/default.html

For your Premises relevant statutory instruments include but are not limited to obligations under the:

- *Environmental Protection (Unauthorised Discharges) Regulations 2004* – these Regulations make it an offence to discharge certain materials such as contaminated stormwater into the environment other than in the circumstances set out in the Regulations.

- *Environmental Protection (Controlled Waste) Regulations 2004* - these Regulations place obligations on you if you produce, accept, transport or dispose of controlled waste.

- *Environmental Protection (Noise) Regulations 1997* – these Regulations require noise emissions from the Premises to comply with the assigned noise levels set out in the Regulations.

You must comply with your licence. Non-compliance with your licence is an offence and strict penalties exist for those who do not comply.

Licence holders are also reminded of the requirements of section 53 of the Act which places restrictions on making certain changes to prescribed premises unless the changes are in accordance with a works approval, licence, closure notice or environmental protection notice.

Licence fees

If you have a licence that is issued for more than one year, you are required to pay an annual licence fee prior to the anniversary date of issue of your licence. Non payment of annual licence fees will result in your licence ceasing to have effect meaning that it will no longer be valid and you will need to apply for a new licence for your Premises.

Ministerial conditions

If your Premises has been assessed under Part IV of the Act you may have had conditions imposed by the Minister for Environment. You are required to comply with any conditions imposed by the Minister.

Premises description and Licence summary

The St Ives Gold Mine (SIGM) is located approximately 8 km south of Kambalda and operated by St Ives Gold Mining Company Pty Ltd (St Ives). Mining operations on Lake Lefroy are licenced under L8485/2010/2 and approved under Ministerial Statement 879. SIGM ore is currently mined from four underground mines, three open pits and 10 surface stockpiles and processed at the Lefroy Mill.

Groundwater in the area is in the range of 50,000 to 300,000 mg/L total dissolved salts (TDS) with groundwater quality in the vicinity of Lake Lefroy ranging between 274,000 to 423,000 mg/L TDS and metal levels reflective of the mineralogy in the region. Mining operations are both land and lake based, where the latter operations are based on Lake Lefroy, a salt lake covering an area of 544 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 & Moore 1999).

Dewatering activities at SIGM have previously been assessed by DER as presenting a low risk to the environment as groundwater mineralogy presents similar characteristics to the lake bed. The OEPA noted that Lake Lefroy is a hypersaline salt lake that generally has low levels of aquatic life and does not experience a freshwater phase. However, it is considered that the riparian zone, playas and clay pans that surround the lake are important in terms of providing habitat for aquatic biota and supporting the ecological function of the area. To minimise any further disturbance to the lake, dewatering pipelines are not bunded and telemetry and trigger alarms are used to assist in detecting leaks.

The main impacts associated SIGM are associated with discharges to land from tailings storage facilities (TSFs). Due to the high salinity of groundwater, mounding around TSFs presents a significant risk to native vegetation. Standing water levels around TSF4 have the potential to rise above the root zone of nearby native vegetation as a result of a recent 2.5 m lift authorised under Works Approval W5795/2015/1, which is expected to increase the hydraulic pressure on entrained water within TSF4 when further tailings are discharged to the facility. Therefore DER has made changes to the Licence to allow for the implementation of further seepage management measures to recover rising groundwater. The use of TSF4 as a primary tailings disposal option is only expected to continue for a short duration until the Leviathan In-pit TSF comes online in the third quarter of 2016.

An amendment was issued in June 2016 to improve conditions relating to mine dewater discharges to surface water and groundwater within Lake Lefroy in a bid to reduce the regulatory requirement for St

Ives to apply for future Licence amendments where the environmental risks of similar dewatering proposals have already been assessed as low. This coincides with St Ives application to relocate North Orchin In-Pit TSF decant water from Thunderer Pit to Bellerophon Pit to allow for the safe mining of Neptune Pit, directly adjacent to Thunderer Pit.

Approval to commence mining/dewatering at Delta Island South is required from the Office of Environmental Protection Authority with an amendment to Ministerial Statement 879. Therefore the current amendment does not authorise the dewatering of Delta Island South and the premises boundary remains unchanged.

The current amendment is to include the Leviathan in-pit TSF which was assessed under Works Approval W5858/2015/1. Before the final amendment for the Leviathan in-pit TSF was issued, SIGM submitted a second application for an amendment to dispose of some asbestos containing material (ACM) within the South Delta Open Pit. This matter is also addressed in the current amendment.

The licences and works approvals issued for the Premises since 01/10/2013 are:

Instrument log		
Instrument	**Issued**	**Description**
W5724/2014/1	15/09/2014	Mine dewatering at Invincible Project
W5583/2014/1	03/04/2014	Construction of TSF3
W5547/2013/1	06/02/2014	Mine dewatering at Idough Project Area
W5558/2013/1	30/01/2014	Mine dewatering at Swiftsure Project
W5557/2013/1	27/01/2014	Mine dewatering at Redback Project Area
W5497/2013/1	14/11/2013	Mine dewatering at Argo/Athena/Hamlet Complex
L8485/2010/2	03/10/2013	Licence re-issue
L8485/2010/2	08/01/2015	Licence amendment to new format and to extend dewatering operations to Invincible Pit
L8485/2010/2	06/08/2015	Licence amendment to expand the dewatering network
L8485/2010/2	11/02/2016	Licence amendment to reduce WWTP monitoring requirements and to authorise the discharge of tailings and return water to the newly lifted TSF4.
L8485/2010/2	17/03/2016	Licence amendment to change the dewatering configuration
L8485/2010/2	16/06/2016	Licence amendment to relocate North Orchin In-Pit TSF decant water from Thunderer Pit to Bellorophon Pit and to improve conditions relating to mine dewater discharges to surface water and ground water within Lake Lefroy.
L8485/2010/2	13/10/2016	Licence amendment to include the Leviathan in-pit TSF following compliance with works approval W5858/2015/1.

Severance
It is the intent of these Licence conditions that they shall operate so that, if a condition or a part of a condition is beyond the power of this Licence to impose, or is otherwise *ultra vires* or invalid, that condition or part of a condition shall be severed and the remainder of these conditions shall nevertheless be valid to the extent that they are within the power of this Licence to impose and are not otherwise *ultra vires* or invalid.

END OF INTRODUCTION

Licence conditions

1 General

1.1 Interpretation

1.1.1 In the Licence, definitions from the *Environmental Protection Act 1986* apply unless the contrary intention appears.

1.1.2 For the purposes of this Licence, unless the contrary intention appears:

ó**Act**ô means the *Environmental Protection Act 1986;*

ó**anniversary date**ô means 31 December of each year;

ó**annual audit compliance report**ô means a report in a format approved by the CEO as presented by the Licensee or as specified by the CEO from time to time and published on the Department's website;

óannual periodô means a 12 month period commencing from 1 January until 31 December in the same year;

óasbestosô means the asbestiform variety of mineral silicates belonging to the serpentine or amphibole groups of rock-forming minerals and includes actinolite, amosite, anthophyllite, chrysolite, crocidolite, tremolite and any mixture containing 2 or more of those;

óasbestos fibresô has the meaning defined in the Guideline for Assessment, Remediation and Management of Asbestos Contaminated Sites, Western Australian, (DOH 2009);

óAS/NZS 2031ô means the Australian Standard AS/NZS 2031 *Selection of containers and preservation of water samples for microbiological analysis;*

óAS/NZS 5667.1ô means the Australian Standard AS/NZS 5667.1 *Water Quality – Sampling – Guidance of the Design of sampling programs, sampling techniques and the preservation and handling of samples;*

óAS/NZS 5667.4ô means the Australian Standard AS/NZS 5667.4 *Water Quality – Sampling – Guidance on sampling from lakes, natural and man-made;*

óAS/NZS 5667.10ô means the Australian Standard AS/NZS 5667.10 *Water Quality – Sampling – Guidance on sampling of waste waters;*

óAS/NZS 5667.11ô means the Australian Standard AS/NZS 5667.11 *Water Quality – Sampling – Guidance on sampling of groundwaters;*

óAS/NZS 5667.12ô means the Australian Standard AS/NZS 5667.12 Water Quality – Sampling – Guidance on sampling of bottom sediments;

óaveraging period’ means the time over which a limit is measured or a monitoring result is obtained;

óCEOô means Chief Executive Officer of the Department of Environment Regulation;

óCEOô for the purpose of correspondence means;

> Chief Executive Officer
> Department Div. 3 Pt. V EP Act
> Locked Bag 33 Cloisters Square
> PERTH WA 6850
> Email: info@der.wa.gov.au;

ócfu/100 mLô means colony forming units per 100 millilitres;

óclean fillô has the meaning defined in Landfill Definitions;

ódepartmentô means the department established under s.35 of the Public Sector Management Act and designated as responsible for the administration of Division 3 Part V of the *Environmental Protection Act 1986*.

ófreeboardô means the distance between the maximum water surface elevations and the top of retaining banks or structures at their lowest point;

óHazardous wasteô has the meaning defined in Landfill Definitions;

óInert Waste Type 1ô has the meaning defined in Landfill Definitions;

óInert Waste Type 2ô has the meaning defined in Landfill Definitions;

“**Landfill Definitions**” means the document titled “Landfill Waste Classification and Waste Definitions 1996” published by the Chief Executive Officer of the Department of Environment as amended from time to time;

“**Licence**” means this Licence numbered L8485/2010/2 and issued under the Act;

“**Licensee**” means the person or organisation named as Licensee on page 1 of the Licence;

“**mbgl**” means metres below ground level;

“**mRL**” means metres Relative Level or, height above a standardised 'mean sea level' datum;

“**NATA**” means the National Association of Testing Authorities, Australia;

“**NATA accredited**” means in relation to the analysis of a sample that the laboratory is NATA accredited for the specified analysis at the time of the analysis;

“**Premises**” means the area defined in the Premises Map in Schedule 1 and listed as the Premises address on page 1 of the Licence;

“**quarterly**” means the 4 inclusive periods from 1 January to 31 March, 1 April to 30 June, 1 July to 30 September and 1 October to 31 December;

“**Schedule 1**” means Schedule 1 of this Licence unless otherwise stated;

“**Schedule 2**” means Schedule 2 of this Licence unless otherwise stated;

“**six monthly**” means the 2 inclusive periods from 1 January to 30 June and 1 July to 31 December in the following year;

“**Special Waste Type 1**” has the meaning defined in Landfill Definitions;

“**spot sample**” means a discrete sample representative at the time and place at which the sample is taken;

“**Stage 1**” means construction of dewatering infrastructure for Temeraire Pit;

“**Stage 2**” means construction of dewatering infrastructure for Intrepide Pit;

“**Stage 3**” means construction of dewatering infrastructure for A5 Pit;

“**Stage 4**” means construction of the turkeys nest and connecting dewatering pipeline infrastructure from Foster Shaft;

“**tipping area**” means the area of the landfill in which waste other than cover material is being deposited;

“**TSF**” means tailings storage facility;

“**turkey’s nest**” means a settlement dam that receives dewater and is lined with a geotextile fabric that allows dewater to permeate through to Lake Lefroy;

“**USEPA**” means United States (of America) Environmental Protection Agency;

“**usual working day**” means 0800 – 1700 hours, Monday to Friday excluding public holidays in Western Australia;

“**WWTP**” means the wastewater treatment plants located at Cave Rocks (P1) and Lefroy Admin (P2), Leviathan (P3), Argo (P4) and Athena Paste (P5) sites as depicted in Schedule 1; and

ázone of influenceô means the area of a receiving environment with the potential to be altered or changed as a result of an emission or discharge.

1.1.3 Any reference to an Australian or other standard in the Licence means the relevant parts of the standard in force from time to time during the term of this Licence.

1.1.4 Any reference to a guideline or code of practice in the Licence means the version of that guideline or code of practice in force from time to time, and shall include any amendments or replacements to that guideline or code of practice made during the term of this Licence.

1.2 Premises operation

1.2.1 The Licensee shall ensure that all pipelines containing saline dewatering effluent, tailings or return water are either:
(a) equipped with telemetry systems and pressure sensors along pipelines to allow for the detection of leaks and failures; or
(b) equipped with automatic cut-outs in the event of a pipe failure; or
(c) provided with secondary containment sufficient to contain any spill for a period equal to the time between routine inspections.

1.2.2 The Licensee shall ensure that any saline dewatering effluent shall only be managed in the following manner:
(a) used for dust suppression in a manner that minimises damage to surrounding vegetation;
(b) discharged to previously mined pits; or
(c) discharged to Lake Lefroy at discharge points defined in Schedule 1.

1.2.3 The Licensee shall ensure that tailings, decant water, dewater effluent and sewage are only discharged into containment cells, ponds and enclosed tanks with the relevant infrastructure requirements and at the locations specified in Table 1.2.1 and identified in Schedule 1.

Table 1.2.1: Containment infrastructure

Containment point reference	Containment cell or dam number(s)	Material	Infrastructure requirements
C1	TSF2	Tailings	Lined with low permeability materials to limit seepage to groundwater
C2	TSF3		
C3	TSF4	Tailings	Lined with low permeability materials to limit seepage to groundwater TSF built to a height no greater than 311.5 mRL
C4	TSF3 Decant Water Pond	Decant Water	Lined with at least 0.5m of clay with a permeability of <10^{-7} m/s or equivalent
C5	TSF1 Decant Water Pond		
C6	TSF4 Decant Water Pond	Decant Water and recovered water from TSF4-11A, TSF-11B, TSF12A, TSF12B, TSF4-16, TSF4-20A, TSF4-21, TSF4-22A and TSF4-24	
C7 and C8	Processing pond for Lefroy Mill	Ore, TSF decant water, process chemicals	Lined with a geotextile liner to limit seepage to groundwater

C9	Processing pond for the Heap Leach Facility	Ore, process chemicals	Lined with an HDPE liner
C10	Leviathan complex in-pit TSF – Leviathan pit	Tailings	A two metre freeboard to be maintained
C11	Leviathan complex in-pit TSF – Paddy's pit		
C12	Leviathan complex in-pit TSF – Britannia pit		
C13	Leviathan complex in-pit TSF – Sirius pit		
C14	Leviathan complex in-pit TSF – Britannia Footwall pit		
P1 to P5	WWTPs	Sewage	Closed tank system

1.2.4 The Licensee shall manage containment cells in Table 1.2.1 such that:
- (a) a minimum top of embankment freeboard of 300 mm (except for C10 – C14) or a 1 in 100 year/72 hour storm event (whichever is greater) is maintained; and
- (b) methods of operation minimise the likelihood of erosion of the embankments by wave action.

1.2.5 The Licensee shall manage TSFs such that:
- (a) a seepage collection and recovery system is provided and used to capture seepage from the TSF;
- (b) seepage is returned to the TSF or re-used in process;
- (c) the supernatant pond on the TSF is minimised as far as practicable.

1.2.6 The Licensee shall:
- (a) undertake inspections as detailed in Table 1.2.2;
- (b) where any inspection identifies that an appropriate level of environmental protection is not being maintained, take corrective action to mitigate adverse environmental consequences as soon as practicable; and
- (c) maintain a record of all inspections undertaken.

Table 1.2.2: Inspection of infrastructure

Scope of inspection	Type of inspection	Frequency of inspection
Tailings pipelines	Visual integrity	8 hourly
Return water lines	Visual integrity	8 hourly
Embankment freeboard	Visual to confirm required freeboard capacity is available	8 hourly
Tailings deposition	Visual to confirm that tailings are deposited evenly around the TSF	Daily
Ponding on the surface of the TSF	Visual to confirm ponding is not concentrated on TSF internal embankments	Daily
External walls of TSF	Visual to confirm no visible seepage is apparent	Daily
Borefield pipelines and pump stations	Visual integrity	Every two days

1.2.7 The Licensee shall undertake an annual assessment of vegetation within the zone of influence of TSF 4. The assessment shall:

(a) photograph and record the presence and condition of key vegetation features within the zone of influence;
(b) compare the results of the assessment against previous years assessments and identify whether any deterioration in the presence and/or quality of vegetation has taken place; and
(c) be undertaken by a person suitably qualified in vegetation identification and sampling.

1.2.8 The Licensee shall undertake an annual water balance for TSF 4. The water balance shall as a minimum consider the following:
(a) site rainfall;
(b) evaporation;
(c) decant water recovery volumes;
(d) seepage recovery volumes; and
(e) volumes of tailings deposited.

1.2.9 The Licensee shall only allow waste to be accepted on to the Premises if:
(a) it is of a type listed in Table 1.2.3; and
(b) the quantity accepted is below any limit listed in Table 1.2.3; and
(c) it meets any specification listed in Table 1.2.3

Table 1.2.3: Waste acceptance		
Waste	**Quantity Limit**	**Specification**[1]
WWTPs		
Sewage	Cumulative total for all WWTPs of 220 m^3/day	Accepted through sewer inflows only
Landfill		
Clean Fill	None	None Specified
Inert Waste Type 1	1,000 tonnes	Waste containing visible asbestos or ACM shall not be accepted.
Inert Waste Type 2		Scrap metal, tyres and plastic only
Putrescible waste		None specified
Special Waste Type 1	None – generated in-situ	Only to be disposed of into designated asbestos disposal area within South Delta Open Pit

Note 1: Additional requirements for the acceptance of controlled waste are set out in the *Environmental Protection (Controlled Waste) Regulations 2004.*

1.2.10 The Licensee shall ensure that where waste does not meet the waste acceptance criteria set out in condition 1.2.9 it is removed from the Premises by the delivery vehicle or, where that is not possible, the Licensee shall contact the CEO to agree a course of action in relation to the waste.

1.2.11 The Licensee shall ensure that the wastes accepted onto the Premises are only subjected to the process(es) set out in Table 1.2.4 and in accordance with any process requirements described in that table.

Table 1.2.4: Waste processing		
Waste type	**Process**	**Process requirements**
Sewage	Physical, biological and chemical treatment	Treatment of sewage waste shall not exceed 200 m^3/day cumulative volume.
Sewage sludge	Disposal	Removed by a licensed controlled waste carrier
All	Disposal of waste by landfilling	The separation distance between the base of the landfill and the highest groundwater level shall not be less than 2m.

Clean Fill	Receipt, handling and storage prior to disposal	Stockpile clean fill to allow for the covering of waste for at least two weeks.
Inert Waste Type 1		Placed into landfill trenches
Inert Waste Type 2		Tyres to be incorporated into waste rock material.
Putrescibles waste	Disposal	Covered with a minimum of 200 mm clean fill at least weekly.
Hazardous waste	Receipt, handling and storage prior to disposal	Must be stored in a bunded area/container prior to disposal offsite.
Special Waste Type 1	Disposal	Asbestos or ACM is covered with a layer of dense, inert and incombustible material at least 1 metre thick.

1.2.12 The Licensee shall manage the landfilling activities to ensure:
(a) the size of the tipping face is kept to a minimum and not larger than 30 m by 30 m;
(b) waste is levelled and compacted to ensure all faces are stable and capable of retaining rehabilitation material;
(c) waste is covered as soon as possible after it is discharged and not later than by the end of the working day; and
(d) rehabilitation of a cell or phase takes place within 6 months after disposal in that cell or phase has been completed.

1.2.13 The Licensee shall take all reasonable and practical measures to ensure that no windblown waste escapes from the Premises and that windblown waste is collected on at least a weekly basis and appropriately contained.

1.2.14 The Licensee shall ensure that no waste is burnt on the Premises.

1.2.15 The Licensee shall manage the irrigation of treated wastewater such that:
(a) treated wastewater is evenly distributed over the irrigation area;
(b) no soil erosion occurs;
(c) irrigation does not occur on land that is waterlogged; and
(d) vegetation cover is maintained over the irrigation area.

1.2.16 The Licensee shall manage the wastewater treatment vessels such that there is no discernible seepage loss from the vessels.

1.2.17 The Licensee shall construct and/or relocate dewatering infrastructure within the licenced premises as operational demands require in accordance with conditions of this Licence.

2 Emissions

2.1 General

2.1.1 The Licensee shall record and investigate the exceedance of any descriptive or numerical limit specified in any part of section 2 of this Licence.

2.2 Point source emissions to air

2.2.1 The Licensee shall ensure that where waste is emitted to air from the emission points in Table 2.2.1 and identified on the map of emission points in Schedule 1 it is done so in accordance with the conditions of this Licence.

Table 2.2.1: Emission points to air			
Emission point reference and location on Map of emission points	**Emission Point**	**Emission point height (m)**	**Source, including any abatement**
A1	Stack 1	2.69	Carbon regeneration stack
A2	Stack 2	13.28	Gold smelting furnace stack

2.3 Point source emissions to surface water

2.3.1 The Licensee is permitted, subject to conditions in the Licence, to emit wastes to water from the emissions points listed in Table 2.3.1 and identified in the Map of emission points in Schedule 1.

Table 2.3.1: Emission points to surface water		
Emission point reference and location on Map of emission points	**Description**	**Source including abatement**
W1, W2, W3, W4, W6, W7, W9, W10, W11, W12, W13 and W14	Mine dewater	Mine dewater to Lake Lefroy from mine voids located within Lake Lefroy[1]. Mine dewater to Lake Lefroy from land-based pits; A5, Africa, Cave Rocks, Foster, Hamlet, West and Idough. Prior to discharge mine dewater must be settled in a turkey's nest lined with a geotextile fabric designed to filter sediment.
W5	Mine dewater	Mine dewater from Bellerophon Pit, Africa Pit and the Leviathan Complex[2] to Lake Lefroy via pipework and/or channels. Prior to discharge mine dewater must be settled in a turkey's nest lined with a geotextile fabric designed to filter sediment.
W8	Mine dewater	Mine dewater from Athena underground mine, Apollo Pit and Argo Pit to Lake Lefroy via the Argo Hydroslide and two settling ponds

Note 1: Includes any mine voids, with the exception of Thunderer Pit, located on or within Lake Lefroy clay pans, saltpans and/or playas
Note 2: The Leviathan Complex consists of Leviathan Pit, Paddys Pit, Sirius Pit, Sirius/Orion Pit, Britannia Pit and Britannia Footwall Pit

2.3.2 The Licensee must cease the dewatering of Bellerophon Pit to Lake Lefroy upon the receipt of decant water from Thunderer Pit.

2.3.3 The Licensee shall not cause or allow point source emissions to surface water that do not meet the limits listed in Table 2.3.2.

Table 2.3.2: Point source emission limits to surface water			
Emission point reference	**Parameter**	**Limit (including units)**	**Averaging period**
W1, W2, W3, W4, W5, W6, W7, W8, W9, W10 W11, W12, W13 and W14	pH[1]	Between 6.0 and 8.0	N/A

2.4 Point source emissions to groundwater

2.4.1 The Licensee shall ensure that where waste is emitted to groundwater from the emission points in Table 2.4.1 and identified on the map of emission points in Schedule 1 it is done so in accordance with the conditions of this Licence.

Table 2.4.1: Point source emissions to groundwater		
Emission point reference and location	**Description**	**Source including abatement**
Africa Pit and mine voids located within Lake Lefroy[1]. Includes discharges to nearby transfer dams associated with each pit.	Dewater from active mining voids to disused mining voids	Mine voids located within the Lake Lefroy[1,2]
Thunderer Pit	Decant water	North Orchin In-Pit TSF
Bellerophon Pit		Thunderer Pit
Africa Pit		Bellerophon Pit, Leviathan Pit, Leviathan underground, Britannia Pit, Brittania underground, Sirius Pit and Sirius underground
Argo Pit		Apollo Pit, Diana Pit and Athena Boxcut
Apollo Pit		Argo Pit

Note 1: Includes any mine voids, with the exception of Thunderer Pit, located on or within Lake Lefroy clay pans, saltpans and/or playas
Note 2: Dewatering of Bellerophon Pit to Lake Lefroy must cease after the receipt of decant water from Thunderer Pit.

2.5 Emissions to land

2.5.1 The Licensee shall ensure that where waste is emitted to land from the emission points in Table 2.5.1 and identified on the map of emission points in Schedule 1 it is done so in accordance with the conditions of this Licence.

Table 2.5.1: Emissions to land		
Emission point reference and location on Map of emission points	**Description**	**Source including abatement**
P1, P2, P3, P4 and P5	Discharge from irrigation pump station to on-site irrigation areas	Treated wastewater from Cave Rocks, Lefroy Admin, Leviathan, Argo and Athena Paste Sewage Treatment Plants.

2.6 Fugitive emissions

2.6.1 The Licensee shall ensure that fugitive emissions are managed in accordance with the documents, or parts of documents, specified in Table 2.6.1.

Table 2.6.1: Dust Management Plan		
Management Plan Reference	**Parts**	**Date of Document**
St Ives Gold Mine Dust Environmental Procedure (SIG-ENV-PR029	Section 3	01/06/2005

3 Monitoring

3.1 General monitoring

3.1.1 The licensee shall ensure that:
- (a) all water samples are collected and preserved in accordance with AS/NZS 5667.1;
- (b) all wastewater sampling is conducted in accordance with AS/NZS 5667.10;
- (c) all surface water sampling is conducted in accordance with AS/NZS 5667.4, AS/NZS 5667.6 or AS/NZS 5667.9 as relevant;
- (d) all groundwater sampling is conducted in accordance with AS/NZS 5667.11;
- (e) all sediment sampling is conducted in accordance with AS/NZS 5667.12;
- (f) all microbiological samples are collected and preserved in accordance with AS/NZS 2031; and
- (g) all laboratory samples are submitted to and tested by a laboratory with current NATA accreditation for the parameters being measured unless indicated otherwise in the relevant table.

3.1.2 The Licensee shall ensure that :
- (a) monthly monitoring is undertaken at least 15 days apart;
- (b) quarterly monitoring is undertaken at least 45 days apart;
- (c) six monthly monitoring is undertaken at least 5 months apart; and
- (d) annual monitoring is undertaken at least 9 months apart.

3.1.3 The Licensee shall, where the requirements for calibration cannot be practicably met, or a discrepancy exists in the interpretation of the requirements, bring these issues to the attention of the CEO accompanied with a report comprising details of any modifications to the methods.

3.2 Monitoring of point source emissions to surface water

3.2.1 The Licensee shall undertake the monitoring in Table 3.2.1 according to the specifications in that table and record and investigate results that do not meet any limit specified.

Table 3.2.1: Monitoring of point source emissions to surface water

Emission point reference	Parameter	Units	Averaging Period	Frequency
W1, W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13 and W14	Volumetric flow rate (cumulative)	L/s m^3/day	Monthly	Continuous
	pH[1]	N/A	Spot sample	Quarterly

Note 1: In-field non-NATA accredited analysis permitted.

3.3 Monitoring of emissions to land

3.3.1 The Licensee shall undertake the monitoring in Table 3.3.1 according to the specifications in that table.

Table 3.3.1: Monitoring of emissions to land

Monitoring point reference and location	Process description	Parameter	Units	Averaging period	Frequency
P1, P2, P3, P4 and P5	Discharge from WWTPs to irrigation fields	*E.coli*	cfu/100 mL	Spot sample	Annually
		pH[1]	N/A		

		Biochemical Oxygen Demand	mg/L		
		Total Nitrogen			
		Total Phosphorus			
		Total Suspended Solids			
		Total Dissolved Solids			
		Ammonium-nitrogen			
		Nitrate+nitrate-nitrogen			

Note 1: In-field non-NATA accredited analysis permitted.

3.4 Monitoring of inputs and outputs

3.4.1 The Licensee shall undertake the monitoring in Table 3.4.1 according to the specifications in that table.

Table 3.4.1: Monitoring of inputs and outputs

Input/Output	Monitoring point reference	Parameter	Units	Averaging period	Frequency
Sewage - Inlet Flow	Inflow meter at P1, P2, P3, P4 and P5	Volumetric flow rate (cumulative)	m^3/day	Monthly	Continuous
Waste Inputs	N/A	Inert Waste Type 1, Inert Waste Type 2	m^3 (where no weighbridge is present)	Annual	Each load arriving at the Premises
Waste Outputs	N/A	Waste type as defined in the Landfill Definitions			Each load leaving or rejected from the Premises

3.5 Ambient environmental quality monitoring

3.5.1 The Licensee shall undertake the monitoring in Tables 3.5.1 and 3.5.2 according to the specifications in those tables and record and investigate results that do not meet any limit specified.

Table 3.5.1: Monitoring of ambient groundwater quality					
Monitoring point reference and location	**Parameter**	**Limit**	**Units**	**Averaging period**	**Frequency**
Heap leach facility bores: CD10114, CD10116, CD10118, CD9261, CD9263, CD9265, CD9267, CD9271 and CD9739 **TSF1:** CD5574 **TSF2:** SID580 **TSF3:** CD10100, CD10104, CD10110, CD10102 **TSF4:** TSF4-4A, TSF4-5A, TSF4-6A, TSF4-7A, TSF4-8A and TSF4-9A **North Orchin TSF:** NOMB09, NOMB02d, NOMB03 d, NOMB04 d **Leviathan in-pit TSF** LEVMB01, LEVMB02, LEVMB03, LEVMB04S and LEVMB05	Standing water level	4	mbgl	Spot sample	Quarterly
TSF4: TSF4-11A, TSF4-11B	Standing water level	4	mbgl	Spot sample	Monthly
TSF4: TSF4-12A, TSF4-12B	Standing water level	4	mbgl	Spot sample	Monthly
TSF4: TSF4-13A, TSF4-13B, TSF4-14A	Standing water level	N/A	mbgl	Spot sample	Monthly
Heap leach facility bores: CD10114, CD10116, CD10118, CD9261, CD9263, CD9265, CD9267, CD9271 and CD9739 **TSF1:** CD6194, CD5574 **Leviathan in-pit TSF** LEVMB01, LEVMB02, LEVMB03, LEVMB04S and LEVMB05	pH[1]	Between 3.0 and 9.0	N/A	Spot sample	Six monthly Quarterly – Leviathan in-pit TSF bores
	Weak Acid Dissociable Cyanide	0.5 mg/L	mg/L		
	Electrical Conductivity	N/A	µS/cm		
	Total Dissolved Solids		mg/L		
	Aluminium				
	Arsenic				
	Calcium				
	Cadmium				
	Chlorine				
	Chromium				
	Chromium (III)				
	Chromium (VI)				
	Cobalt				
	Copper				
	Iron				
	Lead				
	Mercury				
	Magnesium				
	Manganese				
	Nickel				
	Potassium				
	Selenium				
	Sodium				
	Strontium				
	Vanadium				

	Zinc				
TSF2: SID580, SID597, CD2538 **TSF3:** CD10099, CD10105, CD10110, CD10102 **TSF4:** TSF4-4A, TSF4-5A, TSF4-7A, TSF4-9A, TSF4-11A, TSF4-12A, TSF4-13B, TSF4-21, TSF4-24 **North Orchin TSF:** NOMB09	pH[1]	Between 3.0 and 9.0	N/A	Spot sample	Quarterly
	Weak Acid Dissociable Cyanide	N/A	µS/cm		
	Electrical Conductivity		mg/L		
	Total Dissolved Solids				
	Aluminium				
	Arsenic				
	Calcium				
	Cadmium				
	Chlorine				
	Chromium				
	Chromium (III)				
	Chromium (VI)				
	Cobalt				
	Copper				
	Iron				
	Lead				
	Mercury				
	Magnesium				
	Manganese				
	Nickel				
	Potassium				
	Selenium				
	Sodium				
	Strontium				
	Vanadium				
	Zinc				

Note 1: In-field non-NATA accredited analysis permitted.

Table 3.5.2: Monitoring of ambient sediment quality

Monitoring point reference and location	Parameter	Units	Averaging Period	Frequency
W1, W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13 and W14	pH[1]	N/A	Spot sample	Annually in the same month
	Aluminium	mg/L		
	Arsenic			
	Beryllium			
	Cadmium			
	Copper			
	Chromium			
	Cobalt			
	Iron			
	Lead			
	Mercury			
	Manganese			
	Nickel			
	Selenium			
	Vanadium			
	Zinc			

Note 1: In-field non-NATA accredited analysis permitted.

4 Information

4.1 Records

4.1.1 All information and records required by the Licence shall:
- (a) be legible;
- (b) if amended, be amended in such a way that the original and subsequent amendments remain legible or are capable of retrieval;
- (c) except for records listed in 5.1.1(d) be retained for at least 6 years from the date the records were made or until the expiry of the Licence or any subsequent licence; and
- (d) for those following records, be retained until the expiry of the Licence and any subsequent licence:
  - (i) off-site environmental effects; or
  - (ii) matters which affect the condition of the land or waters.

4.1.2 The Licensee shall ensure that:
- (a) any person left in charge of the Premises is aware of the conditions of the Licence and has access at all times to the Licence or copies thereof; and
- (b) any person who performs tasks on the Premises is informed of all of the conditions of the Licence that relate to the tasks which that person is performing.

4.1.3 The Licensee must submit to the CEO within 90 days after the Anniversary Date, an Annual Audit Compliance Report indicating the extent to which the Licensee has complied with the Conditions in this Licence for the Annual Period.

4.1.4 The Licensee shall implement a complaints management system that as a minimum records the number and details of complaints received concerning the environmental impact of the activities undertaken at the Premises and any action taken in response to the complaint.

4.2 Reporting

4.2.1 The Licensee shall submit to the CEO an Annual Environmental Report within 90 calendar days after the end of the annual period. The report shall contain the information listed in Table 4.2.1 in the format or form specified in that table.

Table 4.2.1: Annual Environmental Report		
Condition or table (if relevant)	**Parameter**	**Format or form[1]**
-	Summary of any failure or malfunction of any pollution control equipment and any environmental incidents that have occurred during the annual period and any action taken	None specified
4.1.4	Complaints summary	None specified
1.2.7	Borefield pipeline log of seepage, spills or leaks	
1.2.8	Annual vegetation monitoring around TSF4	
1.2.9	Annual water balance for TSF4	
2.6.1	Measures taken to suppress dust	
Table 3.2.1	Monitoring of point source emissions to surface waters	WR1
Table 3.3.1	Monitoring of emissions to land	LR1
	Contaminant loading (total annual loading kg/yr and kg/ha/yr) to land of parameters monitored in Table 3.3.1 (except pH and E.coli)	None specified
Table 3.4.1	Monitoring of inputs and outputs	None specified
Table 3.5.1	Monitoring of ambient groundwater quality	AGWQ1
Table 3.5.2	Monitoring of ambient sediment quality	None specified

Note 1: Forms are in Schedule 2

4.2.1 The Licensee shall ensure that the Annual Environmental Report also contains:
(a) an assessment of the information contained within the report against previous monitoring results and Licence limits; and
(b) a Dewatering Discharge Report.

4.2.2 The Dewatering Discharge Report required by condition 4.2.2 (b) shall address the environmental effects of mine dewater discharge to the Lake Lefroy environment and include but not limited to:
(a) cumulative discharge volumes;
(b) a map depicting dewater source locations and discharge points to Lake Lefroy; and
(c) methods/infrastructure used to prevent environmental impacts at each discharge location

4.3 Notification

4.3.1 The Licensee shall ensure that the parameters listed in Table 5.3.1 are notified to the CEO in accordance with the notification requirements of the table.

Table 5.3.1: Notification requirements

Condition or table (if relevant)	Parameter	Notification requirement[1]	Format or form[2]
2.1.1	Breach of any limit specified in the Licence	Part A: As soon as practicable but no later than 5pm of the next usual working day. Part B: As soon as practicable	N1
3.1.5	Calibration report	As soon as practicable.	None specified

Note 1: Notification requirements in the Licence shall not negate the requirement to comply with s72 of the Act
Note 2: Forms are in Schedule 2

4.3.2 The Licencee shall submit a compliance document to the CEO, following the construction of each of Stage 1, Stage 2, Stage 3 and Stage 4 of the works and prior to commissioning of the same.

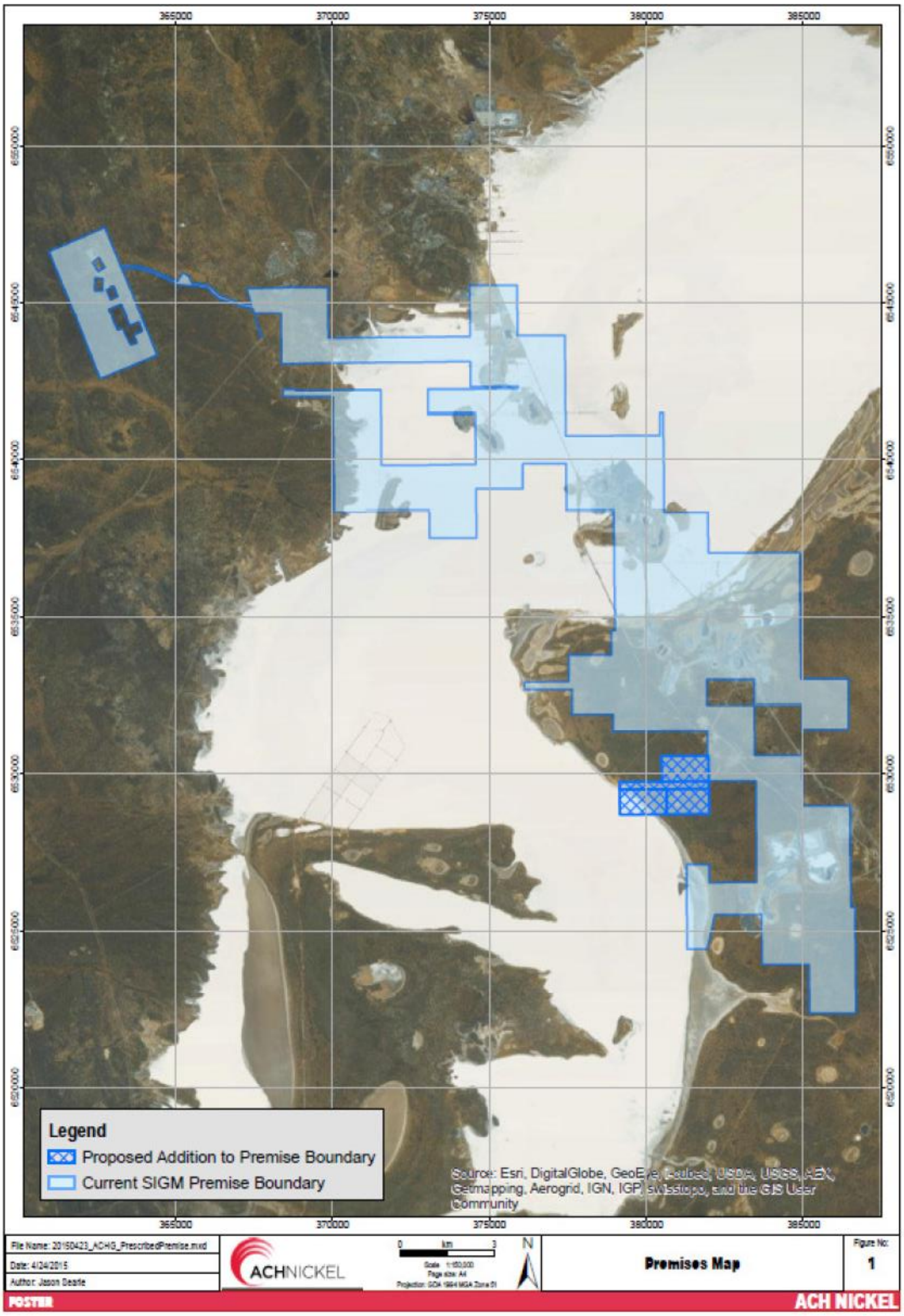
4.3.3 The compliance document shall:
(a) certify that the works were constructed in accordance with the conditions of the Licence;
(b) be signed by a person authorised to represent the Licensee and contain the printed name and position of that person within the company.

Government of **Western Australia**
Department of **Environment Regulation**

Schedule 1: Maps

Premises map

The Premises is shown in the map below. The blue line depicts the Premises boundary.



Premises tenement list

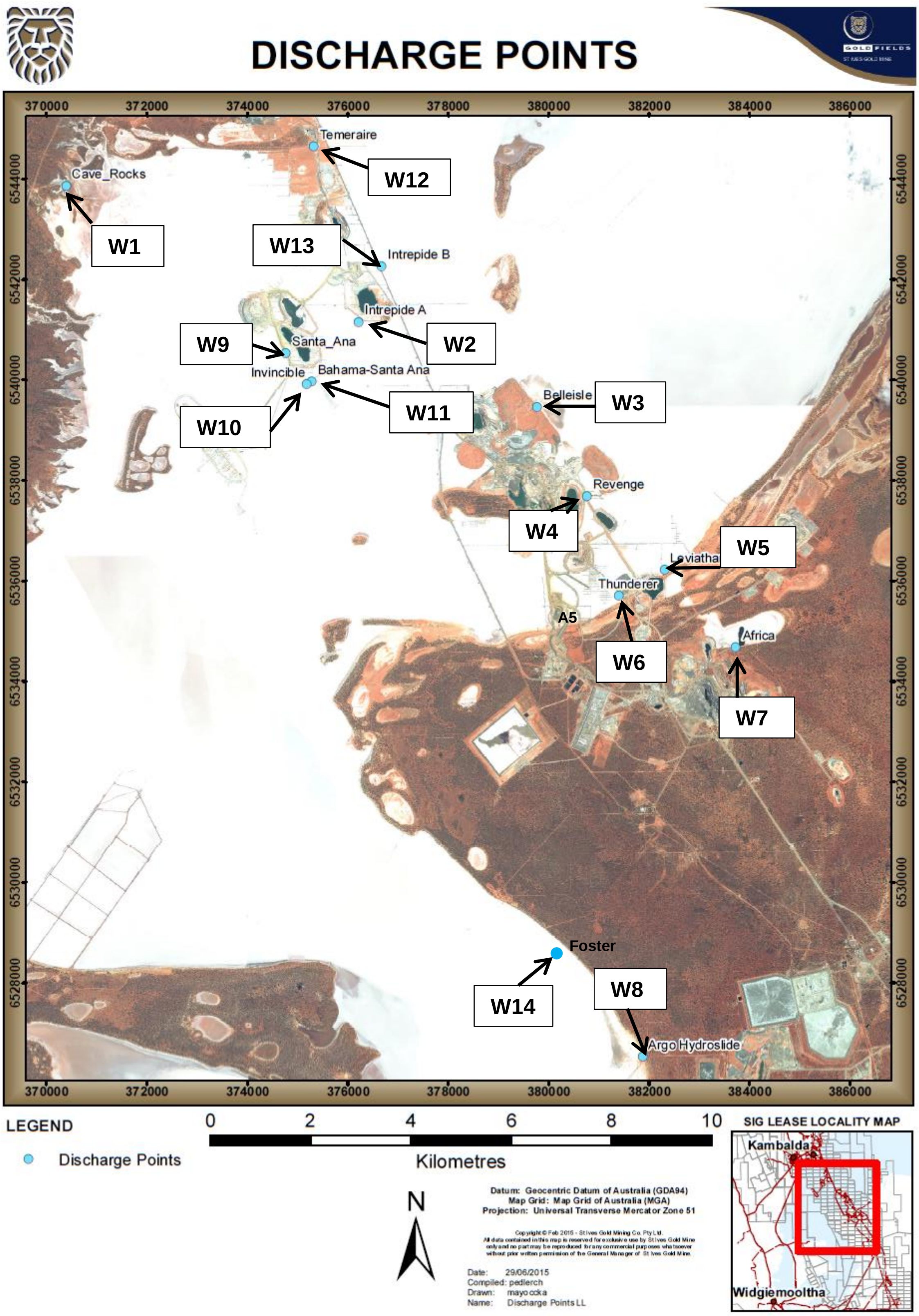
The Premises boundary is defined by the tenements listed in the table below:

St Ives Gold Mining Pty Ltd				
L15/214	M15/1544	M15/1579	M15/1629	M15/1695
M15/300	M15/1546	M15/1580	M15/1630	M15/1698
M15/476	M15/1549	M15/1581	M15/1631	M15/1699
M15/1226	M15/1550	M15/1590	M15/1632	M15/1702
M15/1495	M15/1556	M15/1591	M15/1633	M15/1703
M15/1496	M15/1559	M15/1593	M15/1634	M15/1802
M15/1503	M15/1560	M15/1594	M15/1657	
M15/1509	M15/1561	M15/1607	M15/1658	
M15/1513	M15/1562	M15/1608	M15/1659	
M15/1516	M15/1564	M15/1610	M15/1664	
M15/1517	M15/1565	M15/1611	M15/1668	
M15/1518	M15/1566	M15/1612	M15/1669	
M15/1527	M15/1567	M15/1614	M15/1670	
M15/1531	M15/1568	M15/1615	M15/1673	
M15/1532	M15/1570	M15/1618	M15/1675	
M15/1537	M15/1572	M15/1619	M15/1687	
M15/1540	M15/1573	M15/1622	M15/1690	
M15/1541	M15/1575	M15/1623	M15/1692	
M15/1542	M15/1576	M15/1627	M15/1693	
M15/1543	M15/1578	M15/1628	M15/1694	

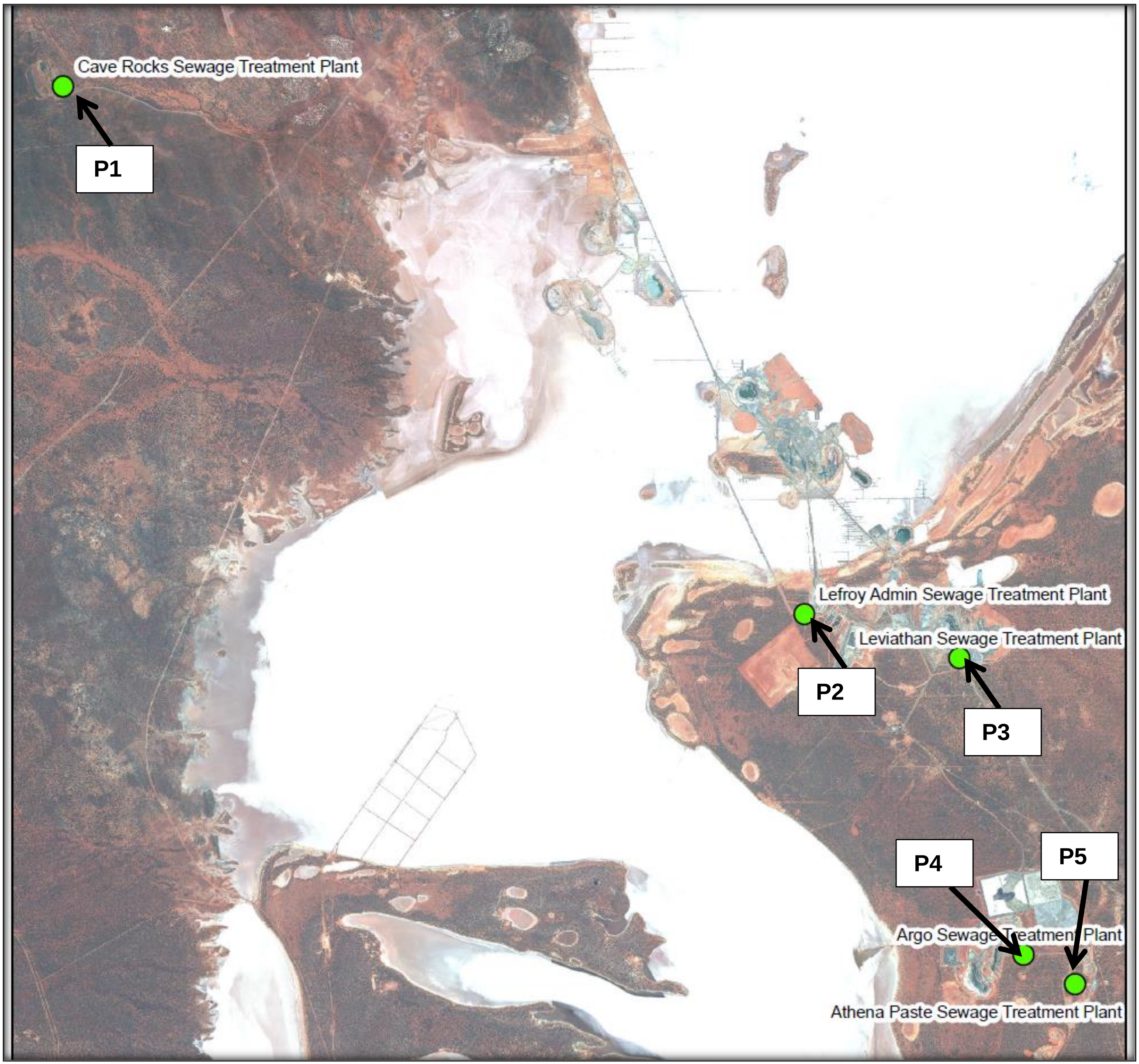
Map of emission and monitoring points

The locations of the emission points defined in Table 2.2.1 are shown below.

The locations of the emission points defined in Tables 2.3.1, 2.3.2 and 2.4.1 are shown below. These locations also indicate the monitoring points defined in Table 3.5.2.

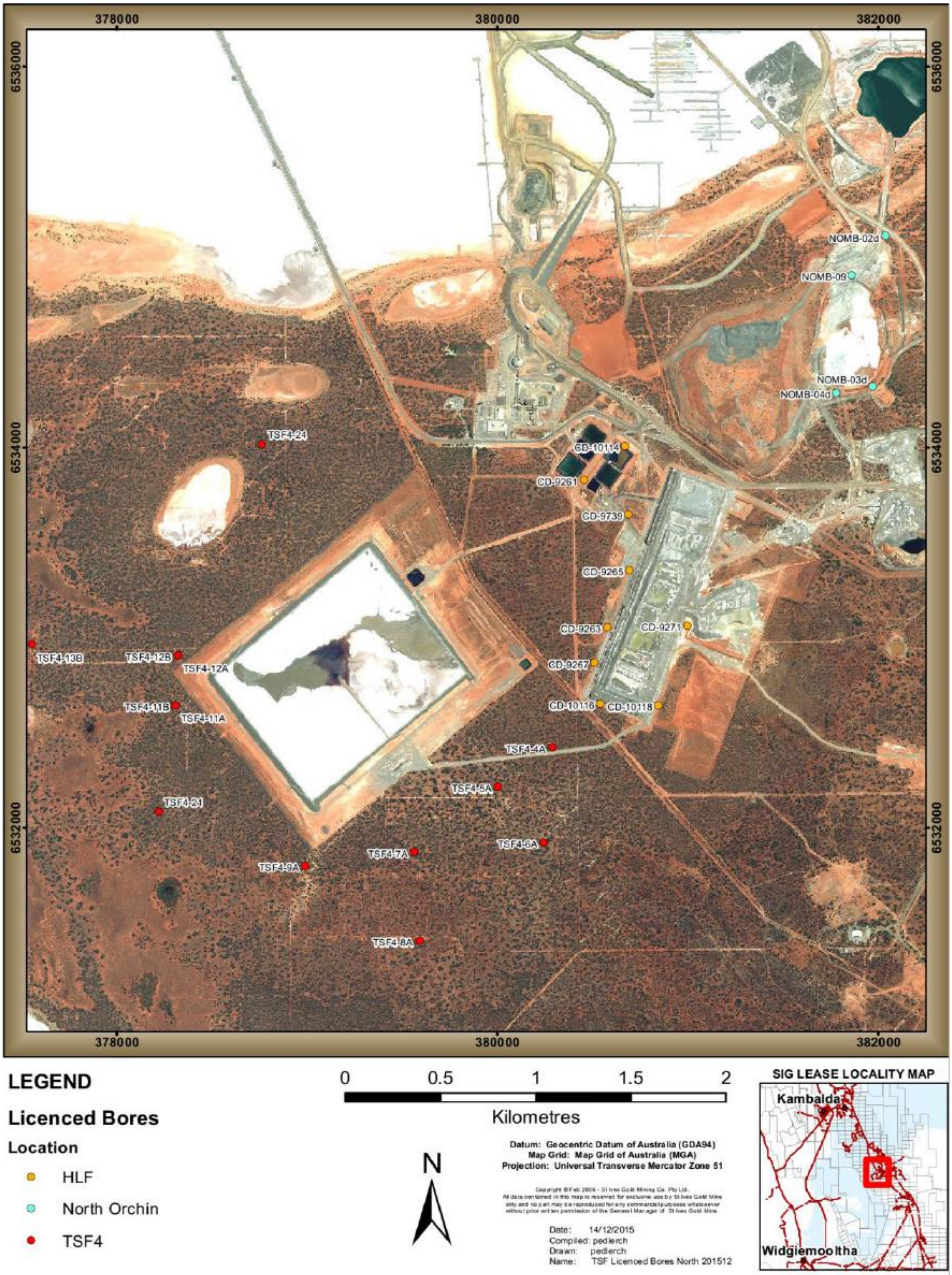


The locations of the emission points defined in Tables 1.2.4, 2.5.1 and 3.4.1 are shown below.



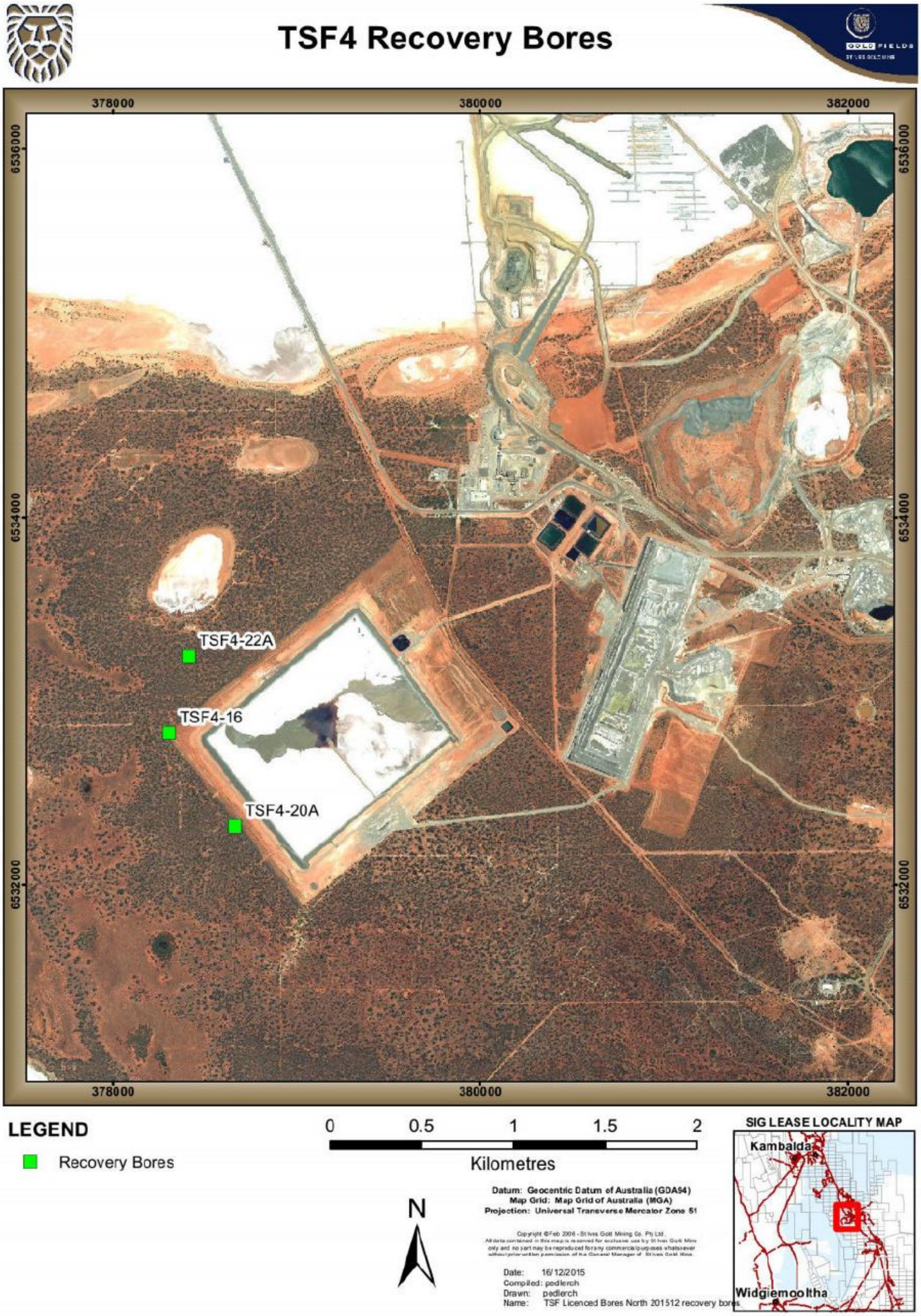
Map of monitoring locations

The locations of the monitoring points defined in Tables 3.5.1 are shown below. Dual monitoring and recovery bores TSF4-21 and TSF4-24 shown below are also defined in Table 1.2.1



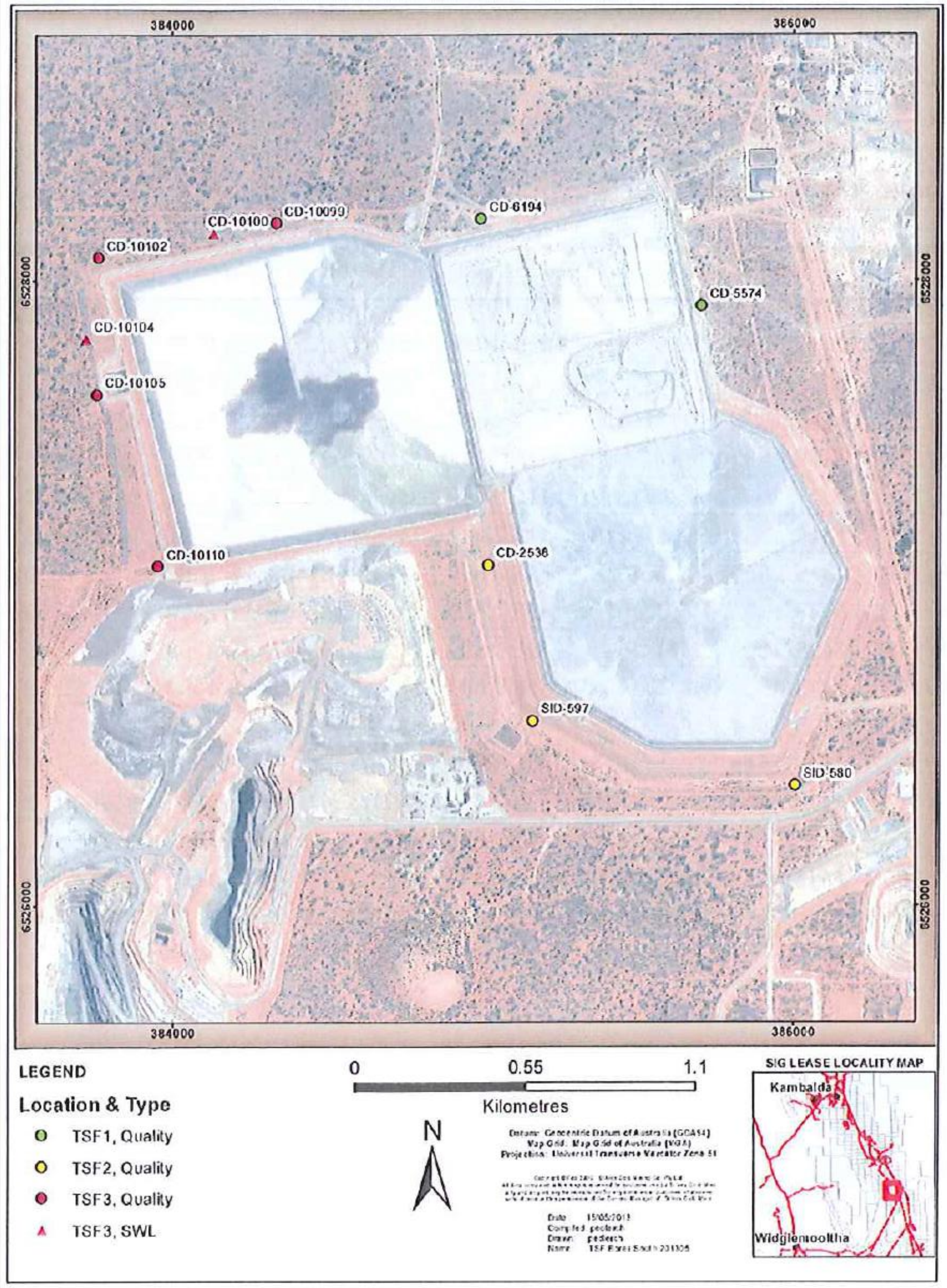
Map of recovery bores

The locations of the seepage recovery bores defined in Table 1.2.1 are shown below.



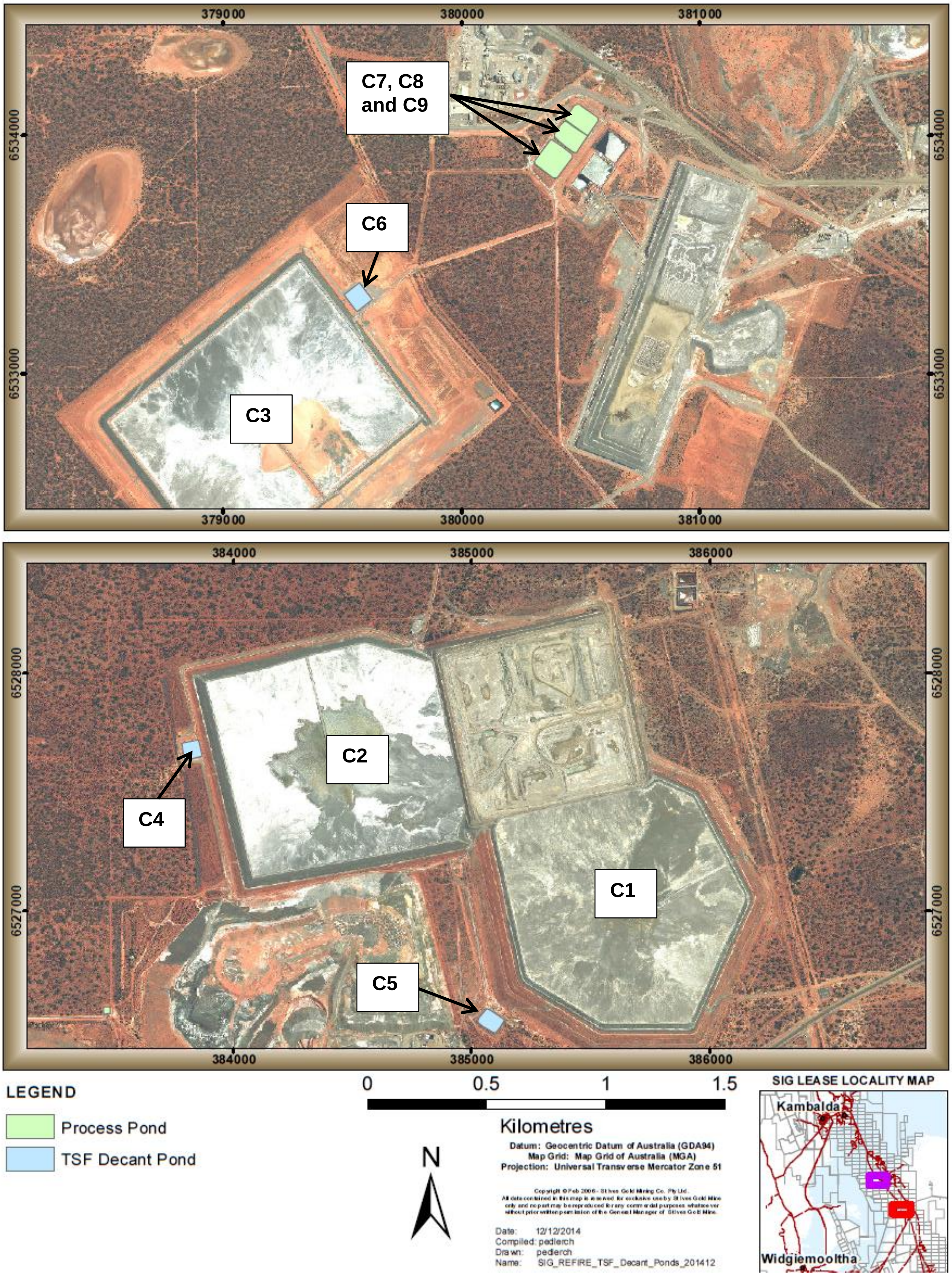
Map of monitoring locations

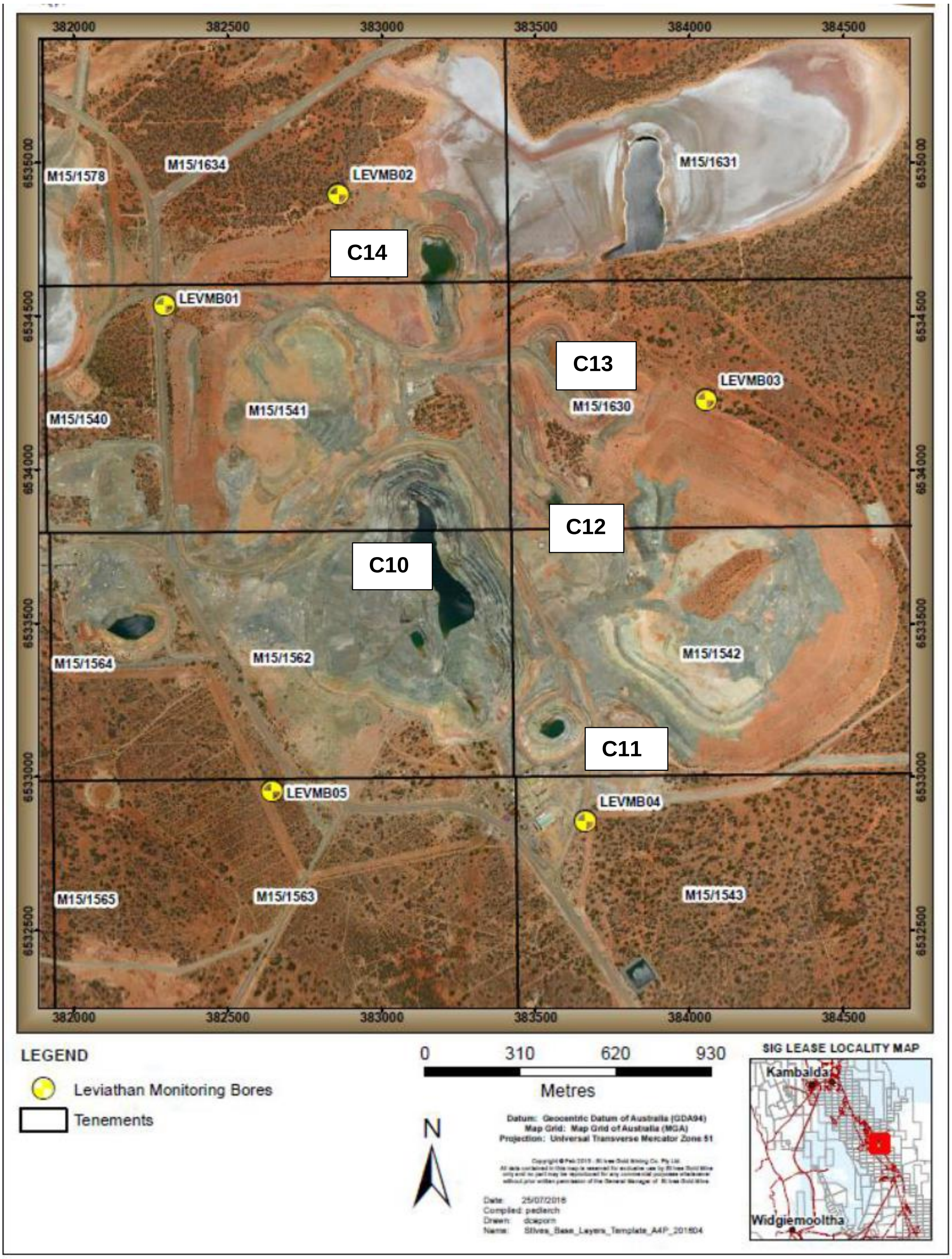
The locations of the monitoring points defined in Tables 3.5.1 are shown below.



Map of storage locations

The location of the storage areas defined in Table 1.2.1 is shown below.




382000
382500
383000
383500
384000
384500
6535000
6534500
6534000
6533500
6533000
6532500
M15/1578
M15/1634
LEVMB02
M15/1631
C14
LEVMB01
C13
LEVMB03
M15/1630
M15/1540
M15/1541
C12
C10
M15/1564
M15/1562
M15/1542
C11
LEVMB05
LEVMB04
M15/1565
M15/1563
M15/1543
LEGEND
Leviathan Monitoring Bores
Tenements
0
310
620
930
Metres
N
SIG LEASE LOCALITY MAP
Kambalda
Widgiemooltha

Schedule 2: Reporting and notification forms

These forms are provided for the proponent to report monitoring and other data required by the Licence. They can be requested in an electronic format.

The Annual Audit Compliance Report template is available on the Department's website.

Licence: L8485/2010/2 Licensee: St Ives Gold Mining Company Pty Ltd
Form: WR1 Period:
Name: Monitoring of point source emissions to surface water

Form WR1: Monitoring of point source emissions to surface water						
Emission point	**Parameter**	**Limit**	**Result[1]**	**Averaging Periods**	**Method**	**Sample date & times**
W1, W2, W3, W4, W5, W6, W7, W8, W9, W10 and W11	Volumetric flow rate	N/A	m^3/s	Spot sample		
	pH	Between 6.0 and 8.0		Spot sample		

Signed on behalf of St Ives Gold Mining Company Pty Ltd: ………………………………………..
Date: …………………….

Licence: L8485/2010/2 Licensee: St Ives Gold Mining Company Pty Ltd
Form: LR1 Period:
Name: Monitoring of emissions to land

Form LR1: Monitoring of emissions to land

Emission point	Parameter	Result	Load (kg/d)	Averaging Periods	Method	Sample date & times
P1 to P5	Volumetric flow rate	kL		Continuous		
	E.coli	cfu/100mL		Spot sample		
	pH[1]	N/A		Spot sample		
	Biochemical Oxygen Demand	mg/L	kg/d	Spot sample		
	Total Nitrogen	mg/L	kg/d	Spot sample		
	Total Phosphorus	mg/L	kg/d	Spot sample		
	Total Suspended Solids	mg/L	kg/d	Spot sample		
	Total Dissolved Solids	mg/L	kg/d	Spot sample		
	Ammonium-nitrogen	mg/L	kg/d	Spot sample		
	Nitrate+nitrate-nitrogen	mg/L	kg/d	Spot sample		

Signed on behalf of St Ives Gold Mining Company Pty Ltd: ………………………………………..
Date: …………………….

Government of **Western Australia**
Department of **Environment Regulation**

Licence: L8485/2010/2 Licensee: St Ives Gold Mining Company Pty Ltd
Form: AGWQ Period :
Name: Ambient groundwater quality monitoring

Form AGQW1: Monitoring of ambient groundwater quality							
Monitoring point	**Parameter**	**Limit**	**Result**	**Result**	**Averaging period**	**Method**	**Sample date & times**
	Standing water level		mbgl				
	pH[1]		N/A				
	Electrical Conductivity		µS/cm				
	Total Dissolved Solids		mg/L				
	Aluminium		mg/L				
	Arsenic		mg/L				
	Calcium		mg/L				
	Cadmium		mg/L				
	Chlorine		mg/L				
	Chromium		mg/L				
	Chromium (III)		mg/L				
	Chromium (VI)		mg/L				
	Cobalt		mg/L				
	Copper		mg/L				
	Iron		mg/L				
	Lead		mg/L				
	Mercury		mg/L				
	Magnesium		mg/L				

	Manganese		mg/L				
	Nickel		mg/L				
	Potassium		mg/L				
	Selenium		mg/L				
	Sodium		mg/L				
	Strontium		mg/L				
	Vanadium		mg/L				

Signed on behalf of St Ives Gold Mining Company Pty Ltd: ………………………………………..
Date: …………………….

Licence:	L8485/2010/2	Licensee:	St Ives Gold Mining Company Pty Ltd
Form:	N1	Date of breach:	

Notification of detection of the breach of a limit.

These pages outline the information that the operator must provide.
Units of measurement used in information supplied under Part A and B requirements shall be appropriate to the circumstances of the emission. Where appropriate, a comparison should be made of actual emissions and authorised emission limits.

Part A

Licence Number	
Name of operator	
Location of Premises	
Time and date of the detection	

Notification requirements for the breach of a limit	
Emission point reference/ source	
Parameter(s)	
Limit	
Measured value	
Date and time of monitoring	
Measures taken, or intended to be taken, to stop the emission	

Part B

Any more accurate information on the matters for notification under Part A.	
Measures taken, or intended to be taken, to prevent a recurrence of the incident.	
Measures taken, or intended to be taken, to rectify, limit or prevent any pollution of the environment which has been or may be caused by the emission.	
The dates of any previous N1 notifications for the Premises in the preceding 24 months.	

Name	
Post	
Signature on behalf of St Ives Gold Mining Company Pty Ltd	
Date	

Government of **Western Australia**
Department of **Environment Regulation**

Decision Document

Environmental Protection Act 1986, Part V

Proponent: St Ives Gold Mining Company Pty Ltd

Licence: L8485/2010/2

Registered office:	Level 5, 50 Colin Street WEST PERTH WA 6005
ACN:	098 386 273
Premises address:	St Ives Gold Mine Mining tenements as described in Schedule 1 KAMBALDA WA 6442
Issue date:	Thursday, 3 October 2013
Commencement date:	Monday, 7 October 2013
Expiry date:	Wednesday, 6 October 2021

Decision

Based on the assessment detailed in this document the Department of Environment Regulation (DER), has decided to issue an amended licence. DER considers that in reaching this decision, it has taken into account all relevant considerations and legal requirements and that the Licence and its conditions will ensure that an appropriate level of environmental protection is provided.

Decision Document prepared by:	Fiona Sharpe Licensing Officer
Decision Document authorised by:	Tim Gentle Delegated Officer

Contents

1 Purpose of this Document

This decision document explains how DER has assessed and determined the application and provides a record of DER's decision-making process and how relevant factors have been taken into account. Stakeholders should note that this document is limited to DER's assessment and decision making under Part V of the *Environmental Protection Act 1986.* Other approvals may be required for the proposal, and it is the proponent's responsibility to ensure they have all relevant approvals for their Premises.

2 Administrative summary

Administrative details		
Application type	Works Approval ☐ New Licence ☐ Licence amendment ☒ Works Approval amendment ☐	
Activities that cause the premises to become prescribed premises	**Category number(s)**	**Assessed design capacity**
	5	9,000,000 tonnes per annual period
	6	30,000,000 tonnes per annual period
	7	3,000,000 tonnes per annual period
	54	220 cubic metres per day
	64	1,000 tonnes per annual period
Application verified Application fee paid	Date: 16 August 2016 Date: 5 October 2016	
Works Approval has been complied with Compliance Certificate received	Yes☒ No☐ N/A☐ Yes☒ No☐ N/A☐	
Commercial-in-confidence claim	Yes☐ No☒	
Commercial-in-confidence claim outcome		

Is the proposal a Major Resource Project?	Yes☒ No☐	
Was the proposal referred to the Environmental Protection Authority (EPA) under Part IV of the *Environmental Protection Act 1986*?	Yes☒ No☐	Referral decision No: Managed under Part V ☐ Assessed under Part IV ☐
Is the proposal subject to Ministerial Conditions?	Yes☒ No☐	Ministerial statement No: 879 EPA Report No: 1493
Does the proposal involve a discharge of waste into a designated area (as defined in section 57 of the *Environmental Protection Act 1986*)?	Yes☐ No☒ Department of Water consulted Yes ☐ No ☒	
Is the Premises within an Environmental Protection Policy (EPP) Area Yes☐ No☒ If Yes include details of which EPP(s) here.		
Is the Premises subject to any EPP requirements? Yes☐ No☒ If Yes, include details here, eg Site is subject to SO_2 requirements of Kwinana EPP.		

3 Executive summary of proposal and assessment

The St Ives Gold Mine (SIGM) is located approximately 8 km south of Kambalda and operated by St Ives Gold Mining Company Pty Ltd (St Ives). Mining operations on Lake Lefroy are licenced under L8485/2010/2 and approved under Ministerial Statement 879. SIGM ore is currently mined from both underground mines and open pits with surface stockpiles processed via both mill/Carbon-In-Pulp (CIP) and heap leach plants.

Groundwater in the area is in the range of 50,000 to 300,000 mg/L total dissolved salts (TDS) with groundwater quality in the vicinity of Lake Lefroy ranging between 274,000 to 423,000 mg/L TDS and metal levels reflective of the mineralogy in the region. Mining operations are both land and lake based, where the latter operations are based on Lake Lefroy, a salt lake covering an area of 544 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 & Moore 1999).

W5858/2015/1 was issued in September 2015 for the development of Leviathan complex as a tailings storage facility (TSF) for the Lefroy Mill. The Leviathan complex consists of the current open-cut pits Leviathan, Paddy's, Britannia, Sirius and Britannia Footwall. The currently active TSF, TSF4, has shown signs of seepage with rising groundwater exceeding trigger levels on the Licence. The high salinity of rising groundwater around the facility presents a risk to surrounding native vegetation should groundwater intercept the root zone. It is estimated that Leviathan has 36,500,000 m^3 of capacity which would accommodate 10 years of tailings disposal and reduce the risk to vegetation.

The Project includes the following aspects:
- Construction of new monitoring bores around the Leviathan complex.
- Installation and commissioning of piping and pumping system for discharging tailings from the Lefroy Mill to the Leviathan complex.

- Installation and commissioning of piping and pumping system for recovering tailings supernatant (return water) from the Leviathan complex to mill process water tanks or mill return dams.

An amendment application to include the Leviathan in-pit TSF within the licence was submitted to DER in July 2016 with the compliance certificate for works approval W5858/2015/1 submitted to DER on 29 September 2016.

Before the final amendment for the Leviathan in-pit TSF was issued, SIGM submitted a second application for an amendment to dispose of some asbestos containing material (ACM) within the South Delta Open Pit. The two amendment applications have been combined in the current licence amendment.

4 Decision table

All applications are assessed in line with the *Environmental Protection Act 1986*, the *Environmental Protection Regulations 1987* and DER's Operational Procedure on Assessing Emissions and Discharges from Prescribed Premises. Where other references have been used in making the decision they are detailed in the decision document.

DECISION TABLE			
Licence section	**Condition number W = works approval L= licence**	**Justification (including risk description & decision methodology where relevant)**	**Reference documents**
Premises operation	L1.2.1, 1.2.3 – 1.2.6 L1.2.9	**Operation** Premises operation conditions on the existing Licence will be retained to manage tailings delivery pipelines, return pipelines and discharges to the TSF. Regular inspections, bunding and telemetry systems will ensure that any unintentional and unauthorised discharge is quickly identified to minimise impacts to the environment. **Operation** DER's assessment and decision making are detailed in Appendix A.	Application supporting documentation General provisions of the *Environmental Protection Act 1986*
Emissions general	L2.1.1	**Operation** The continued recording and investigation of limit exceedances will remain a requirement of the Licence.	General provisions of the *Environmental Protection Act 1986*
Point source emissions to air including monitoring	N/A	**Operation** No point source emissions to air are anticipated during the operation of the Leviathan In-pit TSF.	General provisions of the *Environmental Protection Act 1986*
Point source emissions to surface water including monitoring	N/A	**Operation** There are no anticipated point source emissions to surface water as a result of operation of the Leviathan In-pit TSF.	Application supporting documentation General provisions of the *Environmental Protection Act 1986*

DECISION TABLE			
Licence section	**Condition number W = works approval L= licence**	**Justification (including risk description & decision methodology where relevant)**	**Reference documents**
			Environmental Protection (Unauthorised Discharges Regulations, 2004).
Point source emissions to groundwater including monitoring	L2.4.1 and L3.5.1	**Operation** DER's assessment and decision making are detailed in Appendix A.	General provisions of the *Environmental Protection Act 1986*
Emissions to land including monitoring	L1.3.1	**Operation** The disposal of tailings to an in-pit TSF is not assessed as an emission to land. See section on point source emissions to groundwater. *Emission Risk Assessment – Pipeline leak or failure* Emission Description *Emission:* Discharge to the land of tailings or return water from a leaking/ruptured pipeline. Tailings and return water is characterised as alkaline, hypersaline with total dissolved solids ranging between 35,000 and 80,000 mg/L and having elevated weak acid dissociable cyanide concentrations (10 to 110 mg/L). *Impact:* Elevated salt and cyanide may cause land contamination and may damage or kill native vegetation. However the area between the Lefroy Mill and Leviathan In-pit TSF is heavily disturbed with little vegetation remaining. In addition, no known priority species or ecological communities have been identified in the vicinity of the proposed works. *Controls:* Leak detection telemetry will be installed on the pipeline to trigger an alarm should a variation in flow rates by more than 5% for 10 minutes or more than 10% for two minutes be detected. In addition, St Ives proposes to construct bunding around all pipelines and regularly inspect the pipeline route for leaks.	*Environmental Protection (Unauthorised Discharges Regulations, 2004).*

DECISION TABLE			
Licence section	**Condition number** **W = works approval** **L= licence**	**Justification (including risk description & decision methodology where relevant)**	**Reference documents**
		<u>Risk Assessment</u> *Consequence:* Minor *Likelihood*: Unlikely *Risk Rating:* Moderate <u>Regulatory Controls</u> Existing Licence conditions requiring regular inspections of pipelines and the operation of telemetry systems/bunding adequately control all pipelines transporting environmentally hazardous materials at SIGM. No further conditions are proposed for the Licence and therefore the residual risk remains unchanged.	
Fugitive emissions	L2.6.1	**Operation** Dust conditions have already been applied to the Licence to require St Ives to operate in accordance with the SIGM Dust Management Procedure (SIG-ENV-PR029), which is expected to adequately manage the generation of dust at SIGM. In addition, the proponent proposes to move a quantity of asbestos-containing materials currently stored on site and to dispose of the materials at the bottom of a disused mine pit. If not carried out correctly, moving and disposing of these materials could release asbestos fibres into the air. DER's assessment and decision making on this matter are detailed in Appendix B.	General provisions of the *Environmental Protection Act 1986*
Odour	N/A	**Operation** The deposition of tailings is not expected to generate significant odours and therefore no additional odour conditions will be added to the Licence.	General provisions of the *Environmental Protection Act 1986*
Noise	N/A	**Operation** Noise is likely to be generated by increased vehicle movements and earth	*Environmental Protection (Noise) Regulations 1997*

DECISION TABLE			
Licence section	**Condition number W = works approval L= licence**	**Justification (including risk description & decision methodology where relevant)**	**Reference documents**
		moving. However, noise is not anticipated to interfere with the amenity of the nearest human receptor during operation as they are located approximately 14 km away. No noise conditions have been applied to the Licence.	
Monitoring general	N/A	**Operation** General monitoring condition 3.1.1 will remain on the Licence to ensure that all samples are collected in accordance to the relevant Australian Standards and are submitted to a laboratory with NATA accreditation.	N/A
Monitoring of inputs and outputs	N/A	**Operation** No input or output monitoring will be included on the Licence as a result of the Leviathan In-pit TSF.	N/A
Process monitoring	N/A	**Operation** There are no specified conditions relating to process monitoring.	N/A
Ambient quality monitoring	L3.5.1	**Operation** Local groundwater contains elevated levels of TDS in the range of 150,000 to 250,000 mg/L. It is anticipated that the operation of the Leviathan In-pit TSF will result in some seepage. Although groundwater uses are limited as a result of high salinities, groundwater mounding has the potential to result in vegetation death in the event that mounding intercepts the root zone. Therefore groundwater monitoring conditions (including standing water level limits and notification requirements) will be applied to the five proposed monitoring bores situated around the Leviathan In-pit TSF.	Australian Standard AS/NZS 5667.1 – Water Quality Sampling – Guidance on the Design of sampling, programs, sampling techniques and the preservation and handling of sample.
Meteorological monitoring	N/A	**Operation** There are no meteorological monitoring requirements under this Licence.	N/A
Improvements	N/A	No improvements are required for the Licence in relation to the Leviathan In-pit TSF.	N/A
Information	L5.3.2	Table 5.2.3 will be updated to include the Leviathan In-pit TSF monitoring bores, requiring the notification of standing water levels rising above the limit of 6 metres below ground level.	N/A

DECISION TABLE			
Licence section	**Condition number W = works approval L= licence**	**Justification (including risk description & decision methodology where relevant)**	**Reference documents**
Works Approval Duration	N/A	The licence is valid until 6 October 2021. This has not been re-assessed during this amendment.	N/A

5 Advertisement and consultation table

Date	Event	Comments received/Notes	How comments were taken into consideration
15/9/2016	Proponent sent a copy of draft instrument	Comments received on the following points: • Table 1.2.3 – hydraulic conductivity requirement. • Bore LEV MB04 to be changed to LEV MB04S • Table 2.3.1 footnote had misspelling of Britannia Footwall	• The hydraulic conductivity of 10^{-7} to 10^{-9} m/s has been mis-interpreted from the works approval application documentation and is referring to the tailings characteristics and not the geology of the pits. It is therefore not justifiable to include this figure in the 'infrastructure requirement' column of the table. Construction of infrastructure is assessed through the works approval and compliance document. The risk assessment for seepage of the tailings is outlined in Appendix A and managed through other licence conditions. • Bore names changed. • Spelling corrected.
06/10/2016	Proponent sent a copy of revised draft instrument with above comments taken into consideration and with an additional amendment as applied for from the proponent to bury asbestos contaminated waste within the South Delta Open Pit.	Signed waiver form received with no further comments.	N/A

6 Risk Assessment

Note: This matrix is taken from the DER Corporate Policy Statement No. 07 - Operational Risk Management

Table 1: Emissions Risk Matrix

Likelihood	Consequence				
	Insignificant	Minor	Moderate	Major	Severe
Almost Certain	Moderate	High	High	Extreme	Extreme
Likely	Moderate	Moderate	High	High	Extreme
Possible	Low	Moderate	Moderate	High	Extreme
Unlikely	Low	Moderate	Moderate	Moderate	High
Rare	Low	Low	Moderate	Moderate	High

Appendix A

Premises Operation

Direct emissions to groundwater may occur from seepage through the base and walls of the in-pit TSF. Previous open-cut and underground mining within the Leviathan complex has required dewatering meaning that standing water levels are expected to rise naturally as the facility acts as a groundwater sink. Modelling suggests that a tailings plume entering the surrounding groundwater would not spread significantly beyond the underground mine footprint as groundwater is expected to flow into the pit or be directed to other nearby sinks such as North Orchin or Thunderer pits.

As groundwater surrounding the Leviathan In-pit TSF is hypersaline with a TDS concentration of on average 150,000 and 250,000 mg/L, it is unlikely that groundwater can support any stygofauna populations. However, the introduction of tailings to the Leviathan In-pit TSF has the potential to lead to rises in groundwater levels beyond what would be naturally occurring.

DER has reviewed St Ives' impact assessment for seepage risks from the TSF and is satisfied that the assessment provided by the proponent has been undertaken in an appropriate manner. DER has scrutinised the St Ives' proposal to ensure they adequately prevent and mitigate the impacts of seepage and is satisfied that appropriate controls will be adopted at the premises.

Emission Risk Assessment – Normal operation

Emission Description

Emission: Seepage from the Leviathan in-pit TSF resulting in groundwater mounding.

Impact: Rising standing water levels into the root zone of native vegetation is likely to result in significant vegetation death due to the high salt content of groundwater.

Controls: The disposal strategy will require rotation of the discharge points to different areas of the open pits to control the size and location of the supernatant pond. Settlement and management of tailings and water recovery will be aided by:

- relocating discharge points and creating new beaches;
- discharging tailings into the Britannia, Sirius, Britannia Footwall and Paddy's pits on a campaign basis, enabling operational pauses in tailings placement to the Leviathan pit, as required; and
- the prioritisation of return water usage at Lefroy Mill.

St Ives proposes to further reduce the risk of groundwater mounding above natural levels by incorporating a two metre freeboard. As the surrounding area of each pit of the Leviathan In-pit TSF is heavily disturbed, with no priority flora identified in the project area, the freeboard is expected to result in standing water levels falling below the root zone at the location of the nearest vegetation.

Risk Assessment

Consequence: Minor

Likelihood: Unlikely

Risk Rating: Moderate

Regulatory Controls

Existing standing water level monitoring (L3.5.1) and notification conditions (L5.3.2) on the Licence will incorporate the proposed bores around the Leviathan In-pit TSF. No further changes will be made to the Licence although DER will closely monitor standing water levels to ensure that the risk to local vegetation does not increase during tailings deposition to the Leviathan In-pit TSF.

Monitoring controls do not reduce the risk of environmental impact although they do serve as tools to trigger further mitigation measures if required. The proponent's commitment to a two metre freeboard has been formalised as a condition in Table 1.2.1.

Residual Risk
Consequence: Minor
Likelihood: Unlikely
Risk Rating: Moderate

Appendix B

Emission Description – Asbestos Containing Material

Emission: 7.8 km of pipework containing asbestos requires on-site disposal. A small number of asbestos buildings/huts as well as some asbestos containing material (ACM) found within the roof of the shed from the core farm also requires disposal. The Licensee has proposed to dispose of the ACM in the South Delta Open Pit. Once placed into the pit it would be submerged below the water level in the pit and will then be encapsulated with a capping of mine waste.

Impact: Asbestos has been identified as the causal agent in many lung diseases including cancers and often as a result of relatively low exposure. Exposure to the environment will not break down asbestos and any asbestos left onsite will continue to present a risk into the future. Public health risk arises if the fibres contaminate materials or areas where the public may be exposed to them.

Controls: The Licensee has implemented onsite controls to manage risks to workers. These include:
-handling all material in accordance with relevant legislative requirements;
-painting all exposed sections of ACM including degraded friable asbestos with a PVA based mixture to encapsulate loose fibres;
-remove any loose friable asbestos from exposed sections of pipe double bag for disposal in 200µm asbestos bags;
-spray sealing and coating of a PVA based mixture on exposed surfaces of pipe; and
-plastic-wrapping of all removed pipework.

The site is a remote minesite with the nearest town being Kambalda, located 8 km away. Onsite activities affecting mining employees are regulated by the Department of Mines and Petroleum (DMP) from a *Mines Safety and Inspection Regulations 1995* perspective due to asbestiform material onsite.

The main risk associated with the proposed burial of the ACM is associated with moving the materials to the pit for disposal. These risks will be regulated by DMP and are therefore not considered further here.

Risk Assessment
Consequence: Severe
Likelihood: Unlikely
Risk Rating: High

Regulatory Controls
The Licensee is required to comply with the following:

- DMP's Guideline on the *Management of fibrous minerals in Western Australian mining operations* (2015); and
- DoH Guidance Note on *Public Health Risk Management of Asbestiform Minerals Associated with Mining* (2013).

The Delegated Officer has assessed the risk and, given the distance to residential receptors and that moving the material will be regulated by DMP, has determined that disposal of the material into the pit as proposed is acceptable. The Licence will state through condition 1.2.9 (Table 1.2.3) that Special Waste Type 1 can be disposed into the designated area within South Delta Open Pit. Table 1.2.4 specifies the waste must be covered with a layer of dense, inert and incombustible material at least 1 metre thick.

Residual Risk
Once the ACMs are buried at the bottom of the pit they will no longer present any risk.

Appendix C Results of the Database Searches

Table C-1: Results of the database searches, relevant to Lake Lefroy.

Group	Family	Scientific Name	Common Name	Distance from St Ives	Conservation Code			
					DBCA (2017)	DBCA (2017)	DBCA (2017)	DEE (2017)
Bird	Apodidae	*Apus pacificus pacificus**	Fork-tailed Swift	<20 km	-	-	-	Threatened
Bird	Ardeidae	*Ardea modesta****	Great Egret	<20 km	-	-	-	Threatened
Bird	Ardeidae	*Ardea ibis****	Cattle Egret	<20 km	-	-	-	Threatened
Bird	Charadriidae	*Thinornis rubricollis*	Hooded Plover	<20 km	-	-	-	Threatened
Bird	Falconidae	*Falco peregrinus*	Peregrine Falcon	<20 km	S	-	-	-
Bird	Megapodiidae	*Leipoa ocellata*	Malleefowl	<20 km	T	-	-	Vulnerable
Bird	Motacillidae	*Motacilla cinerea***	Grey Wagtail	<20 km	-	-	-	Threatened
Bird	Psittaculidae	*Pezoporus occidentalis*	Night Parrot	<20 km	-	-	-	Endangered
Crustacean	Thamnocephalidae	*Branchinella apophysata*	-	n/a	-	P1	-	-
Crustacean	Thamnocephalidae	*Branchinella denticulata*	-	n/a	-	P1	-	-
Crustacean	Thamnocephalidae	*Branchinella simplex*	-	n/a	-	P1	-	-
Insect	Carabidae	*Cicindela (Rivacindela) salicursoria*	-	<20 km	Locally endemic	-	-	-
Insect	Colletidae	*Euhesma (Euhesma) atra*	-	<20 km	Locally endemic	-	-	-
Insect	Formicidae	*Amblyopone longidens*	-	<20 km	Locally endemic	-	-	-
Insect	Formicidae	*Myrmecia cephalotes*	-	<20 km	Locally endemic	-	-	-
Insect	Halictidae	*Lasioglossum (Chilalictus) amplexum*	-	<20 km	Locally endemic	-	-	-
Insect	Halictidae	*Lasioglossum (Chilalictus) greavesi*	-	<20 km	Locally endemic	-	-	-
Insect	Halictidae	*Lasioglossum (Chilalictus) triangulatum*	-	<20 km	Locally endemic	-	-	-
Insect	Lycosidae	*Pardosa pexa*	-	<20 km	Locally endemic	-	-	-
Insect	Miturgidae	*Diaprograpta peterandrewsi*	-	<20 km	Locally endemic	-	-	-
Mammal	Dasyuridae	*Dasyurus geoffroii*	Chuditch, Western Quoll	<20 km	T	-	-	-
Lichen	Parmeliaceae	*Xanthoparmelia dayiana*	-	<20 km	P3	-	-	-
Lichen	Parmeliaceae	*Xanthoparmelia fumigata*	-	<20 km	P1	-	-	-
Lichen	Parmeliaceae	*Xanthoparmelia kondininensis*	-	<20 km	P2	-	-	-
Lichen	Parmeliaceae	*Xanthoparmelia xanthomelanoides*	-	<20 km	P2	-	-	-
Plant	Amaranthaceae	*Ptilotus rigidus*	-	<20 km	P1	-	-	-
Plant	Araliaceae	*Trachymene pyrophila*	-	<20 km	P2	-	-	-
Plant	Asparagaceae	*Sowerbaea multicaulis*	Many Stemmed Lily	<20 km	P4	-	-	-
Plant	Asteraceae	*Cratystylis conocephala x microphylla*	-	<20 km	Locally endemic	-	-	-
Plant	Asteraceae	*Cratystylis sp.*	-	<20 km	Locally endemic	-	-	-

Group	Family	Scientific Name	Common Name	Distance from St Ives	Conservation Code			
					DBCA (2017)	DBCA (2017)	DBCA (2017)	DEE (2017)
Plant	Brassicaceae	*Phlegmatospermum eremaeum*	-	<20 km	P3	-	-	-
Plant	Casuarinaceae	*Allocasuarina eriochlamys subsp. grossa*	-	<20 km	P3	-	-	-
Plant	Chenopodiaceae	*Tecticornia flabelliformis*	Bead Glasswort	<20 km	P1	-	-	Vulnerable
Plant	Chenopodiaceae	*Tecticornia mellarium*	-	<20 km	P1	-	-	-
Plant	Cyperaceae	*Lepidosperma* sp. Kambalda	-	<20 km	Locally endemic	-	-	-
Plant	Fabaceae	*Acacia cylindrica*	-	<20 km	P3	-	-	-
Plant	Fabaceae	*Acacia dorsenna*	-	<20 km	P1	-	-	-
Plant	Fabaceae	*Gastrolobium graniticum*	Granite Poison	<20 km	-	-	-	Endangered
Plant	Goodeniaceae	*Lechenaultia pulvinaris*	Cushion Leschenaultia	<20 km	P4	-	-	-
Plant	Lamiaceae	*Dicrastylis reticulata*	-	<20 km	P3	-	-	-
Plant	Lamiaceae	*Pityrodia scabra subsp. dendrotricha*	-	<20 km	P3	-	-	-
Plant	Lamiaceae	*Prostanthera splendens*	-	<20 km	P1	-	-	-
Plant	Myrtaceae	*Cyathostemon divaricatus*	-	<20 km	P1	-	-	-
Plant	Myrtaceae	*Eucalyptus platydisca*	-	<20 km	T	-	-	-
Plant	Myrtaceae	*Eucalyptus websteriana subsp. norsemanica*	-	<20 km	P1	-	-	-
Plant	Myrtaceae	*Eucalyptus x brachyphylla*	-	<20 km	P4	-	-	-
Plant	Myrtaceae	*Melaleuca coccinea*	Goldfields Bottlebrush	<20 km	P3	-	-	-
Plant	Myrtaceae	*Verticordia dasystylis subsp. dasystylis*	-	<20 km	P2	-	-	-
Plant	Poaceae	*Austrostipa blackii*	-	<20 km	P3	-	-	-
Plant	Poaceae	*Austrostipa* sp. Carlingup	-	<20 km	P1	-	-	-
Plant	Portulacaceae	*Calandrinia* sp. Widgiemooltha	-	<20 km	P1	-	-	-
Plant	Proteaceae	*Grevillea phillipsiana*	-	<20 km	P1	-	-	-
Plant	Rutaceae	*Phebalium clavatum*	-	<20 km	P2	-	-	-
Plant	Rutaceae	*Philotheca apiculata*	-	<20 km	P2	-	-	-
Plant	Scrophulariaceae	*Diocirea acutifolia*	-	<20 km	P3	-	-	-
Plant	Scrophulariaceae	*Eremophila annosocaulis*	-	<20 km	P3	-	-	-
Plant	Scrophulariaceae	*Eremophila arachnoides subsp. tenera*	-	<20 km	P1	-	-	-
Plant	Scrophulariaceae	*Eremophila perglandulosa*	-	<20 km	P1	-	-	-
TEC / PEC	-	-	Lake Giles vegetation complexes	>200km	-	-	P1	-

*Note: *Migratory marine birds, **Migratory terrestrial species, ***Migratory wetlands species*

Appendix D Peripheral Wetlands Data

Data Source: (Stantec unpublished data 2017)

Table D1: Surface water quality data from the northern peripheral wetlands (September 2017), compared to ANZECC & ARMCANZ (2000) guideline trigger values for 80% protection of species in freshwaters (FW).

	Water Quality Parameters	North East CP01	North East CP02A	North East CP02B	ANZECC & ARMCANZ (2000) FW
Basic	pH (units)	9.36	9.61	9.01	-
	Total Dissolved Solids	194	226	212	-
	Electrical Conductivity (µS/cm)	300	312	333	-
Major Ions	Sodium	58	60	69	-
	Magnesium	5	5	6	-
	Potassium	3	2	3	-
	Calcium	2	2	4	-
	Bicarbonate	69	54	106	-
	Chloride	24	25	26	-
	Sulphate	6	6	6	-
	Carbonate	43	61	25	-
	Hydroxide	<1	<1	<1	-
Nutrients	Total Nitrogen	0.6	0.5	0.7	-
	Total Phosphorus	0.02	0.04	0.05	-
	Total Kjeldahl Nitrogen	0.6	0.5	0.7	-
	Nitrite + Nitrate	<0.01	<0.01	<0.01	-
Metals and Trace Elements	Aluminium	0.20	0.64	0.54	0.15
	Arsenic	0.002	0.002	0.002	0.36
	Barium	0.004	0.005	0.01	-
	Beryllium	<0.001	<0.001	<0.001	-
	Cadmium	<0.0001	<0.0001	<0.0001	0.0008
	Chromium	0.001	0.003	0.002	0.04
	Cobalt	<0.001	<0.001	<0.001	-
	Copper	0.003	0.005	0.005	0.0025
	Iron	0.13	0.38	0.34	-
	Lead	<0.001	<0.001	<0.001	0.0094
	Manganese	0.017	0.018	0.009	3.6
	Mercury	<0.0001	<0.0001	<0.0001	0.0019
	Nickel	0.003	0.005	0.006	0.017
	Selenium	<0.01	<0.01	<0.01	0.034
	Strontium	0.016	0.011	0.023	-
	Sulphur	2	2	2	-
	Vanadium	0.01	0.01	0.01	-
	Zinc	<0.005	<0.005	<0.005	0.031

Note: parameters presented in mg/L unless stated; orange highlighted cell indicates exceedance of ANZECC & ARMCANZ (2000) trigger value.

Table D2: Sediment quality data from the peripheral wetlands, based on analytical data (September and October 2017), compared to ANZECC & ARMCANZ (2000) guideline trigger values for interim sediment quality guidelines (ISQG).

Sediment Quality Parameters		September 2017 Survey			October 2017 Survey																ANZECC & ARMCANZ (2000) Triggers	
		NE CP01	NE CP02A	NE CP02B	CP01	CP02	CP03	CP06	CP8	CP9	CP10	CP11	CP13	CP17	CP14	CP18	CP20	CP16	CP21	CP22	ISQG-Low	ISQG-High
Basic	pH (units)	8.3	8.6	8.2	5.3	6.4	6.7	7.9	4.9	6.6	7	7.7	5.9	7.2	8.2	7.4	7.7	7	7.9	7.8	-	-
	Total Soluble Salts	190	326	482	95400	25100	73400	14600	16400	81900	66500	33500	69500	77700	91800	78600	65200	90800	11400	15400	-	-
	Moisture Content (%)	13.2	22.3	33.3	28.9	16.2	23.2	19.6	7.3	22.9	24.8	26.2	28.1	23.2	21.7	22.8	19.6	29.7	20	5.8	-	-
Nutrients	Total Nitrogen	70	90	780	220	170	820	220	40	100	210	700	220	220	760	260	280	270	170	250	-	-
	Total Phosphorus	121	162	145	214	141	194	88	49	62	32	311	172	46	229	168	111	121	116	175	-	-
	Total Kjeldahl Nitrogen	70	90	780	220	170	820	220	40	100	210	700	220	220	760	260	280	270	170	250	-	-
	Nitrite + Nitrate	<0.1	<0.1	<0.1	1.4	1	1.4	0.3	1	<0.1	0.2	0.2	0.5	3.7	0.1	0.2	1.7	0.3	0.2	2.7	-	-
Metals and Trace Elements	Aluminium	2750	5310	16000	24400	18500	18200	4290	14300	8920	4750	20000	19200	8190	20600	17200	15400	20400	8100	12900	-	-
	Arsenic	<5	<5	6	7	<5	8	<5	<5	<5	<5	6	6	9	9	13	12	19	6	7	20	70
	Barium	90	230	140	120	160	50	40	30	20	20	140	70	180	130	40	60	220	100	40	-	-
	Beryllium	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1	-	-
	Cadmium	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.5	10
	Chromium	228	353	257	111	126	178	34	95	61	44	175	94	125	185	212	234	254	123	132	80	370
	Cobalt	6	11	22	40	10	14	3	<2	19	5	10	6	6	12	15	21	13	15	11	-	-
	Copper	9	18	51	28	16	26	7	12	10	<5	26	25	18	34	32	28	24	23	23	65	270
	Iron	32000	62400	45300	21800	21000	31100	5210	16500	9800	6130	25900	17300	16300	27100	32200	35500	30200	17700	22300	-	-
	Lead	6	15	8	7	<5	8	<5	<5	<5	<5	7	<5	<5	9	9	11	10	13	8	50	220
	Manganese	261	809	774	411	142	437	44	23	159	29	345	70	87	350	607	560	306	318	789	-	-
	Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.15	1
	Nickel	39	71	96	66	29	62	12	7	71	14	46	53	32	69	78	80	70	68	54	21	52
	Selenium	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	-	-
	Silicon	526	38	26	30	27	24	19	18	13	12	21	29	11	8	9	10	10	16	20	-	-
	Vanadium	65	110	114	51	48	63	16	49	28	19	65	42	52	69	79	91	87	44	51	-	-
	Zinc	14	34	40	18	15	28	6	5	19	8	35	16	14	43	35	30	31	33	28	200	410

Note: parameters presented in mg/kg unless stated; NE = North East; yellow and orange highlighted cells indicate exceedance of ANZECC & ARMCANZ (2000) ISQG-Low and High trigger values, respectively.

Table D3: Phytoplankton recorded from the northern peripheral wetlands (September 2017).

Phytoplankton Taxa	Sites		
	NE CP01	NE CP02	NE CP20B
Bacillariophyceae			
Amphora coffeaeformis	●	●	●
Amphora veneta			●
Caloneis bacillum	●	●	●
Craticula ambigua		●	
Navicula cryptocephala	●	●	
Nitzschia palea		●●	●
Nitzschia sp. aff. *rostellata*	●	●	●
Nitzschia sp. SIGM01		●	●
Nitzschia sp. SIGM02		●	
Rhopalodia gibba		●	●
Chlorophyceae			
Ankistrodesmus spiralis	●	●	
Botryococcus braunii	●		
Closterium sp.	●	●●	●
Cosmarium granatum		●	●
Cosmarium quadrum	●	●	●
Cosmarium sp. SIGM01			●
Euastrum lacustre	●		
Euastrum spinulosum	●		●
Oedogonium sp.	●●●	●	●
Pleurotaenium sp.			●
Staurastrum gracile	●	●	●
Cyanophyceae			
Anabaena sp.	●●●	●	●
Phormidium sp.		●	
Planktolynbya sp.			●
Diversity	13	17	17

Note: NE=North East; ● = few, ●● = common, and ●●● =abundant.

Table D4: Benthic algae recorded from the peripheral wetlands, based on fresh collection (September 2017) and re-wetting trials (October 2017).

Diatom Taxa	September 2017			October 2017																	
	NE CP01	NE CP02A	NE CP02B	CP01	CP02	CP03	CP04	CP06	CP08	CP09	CP10	CP11	CP13	CP14	CP16	CP17	CP18	CP20	CP21	CP22	CP22
Bacillariophyceae																					
Amphora coffeaeformis	●●	●		●		●			●	●●	●				●	●		●	●		
Amphora fontinalis		●	●																		
Caloneis bacillum	●	●	●		●															●	
Craticula ambigua		●	●	●	●			●											●		
Hantzschia amphioxys		●																			●
Hantzschia distinctipuntata					●			●				●●●	●							●	
Hantzschia sp. aff. *baltica*				●		●			●		●			●●●				●			
*Hantzschia*sp. aff. *weyprechtii*											●				●						
Mastogloiapumila														●							
Mastogloiasmithii					●																
Navicula cryptocephala	●	●	●																		●
*Navicula*sp. aff. *cincta*										●											
Navicula sp. aff. *incertata*									●												
Navicula tenelloides						●										●			●		
Nitzschia closterium					●																
Nitzschia palea				●	●	●										●					
Nitzschia sp. aff. *rostellata*			●		●			●													
Nitzschia sp. SIGM01	●	●	●●																		
Pinnularia sp. aff. *intermedia*													●								
Rhopalodia gibba		●	●●																		
Chlorophyceae																					
Ankistrodesmus spiralis		●																			
Botryococcus braunii	●●	●																			
Bulbochaete sp.	●																				
Closterium sp.	●●	●	●●																		
Cosmarium granatum			●																		
Cosmarium quadrifarium	●	●	●																		
Cosmarium quadrum	●																				
Cosmarium sp. SIGM01	●		●																		
Euastrum lacustre	●●●	●	●																		
Euastrum spinulosum			●																		
Oedogonium sp.	●	●																			
Oocystis sp.	●																				
Pleurotaenium sp.			●																		
Staurastrum gracile	●	●	●●																		
Zygnema sp.	●																				
Cyanophyceae																					
Calothrix sp.							●							●							
Lyngbya sp.							●●														
Microcoleus sp.							●●●			●											●●●
Microcystis sp.	●●●				●																
Oscillatoria sp.																					●
Phormidium sp.					●			●●						●					●		

Diatom Taxa	September 2017			October 2017																	
	NE CP01	NE CP02A	NE CP02B	CP01	CP02	CP03	CP04	CP06	CP08	CP09	CP10	CP11	CP13	CP14	CP16	CP17	CP18	CP20	CP21	CP22	CP22
Planktolyngbya sp.																●					
Pseudanabaena sp.					●																
Spirulina sp.		●																			
Euglenophyceae																					
Phacus sp.						●		●													
Diversity	16	16	15	4	10	5	3	5	3	3	3	1	2	4	2	4	0	2	4	2	4

Note: ● = few, ●● =common, and ●●● =abundant.

Table D5: Diatoms recorded from the peripheral wetlands, based on fresh collection (September 2017) and re-wetting trials (October 2017).

Diatom Taxa	September 2017		October 2017															
	NE CP01	NE CP02	CP01	CP02	CP03	CP06	CP08	CP09	CP10	CP11	CP13	CP14	CP16	CP17	CP18	CP20	CP21	CP22
Achnanthidium duthiei					4									15				
Achnanthidium sp. SIGM01	1	1																
Amphora coffeaeformis	28	8	12		69		26	87	36				54	25		2	37	
Amphora fontinalis	27	10																
Amphora veneta	5	8															3	
Brachysira vitrea				42														
Caloneis bacillum	20	22																
Craticula ambigua			6	10	2	7				5		3						
Craticula cuspidata	1					1				1							1	
Cyclotella stelligera																		1
Gomphonema auritum		1																
Hantzschia amphioxys			8	1														
Hantzschia distinctepunctata		3		14		40				62		6						20
Hantzschia sp. aff. *baltica*			11		6		4	4				90	28			4		
Hantzschia sp. aff. *weyprechtii*			12										2					
Luticola mutica							3										1	6
Lutica nivalis																		1
Navicella pusilla							2		6							11	1	
Navicula crytocephala	12	18																
Navicula sp. aff. *arvensis*			2		1						1							
Navicula sp. aff. *cincta*								2										
Navicula sp. aff. *erifuga*	1																	2
Navicula sp. aff. *incertata*							65	3	11				16					
Navicula sp. aff. *salinicola*			11					4			60							
Navicula sp. 1 (LC2005)											3							
Navicula tenelloides			5		9					16							38	
Navicula tripunctata																	18	
Nitzschia ovalis									11						2			
Nitzschia palea	2	17	33	20	9	49				13				60		4	1	
Nitzschia sp. aff. *filiformis*						3												
Nitzschia sp. aff. *rostellata*	2																	
Nitzschia sp. aff. *sigma*										3								
Nitzschia sp. SIGM01	1	1																
Nitzschia subinflata									36		5							
Pinnularia gibba												1						
Pinnularia microstauron				13														
Pinnularia sp. aff. *intermedia*											31				4			

Diatom Taxa	September 2017		October 2017															
	NE CP01	NE CP02	CP01	CP02	CP03	CP06	CP08	CP09	CP10	CP11	CP13	CP14	CP16	CP17	CP18	CP20	CP21	CP22
Rhopalodia gibba		9																
Tryblionella levidensis		2																
Abundance	100	100	100	100	100	100	100	100	100	100	100	100	100	100	6	21	100	30
Diversity	11	12	9	6	7	5	5	5	5	6	5	4	4	3	2	4	8	5

Table D6: Macrophytes recorded from the peripheral wetlands, based on fresh collection (September 2017) and re-wetting trials (October 2017).

Macrophyte Taxa	September 2017			October 2017															
	NE CP01	NE CP02A	NE CP02B	CP01	CP02	CP03	CP06	CP08	CP09	CP10	CP11	CP13	CP14	CP16	CP17	CP20A	CP20B	CP21	CP22
Charophyceae																			
Chara sp. SIGM01 (Stantec)	●	●	●																
Chara sp. SIGM02 (Stantec)			●																
Chara sp. SIGM03 (Stantec)						●			●							●	●		
Nitella sp. SIGM01 (Stantec)	●	●	●																
Marchantiopsida																			
Marchantiopsida sp. SIGM01 (Stantec)	●	●					●												
Ruppiaceae																			
Ruppia sp. SIGM01 (Stantec)																●	●		
Diversity	3	3	3	0	0	1	1	0	1	0	0	0	0	0	0	2	2	0	0

Note: ● = present.

Table D7: Aquatic invertebrate recorded from the peripheral wetlands, based on fresh collection (September 2017) and re-wetting trials (October 2017).

Aquatic Invertebrate Taxa	September 2017			October 2017														
	NE CP01	NE CP02	NE CP02B	CP01	CP02	CP03	CP06	CP09	CP10	CP11	CP13	CP14	CP16	CP17	CP18	CP20	CP21	CP22
Arachnida																		
Trombidioidea sp.		1																
Crustacea																		
Anostraca																		
Parartemia nr *serventyi* MWH01								1							1			
Parartemia serventyi									2		10						1	
Parartemia sp. (juvenile)														1				
Cladocera																		
Ceriodaphnia quadrangula s.l.			1															
Coronatella cf. *rectangula novaezelandiae*			1															
Daphnia carinata s.l.	125	110	10															
Macrothrix pectinata			2															
Copepoda																		
Australocyclops australis	25	26	48															
Boeckella triarticulata	102	32	105															
Calamoecia ampulla var. B01	185	98	152															
Calamoecia sp.			2															
Cyclopoida sp.	1	4																
Pescecyclops laurentiisae			4															
Notostraca																		
Triops australiensis					8													
Ostracoda																		
'*Dragoncypris outbacki*' ms				6		299		1	72	5	58	1	129	89	118		46	
`Ramucypris davisae` ms							27									27		49
Bennelongia barangaroo	185	189	485															
Candonocypris novaezelandiae			24															
Cyprididae sp.						5												
Cyprinotus sp. BOS1026 (Yilgarn)					16	17	5											
Diacypris whitei					26	6		82										
Ilyodromus sp. BOS1031	3	3	24															
Limnocythere sp. BOS1035	27	16																
Reticypris pinguis																40		
Sarscypridopsis sp. BOS1030			36															
Spinicaudata																		
Eocyzicus sp. MWH01					1													
Ozestheria sarsii			2															
Insecta																		
Coleoptera																		
Antiporus sp.		7	3															
Berosus sp.		2	1															
Haliplus sp.			2															
Laccophilus sp.	1																	
Sternopriscus sp.		1	3															
Diptera																		
Ablabesmyia notabilis	8	27	4															
Chironominae sp.			1															
Coelopynia pruinosa		3	4															
Dicrotendipes 'CA1'	14	24	19															

Aquatic Invertebrate Taxa	September 2017			October 2017													
	NE CP01	NE CP02	NE CP02B	CP01	CP02	CP03	CP06	CP09	CP10	CP11	CP13	CP14	CP16	CP17	CP18	CP20	CP21	CP22
Monohelea sp.		1	6															
Nilobezzia sp			1															
Orthocladiinae sp.	1																	
Polypedilum nubifer			121															
Procladius paludicola		2	35															
Tanypodinae sp.		2																
Tanytarsus nr sp. C	1	2	45															
Ephemeroptera																		
Baetidae sp.		1	4															
Cloeon sp.	1																	
Hemiptera																		
Anisops sp.	2	23	11															
Corixidae sp.	5	11	27															
Micronecta robusta	1	1	5															
Micronecta sp.	1	2	4															
Sigara mullaka	1																	
Odonata																		
Austrolestes annulosus		1																
Coenagrionidae sp.		1																
Diplacodes bipunctata	6	13	2															
Hemicordulia tau	5	26																
Orthetrum caledonicum	2																	
Trichoptera																		
Notalina spira		2																
Abundance	702	631	1194	6	51	327	32	84	74	5	68	1	129	90	119	67	47	49
Diversity	22	29	33	1	4	4	2	3	3	1	2	1	1	2	2	2	2	1

Table D8: Resting stages of macrophyte taxa recorded within the sediment of the peripheral wetlands (October 2017).

Resting Stages Macrophyte Taxa	October 2017															
	CP01	CP02	CP03	CP06	CP08	CP09	CP10	CP11	CP13	CP14	CP16	CP17	CP18	CP20	CP21	CP22
Charophyceae																
Chara sp.			57													
Ruppiaceae																
Ruppia sp.							44									
Abundance			57				44									
Diversity	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0

Table D9: Resting stages of aquatic invertebrate taxa recorded within the sediment of the peripheral wetlands (October 2017).

Resting Stages Aquatic Invertebrate Taxa	October 2017															
	CP01	CP02	CP03	CP06	CP08	CP09	CP10	CP11	CP13	CP14	CP16	CP17	CP18	CP20	CP21	CP22
Crustacea																
Anostraca																
Parartemia sp.							44		41	44	19	27	21			43
Ostracoda																
red variety			23			53			41					18		
white variety			723	46			132				19		104	127	251	86
Cladocera																
Cladocera sp.			11													
Abundance	0	0	757	46		53	175		83	44	39	27	125	145	251	129
Diversity	0	0	4	1	0	1	3	0	2	1	2	1	2	2	1	2

Appendix E Water Quality Range & Preliminary Sediment Quality Trigger Values, Lake Lefroy

Table E-1: Water quality ranges developed for Lake Lefroy reference sites and discharge sites, 2009 to 2017.

Water Parameters		Reference Dataset				ANZECC & ARMCANZ (2000) Trigger
		Min	Max	Mean	#Records	
Basic	pH (unit)	1.0	7.3	6.0	18	-
	Total Dissolved Solids	127,000	569,000	327,056	18	-
	Electrical Conductivity (us/cm)	138,000	307,000	260,722	18	-
Major Ions	Sodium	46,900	145,000	110,311	18	-
	Magnesium	2,470	10,800	5,307	18	-
	Potassium	344	2,470	943	18	-
	Calcium	289	1,000	807	18	-
	Chloride	68,600	198,000	169,478	18	-
	Sulphate	4,000	19,100	9,354	18	-
	Bicarbonate	3	62	33	18	-
	Carbonate	-	-	-	18	-
	Hydroxide	-	-	-	12	-
	Total alkalinity	3	62	33	18	-
Nutrients	Total Nitrogen	6.0	7.0	6.7	8	-
	Total Phosphorus	-	-	-	8	-
	Total Kjeldahl Nitrogen	6.0	6.7	6.5	8	-
	Nitrite + Nitrate	0.3	0.9	0.5	8	-
Metals & Metalloids	Aluminium	-	-	-	18	
	Arsenic	-	-	-	18	
	Barium	0.057	0.152	0.092	18	
	Beryllium	-	-	-	2	
	Cadmium	0.002	0.002	0.002	18	0.036
	Chromium	0.055	0.055	0.055	18	0.085
	Cobalt	0.004	0.004	0.004	18	0.150
	Copper	-	-	-	18	0.008
	Iron	-	-	-	18	
	Lead	0.010	0.010	0.010	18	0.012
	Manganese	0.106	0.301	0.243	18	
	Mercury	-	-	-	18	0.001
	Nickel	0.008	0.112	0.056	18	0.560
	Selenium	-	-	-	18	
	Silica	-	-	-	0	
	Silicon	-	-	-	0	
	Strontium	2.730	9.640	4.223	12	
	Sulphur	4.920	6,360	3,430	18	
	Vanadium	0.009	0.009	0.009	18	0.280
	Zinc	-	-	-	18	0.043

Note: Units are mg/L unless otherwise stated; orange shading indicates a trigger value could not be calculated for that parameter; red shading indicates total number of data records is less than 30; "-" indicates insufficient data to form a range or trigger value, or all data records were below analytical detection.

Table E-1: Sediment quality ranges developed for Lake Lefroy reference sites, 2004 to 2017.

	Sediment Parameters	Min	Max	Mean	20th Percentile	80th Percentile	# Records	ANZECC & ARMCANZ (2000) Trigger	
								ISQG-Low	ISQG-High
Basic	pH (unit)	4.5	8.8	7.6	6.9	8.4	43	-	-
	Total Soluble Salts	7,800	363,000	94,951	46,980	106,400	43	-	-
	Moisture Content (%)	2	27	15	12	17	43	-	-
Major Ions	Sodium	7,520	212,000	56,775	19,700	95,460	24	-	-
	Magnesium	1,340	10,700	3,988	1,546	5,848	24	-	-
	Potassium	130	2,590	721	292	926	24	-	-
	Calcium	70	5,440	988	150	1,022	24	-	-
	Chloride	9,550	287,000	80,773	29,940	139,400	24	-	-
	Sulphate	2,090	20,400	7,243	3,786	10,560	24	-	-
	Bicarbonate	3	763	94	8	23	24	-	-
	Carbonate	-	-	-	-	-	24	-	-
	Total	3	763	106	10	51	17	-	-
Nutrients	Total Nitrogen	10.00	620.00	108.70	20.00	161.60	40	-	-
	Total Phosphorus	1.00	300.00	58.80	9.00	97.20	43	-	-
	Total Organic Carbon (%)	0.00	9.40	1.50	0.10	2.40	24	-	-
	Organic Matter (%)	2.00	16.20	5.70	2.40	4.90	8	-	-
	Total Kjeldahl Nitrogen	0.50	620.00	109.20	10.00	150.00	31	-	-
	Nitrate	-	-	-	-	-	3	-	-
	Nitrite	0.40	0.60	0.50	0.40	0.50	3	-	-
	Nitrite + Nitrate	0.10	1.60	0.70	0.20	1.20	28	-	-
Metals & Metalloids	Aluminium	1,230	24,200	6,479	2,228	11,140	34	-	-
	Arsenic	6	18	12	8	16	40*	20	70
	Barium	5	200	69	20	100	37	-	-
	Beryllium	-	-	-	-	-	29	-	-
	Cadmium	-	-	-	-	-	40*	2	10
	Chromium	34	631	174	87	242	40	80	370
	Cobalt	1	32	9	3	14	37	-	-
	Copper	3	40	15	5	27	39	65	270
	Iron	5,080	83,800	22,141	10,464	32,680	34	-	-
	Lead	5	18	9	6	11	40*	50	220
	Manganese	14	1,080	217	39	328	37	-	-
	Mercury	-	-	-	-	-	37*	0.15	1.00
	Nickel	8	178	49	15	94	40	21	52
	Selenium	-	-	-	-	-	34*	-	-
	Silicon	3	36	10	4	12	34	-	-
	Strontium	10	3,480	574	15	1,368	25	-	-
	Sulphur	700	5,470	3,230	1,276	4,838	5	-	-
	Vanadium	14	196	57	30	87	37	-	-
	Zinc	3	51	15	5	24	40	200	410

*Note: Units are mg/kg unless otherwise stated; green shading indicates a trigger value could be calculated for that parameter and orange shading indicates where a trigger value could not be calculated; red shading indicates total number of data records is less than 30; * indicates that although the number of data records was greater than 30, more than 50% of them were below detection; blue shading indicates trigger value exceeds ANZECC & ARMCANZ (2000) ISQG-Low trigger; yellow shading indicates trigger value exceeds ANZECC & ARMCANZ (2000) ISQG-High trigger.*

Table E-2: Sediment quality trigger values (20th and 80th percentile values) developed for Lake Lefroy reference sites, 2004 to 2017.

Sediment Parameters		Min	Max	Mean	20th Percentile	80th Percentile	# Records	ANZECC & ARMCANZ (2000) Trigger	
								ISQG-Low	ISQG-High
Basic	pH (unit)	4.5	8.8	7.6	6.9	8.4	43		
	Total Soluble Salts	7,800	363,000	94,951	46,980	106,400	43		
	Moisture Content (%)	2.4	26.7	14.6	12	17.3	43		
Nutrients	Total Nitrogen	10	620	108.7	20	161.6	40		
	Total Phosphorus	1	300	58.8	9	97.2	43		
	Total Kjeldahl Nitrogen	0.5	620	109.2	10	150	31		
Metals & Metalloids	Aluminium	1,230	24,200	6,479	2,228	11,140	34		
	Barium	5	200	68.5	20	100	37		
	Chromium	34	631	174.1	87.2	241.6	40	80	370
	Cobalt	1	32	8.5	3	14	37		
	Copper	2.5	40	15.2	5	27.4	39	65	270
	Iron	5,080	83,800	22,141	10,464	32,680	34		
	Manganese	14	1,080.00	216.8	39.2	327.8	37		
	Nickel	8	178	49	15	93.8	40	21	52
	Silicon	2.5	36	9.5	3.6	11.8	34		
	Vanadium	14	196	57.4	30.2	86.6	37		
	Zinc	2.5	51	15.1	4.5	24.4	40	200	410

Note: Units are mg/kg unless otherwise stated; green shading indicates a trigger value could be calculated for that parameter; blue shading indicates trigger value exceeds ANZECC & ARMCANZ (2000) ISQG-Low trigger; yellow shading indicates trigger value exceeds ANZECC & ARMCANZ (2000) ISQG-High trigger.

Appendix F Historic Biological Data for Algae, Macrophytes, Aquatic Invertebrates and Riparian Vegetation

Table F-1: Phytoplankton taxa recorded from Lake Lefroy and peripheral wetlands over time.

Phytoplankton Taxa	Year		
	2014+	2014^	2017^
Bacillariophyceae			
Achnanthidium sp.		●	
Amphora coffeaeformis			●
Amphora sp.		●	
Amphora sp. 2		●	
Amphora veneta			●
Caloneis bacillum			●
Craticula ambigua			●
Navicula sp.		●	
Navicula cryptocephala			●
Nitzschia palea			●
Nitzschia sp. aff. *rostellata*			●
*Nitzschia*sp. SIGM01 (Stantec)			●
*Nitzschia*sp. SIGM02 (Stantec)			●
Nitzschia sp.		●	
Pinnularia sp.		●	
Rhopalodia gibba			●
Chlorophyceae			
Ankistrodesmus spiralis			●
Botryococcus braunii			●
Carteria 'SIGM001'		●	
Chlamydomonas 'SIGM001' (Phoenix)		●	
Chlamydomonas 'SIGM002' (Phoenix)		●	
Chlorogonium 'SIGM001' (Phoenix)		●	
Closterium sp.			●
Cosmarium granatum			●
Cosmarium quadrum			●
Cosmarium sp. SIGM01 (Stantec)			●
Dictyosphaerium 'SIGM001' (Phoenix)		●	
Dunaliella 'SIGM001' (Phoenix)	●		
Euastrum lacustre			●
Euastrum spinulosum			●
Golenkinia 'SIGM001' (Phoenix)		●	
Lagerheimia 'SIGM001' (Phoenix)		●	
Micractinium 'SIGM001' (Phoenix)		●	
Monoraphidium 'SIGM001' (Phoenix)		●	
Monoraphidium 'SIGM002' (Phoenix)		●	
Monoraphidium 'SIGM003' (Phoenix)		●	
Monoraphidium 'SIGM004' (Phoenix)		●	
Oedogonium sp.			●
Oocystis 'SIGM001' (Phoenix)		●	
Oocystis 'SIGM002' (Phoenix)		●	
Pleurotaenium sp.			●
Pteromonas 'SIGM001' (Phoenix)		●	
Staurastrum gracile			●
Tetrastrum 'SIGM001' (Phoenix)		●	
Treubaria 'SIGM001' (Phoenix)		●	
Chrysophyceae			
Mallomonas 'SIGM001' (Phoenix)		●	

Phytoplankton Taxa	Year		
	2014+	2014^	2017^
Cryptophyceae			
Rhodomonas 'SIGM001' (Phoenix)		●	
Cyanophyceae			
Anabaena 'SIGM001' (Phoenix)		●	
Anabaena sp.			●
Chroococcus 'SIGM001' (Phoenix)	●	●	
Cyanobacteria 'SIGM001' (Phoenix)		●	
Gloeocapsa 'SIGM001' (Phoenix)		●	
Phormidium sp.			●
Planktolynbya sp.			●
Euglenophyceae			
Trachelemonas 'SIGM001' (Phoenix)		●	
Trachelemonas 'SIGM002' (Phoenix)		●	
Diversity	2	31	24

Note: + = playa; ^ = peripheral wetland; ● present.

Data Sources: (Phoenix Environmental Sciences 2014); Stantec unpublished data 2017.

Table F-2: Benthic algae taxa recorded from Lake Lefroy and peripheral wetlands over time.

Benthic Algae Taxa	Year										
	1999[+#]	1999[^#]	2004[+]	2004[^]	2010[+]	2010[^]	2010[+#]	2010[^#]	2014[+]	2014[^]	2017[^#]
Bacillariophyceae											
Amphora coffeaeformis	●	●								●	●
Amphora fontinalis											●
Achnanthidium 'SIGM001' (Phoenix)										●	
Amphora spp.						●					
Amphora ventricosa	●										
Caloneis bacillum											●
Craticula ambigua											●
Hantzschia amphioxys											●
Hantzschia distinctipunctata											●
Hantzschia 'SIGM001' (Phoenix)										●	
Hantzschia sp. aff. baltica											●
Hantzschia sp. aff. *weyprechtii*											●
Hantzschia virgata	●										
Mastogloiapumila											●
Mastogloia smithii											●
Navicella spp.						●					
Navicula cryptocephala											●
Navicula 'SIGM001' (Phoenix)										●	
Navicula 'SIGM002' (Phoenix)										●	
Navicula sp. aff. *cincta*											●
Navicula sp. aff. *incertata*	●	●									●
Navicula tenelloides											●
Nitzschia closterium											●
Nitzschia 'SIGM001' (Phoenix)										●	
Nitzschia sp. aff. *rostellata*											●
Nitzschia palea	●	●									●
Nitzschia sp. SIGM01 (Stantec)											●
Nitzschia spp.						●					
Pinnularia 'SIGM001' (Phoenix)										●	

Benthic Algae Taxa	Year										
	1999+#	1999^#	2004+	2004^	2010+	2010^	2010+#	2010^#	2014+	2014^	2017^#
Pinnulariasp. aff. *intermedia*											●
Rhopalodia gibba											●
Synedra 'SIGM001' (Phoenix)										●	
Chlorophyceae											
Ankistrodesmus spiralis											●
Botryococcus braunii											●
Bulbochaete sp.											●
Closterium sp.											●
Cosmarium granatum											●
Cosmarium quadrifarium											●
Cosmarium quadrum											●
Cosmarium sp. SIGM01 (Stantec)											●
Dunaliella sp.			●								
Euastrum lacustre											●
Euastrum spinulosum											●
Oedogonium sp.											●
Oocystis sp.											●
Pleurotaenium sp.											●
Staurastrum gracile											●
Zygnema sp.											●
Cyanophyceae											
Anabaena sp.	●		●								
Calothrix sp.											●
Chroococcus sp.	●		●	●	●						
Coelosphaerium sp.		●									
Geitlerinema sp. 003							●	●			
Gomphosphaeria sp.		●									
Komvophoron sp. 001					●	●	●	●			
Komvophoron sp. 002							●				
Leptolyngbya sp. 001					●	●	●	●			
Lyngbya sp.											●
Microcoleus sp.											●

Benthic Algae Taxa	Year										
	1999+#	1999^#	2004+	2004^	2010+	2010^	2010+#	2010^#	2014+	2014^	2017^#
Microcystis sp.											●
Oscillatoria earlie	●	●									
Oscillatoria sp.				●							●
Oscillatoria sp. 002					●		●	●			
Oscillatoria sp. 003								●			
Oscillatoria sp. 004								●			
Oscillatoria sp. 005					●		●	●			
Phormidium sp.	●	●								●	●
Phormidium sp. 1				●							
Phormidium sp. 2			●								
Phormidium sp. 001								●			
Phormidium sp. 002								●			
Phormidium sp. 003								●			
Phormidium sp. 004					●			●			
Phormidium sp. 005					●			●			
Phormidium sp. 006								●			
Phormidium sp. 007							●	●			
Phormidium sp. 008								●			
Phormidium sp. 009					●			●			
Phormidium sp. 010								●			
Phormidium sp. 011							●				
Phormidium sp. 012							●				
Phormidium sp. 013							●				
Planktolyngbya sp.											●
Pseudanabaena sp.											●
Pseudanabaena sp. 001							●				
Pseudanabaena sp. 002					●	●	●				
Pseudanabaena sp. 003					●		●				
Schizothrix sp.	●	●		●							
Schizothrix sp. 001								●			
Schizothrix sp. 002								●			
Spirulina sp.	●										●

Benthic Algae Taxa	Year										
	1999+#	1999^#	2004+	2004^	2010+	2010^	2010+#	2010^#	2014+	2014^	2017^#
Euglenophyceae											
Phacus sp.											●
Diversity	11	8	4	4	10	6	13	19	0	9	45

Note: + = playa; ^ = peripheral wetland; data based on fresh collection except where indicated, with # = fresh collection and re-wetting trials; ● = present.

Data Sources: (Curtin University of Technology 1999a; Dalcon Environmental 2010a; Outback Ecology 2004b; Phoenix Environmental Sciences 2014); Stantec unpublished data 2017.

Table F-3: Diatom taxa recorded from Lake Lefroy and peripheral wetlands over time (● indicates presence).

Diatom Taxa	Year																
	2004+	2004^	2005+	2005^	2006+	2006^	2007+	2007^	2008+	2008^	2010+	2010^	2015+	2015^	2016+	2016^	2017^#
Achnanthidium brevipes			●														
Achnanthidium coarctata			●	●													
Achnanthidium duthiei																	●
Achnanthidium oblongella											●						
Achnanthidium sp.	●																
Achnanthidium sp. SIGM01																	●
Amphora coffeaeformis	●	●	●	●	●	●		●	●		●	●	●	●	●	●	●
Amphora fontinalis																	●
Amphora holsatica										●							
Amphora sp. 001											●						
Amphora sp. 002											●						
Amphora sp. 003												●					
Amphora veneta																	●
Amphora ventricosa				●													
Brachysira brebissonii											●						
Brachysira vitrea																	●
Caloneis bacillum													●				●
Caloneis sp. 001											●	●					
Caloneis sp. 002											●	●					
Cocconeis placentula var. *euglypta*											●	●					
Craticula ambigua																	●
Craticula cuspidata																	●
Craticula sp. aff. *cuspidata*															●	●	
Cyclotella sp.	●																
Cyclotella stelligera												●					●
Diadesmis confervacea											●	●					
Diatom sp. 004											●						
Diatom sp. 006											●						
Diatom sp. 007											●	●					
Diatom sp. 018											●						
Diatom sp. 020											●						
Diatom sp. 021											●						
Diatom sp. 022											●	●					
Diatom sp. 023											●	●					
Diatom sp. 024											●						
Diatom sp. 025											●	●					
Diatom sp. 026											●						
Diatom sp. 027											●						
Diatom sp. 028											●						
Diatom sp. 029											●						
Diatom sp. 030											●						
Diatom sp. 031											●						
Diatom sp. 032											●	●					
Diatom sp. 033											●						
Diatom sp. 034											●						
Diatom sp. 035											●						
Diatom sp. 036											●	●					
Diatom sp. 037											●						
Diatom sp. 038											●	●					

Diatom Taxa	Year																
	2004+	2004^	2005+	2005^	2006+	2006^	2007+	2007^	2008+	2008^	2010+	2010^	2015+	2015^	2016+	2016^	2017^#
Diatom sp. 039											●	●					
Diatom sp. 040											●						
Diatom sp. 041											●	●					
Diatom sp. 042											●	●					
Diatom sp. 043												●					
Diatom sp. 044												●					
Diploneis ovalis											●						
Fragilaria sp. 001											●	●					
Fragilaria sp. 002											●						
Frustulia sp. 001											●						
Gomphonema auritum																	●
Hantzschia amphioxys					●		●	●	●		●				●		●
Hantzschia distinctipunctata																	●
Hantzschia sp. aff. *baltica*						●	●	●		●			●	●	●	●	●
Hantzschia sp. aff. *weyprechtii*																	●
Hantzschia virgata	●	●	●	●							●	●					
Hyppodonta capitata											●						
Luticola mutica	●				●	●			●		●	●	●		●	●	●
Lutica nivalis																	●
Luticola sp.		●															
Luticola sp. aff *kotschyi*													●				
Navicella pusilla	●	●			●			●						●		●	●
Navicula crytocephala																	●
Navicula elegans			●								●	●					
Navicula ergadensis	●	●															
Navicula exigua											●						
Navicula sp. 1	●			●		●											
Navicula sp. 2					●												
Navicula sp. 1 (LC2005)																	●
Navicula sp. aff. *arvensis*													●		●		●
Navicula sp. aff. *cincta*																	●
Navicula sp. aff. *erifuga*																	●
Navicula sp. aff. *incertata*	●	●	●	●	●	●	●	●	●	●			●	●	●	●	●
Navicula sp. aff. *salinicola*					●	●		●	●				●	●	●	●	●
Navicula sp. aff. *seminulum*															●		
Navicula tenelloides																	●
Navicula tripunctata																	●
Nitzschia ovalis								●		●			●	●	●	●	●
Nitzschia palea	●																●
Nitzschia sp.											●						
Nitzschia sp. 001											●						
Nitzschia sp. 002											●						
Nitzschia sp. 003											●						
Nitzschia sp. 004											●	●					
Nitzschia sp. 005												●					
Nitzschia sp. 006											●	●					
Nitzschia sp. 007												●					
Nitzschia sp. aff. *filiformis*																	●
Nitzschia sp. aff. *hybrida*							●										
Nitzschia sp. aff. *latens*															●		

Diatom Taxa	Year																
	2004+	2004^	2005+	2005^	2006+	2006^	2007+	2007^	2008+	2008^	2010+	2010^	2015+	2015^	2016+	2016^	2017^#
Nitzschia sp. aff. *rostellata*																	●
Nitzschia sp. aff. *sigma*																	●
Nitzschia sp. SIGM01 (Stantec)																	●
Nitzschia subinflata																	●
Pinnularia borealis	●		●	●	●		●				●				●		
Pinnularia gibba											●	●					●
Pinnularia microstauron																	●
Pinnularia sp.											●						
Pinnularia sp. 001						●	●				●	●					
Pinnularia sp. 002											●	●					
Pinnularia sp. 003											●	●					
Pinnularia sp. aff. *intermedia*																	●
Pinnularia sp. aff. *obscura*							●		●				●	●	●	●	
Pinnularia sp. aff. *subcapitata*													●		●		
Pinnularia viridis						●											
Proschkinia sp. aff. *complanata*										●			●		●	●	
Rhopalodia gibba																	●
Rhopalodia gibberula	●																
Rhopalodia sp. 001											●						
Sellaphora pupula	●				●						●						
Staurosira construens											●	●					
Stauroneis sp. MWH1 (STIV)															●		
Synedra sp.	●										●						
Tryblionella levidensis																	●
Diversity	14	6	7	7	9	8	7	7	6	5	62	32	12	7	16	10	39

Note: + = playa; ^ = peripheral wetland; data based on fresh collection except where indicated, with # = fresh collection and re-wetting trials; ● = present.

Data Sources: (MWH 2016b;2017; Outback Ecology 2004b;2005;2006;2007;2009).

Dalcon Environmental 2010a data source included in above table but removed from summary in Section 2.4.5.1.2 due to limited taxonomic resolution.

Table F-4: Aquatic invertebrate taxa recorded from Lake Lefroy and peripheral wetlands over time.

Aquatic Invertebrate Taxa	Year									
	1999$^{+\#}$	1999$^{\wedge\#}$	2010^{+}	2010$^{\wedge}$	2014^{+}	2014$^{\wedge}$	2015^{+}	2015$^{\wedge}$	2016$^{\wedge}$	2017$^{\wedge\#}$
Arachnida										
Trombidioidea sp.										●
Crustacea										
Anostraca										
Branchinella sp.		●								
Parartemia contracta		●				●				
Parartemia nr *serventyi* MWH01										●
Parartemia serventyi	●							●	●	●
Parartemia sp. nov.	●	●								
Parartemia sp. (juvenile)										●
Copepoda										
Apocyclops dengizicus		●								
Australocyclops australis						●				●
Boeckella triarticulata					●					●
Calamoecia ampulla var. B01										●
Calamoecia cf. *salina*			●							
Calamoecia sp.	●	●								●
Cyclopoida sp.										●
Meridiecyclops baylyi					●	●				
Metacyclops sp.	●	●								
Pescecyclops laurentiisae										●
Cladocera										
Bosmina meridionalis		●								
Ceriodaphnia quadrangula s.l.										●
Coronatella cf. rectangula novaezelandiae										●
Daphnia carinata s.l.										●
Macrothrix pectinata										●
Moina sp.		●								
Notostraca										
Triops australiensis		●				●				●
Ostracoda										
'Dragoncypris outbacki'	●	●			●	●				●
`Ramucypris davisae` ms										●
Ampullacypris oblongata						●				
Bennelongia barangaroo										●
Candonocypris novaezelandiae										●
Cyprididae sp.										●
Cyprinotus kimberleyensis s.l.					●	●				
Cyprinotus sp. BOS1026 (Yilgarn)										●
Diacypris phoxe								●		
Diacypris whitei										●
Ilyodromus sp. BOS1031										●
Limnocythere sp. BOS1035										●
Reticypris pinguis										●
Reticypris sp. nov		●								
Sarscypridopsis sp. BOS1030										●
Spinicaudata										
Cyzicus sp.		●								

Aquatic Invertebrate Taxa	Year									
	1999[+#]	1999[^#]	2010[+]	2010[^]	2014[+]	2014[^]	2015[+]	2015[^]	2016[^]	2017[^#]
Eocyzicus sp. MWH01										●
Eulimnadia sp.		●								
Limnadia sp.		●								
Ozestheria sarsii										●
Insecta										
Diptera										
Ablabesmyia notabilis										●
Cladotanytarsus sp.						●				
Cryptochironomus griseidorsum						●				
Ceratopogonidae sp. 1 (black)	●	●								
Ceratopogonidae sp. 2		●								
Ceratopogonidae sp. 3			●	●						
Chironominae sp.										●
Coelopynia pruinosa										●
Culicidae sp. 1		●								
Culicoides sp.						●	●	●		
Dasyhelea sp.					●					
Dicrotendipes 'CA1'										●
Dicrotendipes nr sp. 'CA1'						●				
Ephydridae sp.						●				
Monohelea sp.										●
Nilobezzia sp										●
Orthocladiinae sp.										●
Polypedilum nubifer						●				●
Procladius sp. P1 (DEC)						●				
Procladius paludicola						●				●
Tabanidae sp. 1						●				
Tabanidae sp. 2						●				
Tanypodinae sp.										●
Tanytarsus barbitarsus								●		
Tanytarsus semibarbitarsus						●				
Tanytarsus nr sp. C										●
Tanytarsus nr sp. 'K2'						●				
Coleoptera										
Antiporus sp.										●
Berosus sp.						●				●
Bidessini sp.						●				
Dytiscidae sp. 1		●								
Dytiscidae sp. 2		●								
Enochrus elongatus						●				
Haliplus sp.										●
Hydrophilidae sp.						●				
Laccophilus sp.										●
Limnoxenus zealandicus						●				
Rhantus sp.						●				
Staphylinidae sp.						●				
Sternopriscus sp.										●
Ephemeroptera										
Baetidae sp.										●
Cloeon sp.						●				●

Aquatic Invertebrate Taxa	Year									
	$1999^{+\#}$	$1999^{\wedge\#}$	2010^{+}	$2010^{\wedge}$	2014^{+}	$2014^{\wedge}$	2015^{+}	$2015^{\wedge}$	$2016^{\wedge}$	$2017^{\wedge\#}$
Hemiptera										
Anisops sp.										●
Anisops thienemanni						●				
Corixidae sp.		●				●				●
Micronecta robusta										●
Micronecta sp.										●
Sigara mullaka										●
Notonectidae sp. 1		●								
Notonectidae sp. 2		●								
Odonata										
Austrolestes annulosus										●
Coenagrionidae sp.										●
Diplacodes bipunctata										●
Hemicordulia tau										●
Orthetrum caledonicum										●
Trichoptera										
Notalina spira										●
Foraminifera										
Foraminifera sp.								●		
Rotifera										
Asplancha herricki		●								
Filinia perjleri		●								
Diversity	6	24	2	1	5	29	1	5	1	57

Note: + = playa; ^ = peripheral wetland; data based on fresh collection except where indicated, with # = fresh collection and re-wetting trials; ● = present.

Data Sources: (Curtin University of Technology 1999a;b; Dalcon Environmental 2010a; MWH 2016b;2017; Phoenix Environmental Sciences 2014); Stantec unpublished data 2017.

Table F-5: Resting stages of aquatic invertebrate taxa recorded within the sediment of Lake Lefroy and peripheral wetlands over time.

Resting Stages Aquatic Invertebrate Taxa	Year																		
	1999+	1999^	2004+	2004^	2005+	2005^	2006^	2007+	2007^	2008+	2008^	2010+	2010^	2014+	2015+	2015^	2016+	2016^	2017^
Invertebrates																			
Crustacea																			
Crustacea red														●					
Crustacea black														●					
Crustacea white														●					
Anostraca																			
Branchinella sp.									●										
Parartemia sp.	●	●	●		●	●	●								●	●	●	●	●
Cladocera																			
Cladocera sp.																			●
Ostracoda/Copepoda																			
Ostracoda/ Copepoda sp.												●*							
Ostracoda red variety			●	●		●		●							●		●		●
Ostracoda white variety						●			●									●	●
Diversity	1	1	2	1	1	3	1	1	2	0	0	1	0	3	2	1	2	2	4

Note: + = playa; ^ = peripheral wetland, ● = present.

Data Sources: (Dalcon Environmental 2010a; MWH 2016b;2017; Outback Ecology 2004b;2005;2006;2007;2009); Stantec unpublished data 2017.

Table F-6: Riparian flora taxa recorded from Lake Lefroy in 2010, 2012, 2013, 2014, 2015, 2016 and 2017.

Riparian Flora Taxa	2010	2012	2013	2014	2015	2016	2017
Aizoaceae							
Disphma crassifolium			●	●	●	●	●
Gunniopsis quadrifida	●	●	●	●	●	●	●
Amaranthaceae							
Surreya diandra						●	
Apocynaceae							
Marsdenia australis			●	●		●	
Asparagaceae							
Lomandra effusa			●				
Thysanotus manglesianus			●	●			
Asteraceae							
Calocephalus multiflorus			●				
Cratystylis subspinescens							●
Senecio pinnatifolius			●				
Roebuckiella ciliocarpa			●				
Chenopodiaceae							
Atriplex spongiosa							●
Atriplex spongiosa			●				
Atriplex vesicaria			●	●	●	●	●
Enchylaena tomentosa			●	●	●	●	●
Maireana amoena		●	●	●			
Maireana appressa					●		
Maireana erioclada			●	●		●	
Maireana georgei			●		●		
Maireana glomerifolia	●	●	●	●	●	●	●
Maireana suaedifolia							●
Maireana tomentosa			●				
Maireana triptera				●			●
Rhagodia drummondii			●	●			
Rhagodia eremaea			●	●			
Sclerolaena eurotioides							●
Tecticornia doliiformis							●
Tecticornia halocnemoides	●		●				
Tecticornia halocnemoides subsp. *catenulata*						●	●
Tecticornia indica	●	●	●	●			
Tecticornia indica subsp. *bidens*						●	●
Tecticornia lepidosperma						●	●
Tecticornia lylei						●	●

Riparian Flora Taxa	2010	2012	2013	2014	2015	2016	2017
Tecticornia mellarium					●		●
Tecticornia pergranulata			●		●	●	
Tecticornia pergranulata subsp. *elongata*					●		
Tecticornia pergranulata subsp. *pergranulata*						●	●
Tecticornia sp. Dennys Crossing						●	●
Tecticornia syncarpa					●		●
Tecticornia undulata					●	●	
Tecticornia mellaria					●		
Cyperaceae							
Lepidosperma sanguinolentum					●	●	●
Ericaceae							
Leucopogon sp. Clyde Hill	●	●	●	●	●	●	●
Fabaceae							
Acacia burkittii					●	●	
Acacia donaldsonii				●			
Acacia ?donaldsonii			●				
Acacia hemiteles		●	●	●			
Acacia prainii					●	●	●
Jacksonia arida	●	●	●	●	●	●	●
Frankeniaceae							
Frankenia cinerea						●	●
Frankenia interioris	●	●	●	●	●		●
Frankenia irregularis						●	●
Frankenia ?laxiflora						●	
Frankenia pauciflora			●		●	●	●
Frankenia setosa			●	●		●	
Goodeniaceae							
Scaevola spinescens			●	●	●	●	●
Sclerolaena densiflora			●	●			
Lamiaceae							
Prostanthera althoferi	●						
Malvaceae							
Sida calyxhymenia			●	●			
Montiaceae							
Calandrinia eremaea			●				
Myrtaceae							
Darwinia sp. Karonie	●	●	●	●	●	●	●
Leptospermum erubescens					●	●	●
Leptospermum roei	●	●	●	●			

Riparian Flora Taxa	2010	2012	2013	2014	2015	2016	2017
Melaleuca hamata			●	●	●	●	●
Melaleuca thyoides	●	●	●	●	●	●	●
Nitrariaceae							
?Nitraria billardierei		●	●	●			
Poaceae							
Aristida contorta							●
Austrostipa elegantissima			●	●			
Austrostipa nitida					●	●	●
Enteropogon ramosus			●				
Eragrostis dielsii			●	●			
Eragrostis eriopoda			●	●			
Proteaceae							
Grevillea acuaria			●				
Grevillea juncifolia	●	●	●	●	●	●	●
Grevillea oncogyne							●
Rutaceae							
Phebalium canaliculatum						●	●
Phebalium lepidotum							●
Santalaceae							
Exocarpos aphyllus	●		●	●			●
Santalum acuminatum			●				
Sapindaceae							
Dodonaea viscosa subsp. *angustissima*			●				
Scrophulariaceae							
Eremophila alternifolia					●	●	
Eremophila decipiens subsp. *decipiens*			●	●		●	●
Eremophila deserti							●
Solanaceae							
Lycium australe			●	●	●	●	●
Solanum hoplopetalum			●				●
Solanum nummularium			●				●
Zygophyllaceae							
Zygophyllum sp.							●
Transect Number	4	5	17	11	12	12	14
Diversity	13	13	50	34	29	37	45

Note: Excludes unidentified/unverified taxa; includes most current taxonomic nomenclature, ● = present.

Data Sources: (Botanica Consulting 2010;2013;2014; MWH 2016b;2017; Native Vegetation Solutions 2014); Stantec unpublished data 2017.

Appendix G Conservation Significant Flora in the Riparian Zone

Map Source: (Phoenix Environmental Sciences 2018)

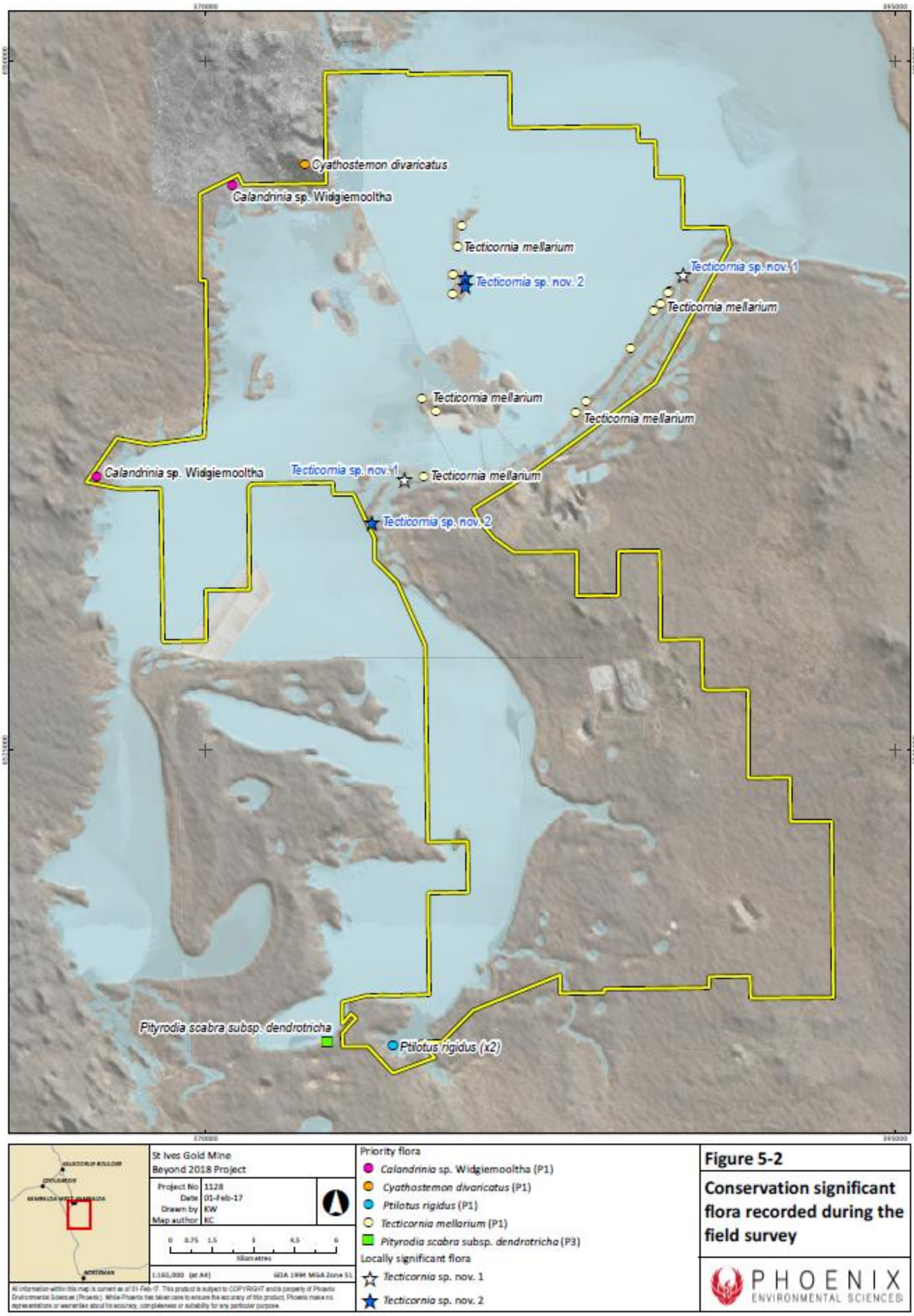


Figure 5-2

Conservation significant flora recorded during the field survey

Perth

41 Bishop Street,
JOLIMONT, WA 6014
Tel +61 (08) 9388 8799

www.stantec.com

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