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PUBLIC ENVIRONMENTAL REVIEW
(EPA Assessment Number 1250)

Gold Mining Developments on Lake Lefroy

for
WMC Resources Ltd (St Ives Gold)

DAMES & MOORE
Ref: SJF/08011-159-071/DK:517-F1488.2/DOC/PER
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INVITATION

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

This Public Environmental Review (PER) describes a proposal to develop gold mining operations on Lake Lefroy near Kambalda, Western Australia. The Proponent for the Project is WMC Resources Ltd (St Ives Gold).

The PER is available for public review for eight weeks from 27 September to 22 November 1999.

Comments from Government agencies and the public will assist the EPA to prepare an Assessment Report in which it will make recommendations to Government.

Why write a submission?
A submission is a way to provide information, express your opinion and put forward your suggested course of action – including any alternative approach. It is useful if you indicate any suggestions you may have to improve the proposal.

All submissions received by the EPA will be acknowledged. Submissions will be treated as public documents unless provided and received in confidence subject to the requirements of the *Freedom of Information Act*, and may be quoted in full or in part in each report.

Why not join a group?
If you prefer not to write your own comments, it may be worthwhile joining with a group or other groups interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to 10 people) please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

Developing a submission
You may agree or disagree with, or comment on, the general issues discussed in the PER or the specific proposals. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal environmentally more acceptable.

When making comments on specific proposals in the PER:

- clearly state your point of view;
- indicate the source of your information or argument if this is applicable; and
- suggest recommendations, safeguards or alternatives.

Points to keep in mind
By keeping the following points in mind, you will make it easier for your submission to be analysed:

- attempt to list points so that the issues raised are clear. A summary of your submission is helpful;
- refer each point to the appropriate section, chapter or recommendation in the PER;
- if you discuss different sections of the PER, keep them distinct and separate, so there is no confusion as to which section you are considering; and
- attach any factual information you may wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:

- your name;
- address;
- date; and
- whether you want your submission to be confidential.

The closing date for submissions is: 22 November 1999.

Submissions should be addressed to:

Environmental Protection Authority
Level 8, Westralia Square
141 St George's Terrace
PERTH WA 6000
Attention: Mark Jefferies

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<u>Photographers/Sources</u>: Greg Morris (WMC Resources Ltd); Bryn McDougall (WMC Resources Ltd – St Ives Gold); Sonia Finucane (Dames & Moore); Shane Chaplin and Karl Brennan (Curtin University of Technology); Ruth Gallagher and Heidi Sowerby (Henry Walker); Evan Collis Photography; Mattiske Consulting Pty Ltd; WMC Archives.

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EXECUTIVE SUMMARY

BACKGROUND

WMC Resources Ltd (St Ives Gold) (hereafter referred to as the Proponent) conducts gold exploration, mining and processing operations on and adjacent to Lake Lefroy, approximately 20km southeast of Kambalda, Western Australia. WMC Resources Ltd also operates nickel exploration, mining and processing operations at Lake Lefroy through its subsidiary, Kambalda Nickel Operations (KNO).

Lake Lefroy is one of the many elongated, medium-sized salt lakes that occur in chains on the Yilgarn Craton of Western Australia. The lake is arc-shaped, with an axial length of 59 km and a maximum width of 16 km. It has a surface area of approximately 554 km^2 (55,400 ha) and a total catchment of 4,528 km^2 (452,800 ha).

The lake bed is flat and has a well-developed halite crust. The crust varies in thickness from location to location and can be up to 10 cm thick. It has been estimated that more than 94 million tonnes (Mt) of salt is present in the halite crust and that 79 Mt of salt is stored in the shallow aquifer. Most of the lake bed is dry for most of the year. When it is present, the surface water is hypersaline and neutral to weakly acid with a dominant sodium-chloride signature.

The Proponent has been mining gold at Lake Lefroy since 1981 and its operations currently constitute the third largest gold producing site in Australia. However, current gold reserves are becoming depleted and additional mining developments are required to ensure an adequate supply of ore to the St Ives Gold Mill.

In the past, new mining developments on Lake Lefroy have been assessed and approved on a mine-by-mine basis. However, the Proponent and the Environmental Protection Authority (EPA) have recognised that this approach does not adequately address the cumulative impacts which might occur through successive mining developments on the lake and did not give the Proponent the level of certainty it requires for long term planning. It was determined that a strategic environmental assessment could be conducted through the existing formal environmental impact assessment process to establish a framework for the management of future mining developments on Lake Lefroy. The EPA therefore elected to formally assess the proposed gold mining developments on Lake Lefroy as a Public Environmental Review (PER).

THE PROPOSAL

The proposed gold mining developments will be located on Mineral Leases administered under the Nickel Refinery (WMC) Agreement Act 1968. To date, 13 potential deposits have been identified within this area, as follows:

- North Shore;
- Formidable;
- Bahama;
- West Intrepide;
- Intrepide South;
- East Yacht Club;
- LT17/Lute;
- North Revenge;
- South Revenge;
- West Revenge;
- Delta Cutback;
- Phoebe; and
- Thunderer.

The majority of the pits will be small and will produce approximately 0.3 to 1.0 Mt of ore, though there is potential for a number of larger pits that will produce around 3.0 Mt of ore. Overburden will be removed during the mining process at an average strip ratio of 20:1, and will be placed in mined-out pits or overburden dumps. Mine scheduling will be conducted so as to maximise opportunities for the backfilling of mined-out pits.

The pits will be dewatered using in-pit sumps and/or bores. The volume of water to be abstracted from each pit will be determined through further hydrological and hydrogeological investigations, but it is expected that the dewatering requirements of the proposed pits will be similar to those of existing pits. The water abstracted from the pits will be hypersaline and will have physical and chemical properties similar to those of the natural lake waters. Some variation may occur as water quality is primarily a function of aquifer geology. Mine water will be directed to settlement ponds to remove sediment loads prior to discharge to Lake Lefroy.

Access to the pits will be through an extension of the existing network of haul roads and causeways. Existing infrastructure will be used where possible but some new causeways will be required to access most of the proposed pits and support facilities. The Project also includes provision to re-route the southern end of the St Ives causeway around the Revenge series of pits. This option will only be implemented if a large resource is identified beneath the existing causeway.

The Project will be supported by the Proponent's existing administration, workshops, contractors' compounds and processing facilities. Additional workshop facilities and contractors' compounds may also be established.

Approximately 480 hectares (ha), or 0.9%, of the lake's surface have been disturbed by WMC's mining operations to date. At the end of the Project's 10 year life, the additional area of disturbance due to the proposed gold mining developments is estimated to be 254 ha (0.4%). Therefore, the total extent of disturbance that will exist on the lake at the end of the Project's life is estimated to be 734 ha, which represents approximately 1.3% of the lake's surface. The disturbances that result from the proposed mining developments and associated activities will be rehabilitated on a progressive basis.

The key characteristics of the proposed mining developments are summarised in Table 1.

Table 1

Key Characteristics Table

Element	Description			
Life of Project	Approximately 10 years.			
Size of Orebodies	Approximately 435 Mt of ore and overburden.			
Mining Rate	Approximately 21 Mt of ore and 414 Mt of overburden will be mined during the life of the Project. The annual mining rate will vary.			
Mining Method	Open pit mining using conventional drilling, blasting, loading and hauling techniques. Underground mining may also be conducted at some deposits.			
Depth of Mining	30 – 150 m.			
Strip Ratio	Approximately 20:1.			
Estimated Area of Disturbance[1] (ha)	Current Project Layout	Project Layout at Year Two	Project Layout at Year Six	Project Layout at Year 10
Mine pits	50	105	240	180
Overburden dumps	270	270	400	480
Bunds, causeways and roads	142	150	130	72
Ore pads, settlement ponds and other infrastructure	18	20	35	2
Total	480	545	805	734
Depth to Water Table	At or near surface.			
Mine Dewatering and Discharge	Further investigations are required to determine the volume of mine water to be abstracted from each pit but is likely to be similar to the volume abstracted from existing pits (5,004 ML was abstracted from June 1997 to June 1998).			

Note: 1. The area of disturbance that will result from the proposed mining developments has been estimated using the indicative project layout maps presented as Figures 2.1 to 2.8. The actual layout of the Project will vary depending on the results of further exploration and resource delineation as well as the results of ongoing monitoring and research.

ENVIRONMENTAL IMPACTS AND MANAGEMENT

The environmental issues associated with the Project are summarised in Table 2 and described below.

Environmental Management and Reporting

The Proponent's Environmental Management System (EMS) provides a framework for the achievement and systematic management of continual improvement in environmental performance. The EMS is reviewed and evaluated periodically in order to identify opportunities for improvement, and to ensure that it remains relevant to the Proponent's activities. Environmental issues relevant to the operations are identified through biennial technical audits, biennial system audits and an annual management review. Environmental objectives and targets are set on an on-going basis, and are reviewed as part of the business planning process each year.

The Proponent's environmental performance, and its compliance with the Ministerial conditions of approval and the environmental management commitments made for this Project, will be reviewed on an annual basis. The mechanism through which this will be achieved is an Annual Environmental Management Plan (AEMP) that will:

- review the development of the Project during the previous 12 months;
- provide a detailed description of the mining developments proposed for the next 12 months (including the environmental management measures incorporated into the design of the mines and associated infrastructure located on Lake Lefroy); and
- provide a summary of projected activities for the next three years.

The AEMP will be provided to the regulatory authorities on an annual basis for review and comment.

Two years prior to the completion of the life of the Project, the Proponent will review its planning for the closure, decommissioning and rehabilitation of the Project. This review will address, but will not necessarily be limited to, the following:

- the removal or, if appropriate, retention of plant and infrastructure developed as a result of the Project;
- the rehabilitation of any remaining disturbances in the Project Area;
- the development of a "walk away" solution for pits, overburden dumps, causeways, borrow pits, haul roads and other associated infrastructure; and
- identification of any contaminated areas, including provision of evidence of notification to relevant statutory authorities.

The findings of this review will be reported through the AEMP process.

Exploration Phase Impacts

The Proponent will continue to explore Lake Lefroy within its approved exploration and mining leases. Exploration on the lake is mainly conducted using a wide-track aircore rig and percussion rig mounted on a hovercraft (an example of which is shown on the front cover of the PER). The hoverplatform supports the weight of the drill and uses wheels to move across the lake surface. Crawler-mounted diamond drill rigs are also utilised. Causeways are only constructed and used in the final stages of resource definition.

The environmental issues associated with exploration on Lake Lefroy are:

- the risk of drill holes collapsing in soft lake sediments, resulting in a small area of depression;
- potential for spills of hydrocarbons and other drilling fluids;
- generation of noise due to the use of equipment; and
- visual impacts associated with hovercraft tracks and drill castings (drill samples) on the lake.

These impacts are of low significance and are easily managed using standard management practices.

Surface Water and Groundwater

The effect of the proposed mining developments on the surface water and groundwater of Lake Lefroy has been identified as one of the most important issues associated with the Project. The key aspects are considered to be:

- changes to the movement of water across the lake due to the creation of new landforms on the lake bed and along its shoreline; and

- potential impacts on the quality and quantity of surface water and groundwater due to:
  - mine dewatering operations and the subsequent discharge of mine water;
  - the accidental release of pollutants and other chemicals; and
  - run-off from any acid-generating materials.

The lake bed is dry for much of the year. When surface water is present, its movement across the lake's surface is influenced primarily by wind direction. Consequently, water will continue to flow around permanent features such as overburden dumps and abandonment bunds around final voids (where these are to be maintained). The Proponent will design these features such that the flow of surface water around them is not impeded. Flow to some areas (such as within the flood protection bunds) will be restricted or prevented. This impact is not considered to be significant as surface water flow will be reinstated once this infrastructure is removed.

A cone of depression will develop around each of the pits being dewatered, but will be restricted to the vicinity of the pit. The total volume of water being abstracted will vary as dewatering operations commence and cease at the different pits, but will be insignificant compared to the large volumes of groundwater present in the lake system. It is also likely that the shallow aquifer (from which most of the dewatering discharge is originally sourced) will be recharged as the discharge seeps into the lake sediments. Therefore, the impact of dewatering the individual pits and the cumulative impact of the proposed dewatering operations are not considered to be significant.

The volume and quality of the mine water discharged to the lake will be similar to that being discharged by the existing operations at Lake Lefroy. The discharge from these mines is hypersaline and generally has similar physical and chemical characteristics to the lake's surface water. However, the concentration of metals can vary as a function of aquifer geology and may result in the precipitation of low-solubility compounds such as iron silicates. Precipitation of such compounds may cause localised hardening and discolouration of the salt crust. However, stained areas are mantled by precipitated salt when the halite crust re-establishes following flood conditions. Therefore, staining of the salt crust is not considered to be a significant environmental impact.

The amount of salt that will be discharged onto the lake surface will be similar to that discharged by current operations (1.2-2.3 Mtpa) and is small in comparison to the volume of salt in storage in the top 1 m of the halite crust (calculated to be 94 Mt) and salt dissolved within hypersaline water in the near surface aquifer (estimated to be 79 Mt). There will be a short term build-up of salt on the surface at the discharge point, but this will be redistributed within the lake system when the surface salt layers dissolve during flood conditions. Therefore, this is not considered to be a significant impact.

The discharge of mine water to Lake Lefroy will be monitored in accordance with the Proponent's pollution control licence. In addition, the Proponent will continue using the existing surface water monitoring network at Lake Lefroy to monitor surface water flows, levels and quality on a regular basis.

Behaviour of Final Voids

Pits will be backfilled with overburden on completion of mining where possible. Those pits that will remain as open voids will fill with water once dewatering ceases. Water levels in the final voids on Lake Lefroy are expected to recover relatively rapidly to a level slightly below the regional water table (which is located just below the surface of the lake). The rate of recovery and the long term water level in final voids will be influenced by:

- the rate of groundwater inflow from the surrounding aquifer. This is primarily a function of aquifer permeability and will decline as the void water level approaches steady state;
- possible reduction in recharge from the surrounding aquifer due to dewatering of adjacent underground operations; and
- variations in evaporative losses due to factors such as:
  - higher total evaporation due to an increase in surface area of the void water body; and
  - a gradual reduction in evaporation rate as void water salinity increases.

Water quality within the final void water bodies will depend on:

- the balance between evaporative losses and recharge as a result of direct rainfall recharge, stormwater inflow and recharge from the surrounding aquifers;
- the quality and relative quantities of recharge from these sources; and
- possible leaching of salts as a result of wall rock chemical reactions.

It is anticipated that these water bodies will be oxygenated with no significant thermal stratification. They are likely to be neutral in pH throughout the profile. Under such conditions, acid generation and resultant metal mobilisation is unlikely to be a significant issue.

Landforms

Most of the proposed mining developments will be located on the lake bed of Lake Lefroy, which is relatively flat and has a well-developed halite crust. Two of the pits (Thunderer and Phoebe) will be developed in the dune system on the eastern shoreline of Lake Lefroy whilst the Delta Cutback will be developed on Delta Island (a small island comprising gypsum and siliclastic dunes on a basement outcrop).

It is estimated that approximately 420 ha (0.7%) of the surface of Lake Lefroy will be converted to islands and that mine voids will cover approximately 155 ha (0.3%). Approximately eight new islands will be constructed on the lake and Alpha, Beta and Delta Island will be extended using overburden from adjacent mines. Mine pits will be backfilled where possible, but some voids will remain. The extensive network of causeways that currently exist in the Project Area, and those causeways developed as a result of this Project, will be removed when no longer required. The St Ives causeway will be maintained for future use by the public.

The stability of the new landforms (ie. the open pits, abandonment bunds and overburden islands) will depend primarily on the stability of the lake sediments on which these features are located and the erosion potential of the landforms. No significant problems with slope stability are expected but the Proponent will conduct further investigations into the long-term stability of pit slopes to facilitate the management of final voids. The risk of erosion will be minimised by rehabilitating disturbed areas on a progressive basis. Temporary stabilisation measures will be adopted where necessary.

Acid Mine Drainage

The acid generating potential of the ore zones and overburden in the proposed mine pits is low. Though sulphide-bearing bedrock does occur in some areas, the pits will generally not be deep enough to expose this material.

Acid generation testwork is, and will be, conducted as part of the Proponent's routine metallurgical testwork. The results of this testwork will be used to identify any overburden with acid-generating potential. This material will be encapsulated within overburden dumps to prevent acid generation. Ore stockpiles on the lake and its shoreline will be bunded to contain any acidic runoff, if this is likely to occur.

Pits will be backfilled where possible. Any voids that remain after mining are expected to flood to above the natural, *in situ* base of oxidation relatively quickly, thus reducing the potential for acid generation from the pit walls.

Terrestrial Flora and Vegetation

Less than 4 ha of vegetation will be cleared during the development of the Project. Most of the area required for the Delta Cutback pit has already been disturbed by previous mining operations. However, a small area of vegetation (~ 0.3 ha) will be cleared during the development of this pit. Less than 3 ha of vegetation will be cleared during the development of the Phoebe and Thunderer pits. This primarily comprises shrublands and woodlands on deep dunal sands. The vegetation in these areas has been disturbed previously through sand mining and is not known or likely to support Declared Rare Flora (DRF) or Priority Flora.

The Proponent will rehabilitate disturbed areas on a progressive basis to minimise disturbance of flora, vegetation and fauna habitats on the islands and along the shorelines of the Project Area.

Aquatic Flora

The salt-encrusted region of Lake Lefroy is generally devoid of aquatic flora. The playas and claypans that occur adjacent to Lake Lefroy are biologically more productive than the lake itself. The presence of algal mats formed by the filamentous cyanobacteria, *Schizothrix* sp., is an important feature of the playas as they provide a food source for macroinvertebrates and protozoans, and help to reduce erosion by binding sand particles together.

The algal mats formed by *Schizothrix* sp. are common throughout the samphire regions and playas that occur along the shoreline of Lake Lefroy, but do not occur on the halite crust of the lake itself. Consequently, the only impacts on these mats that are likely to occur as a result of the Project will be associated with the development the Phoebe and Thunderer pits on the shoreline of Lake Lefroy. The development of these pits will result in the disturbance of approximately 2.4 ha of this habitat type. This represents an insignificant portion of the total area of suitable habitat in the Lake Lefroy area. Consequently, this disturbance is not considered to be of local or regional significance.

Though little is known about the salt tolerances of *Schizothrix*, it is unlikely to be able to tolerate hypersaline conditions. Therefore, the playas and ephemeral pools adjacent to Lake Lefroy will not be used for any new discharge of mine water.

Vertebrate Fauna

Despite the presence of the existing mining operations, the fauna assemblage of the Kambalda area is considered to be relatively intact where disturbance is low to moderate. The low rocky hills adjacent to the northern shoreline of Lake Lefroy are significantly richer in species than other habitats within the Project Area. These hills will not be impacted by the proposed mining developments. Those habitats with the lowest species richness are the foredunes adjacent to Lake Lefroy that were mined previously for sand (where Phoebe and Thunderer will be developed), Delta Island and the lake bed itself.

The fauna habitats in the Project Area are well represented throughout the region and none are considered to be regionally significant. CALM has advised that the undisturbed natural islands on Lake Lefroy may be locally significant as they may provide breeding sites for bird species, particularly waterbirds. The lake is not an important breeding site for waterbirds but the Proponent will nonetheless minimise disturbance of these islands.

Terrestrial Invertebrates

More than 160 species of terrestrial invertebrates were collected during a 1999 survey of Lake Lefroy. The most abundance species were the ants (49 species), spiders (41 species) and beetles (20 species). Most of the species recorded at Lake Lefroy have been recorded at other salt lakes in the Goldfields region but some species (such as a species of comb spider and two species of tiger beetles) are currently considered to be endemic to Lake Lefroy. However, this may change as other surveys are conducted in the region.

The proposed mining developments may impact on the terrestrial invertebrate fauna of the Project Area through:

- direct disturbance of their habitats through clearing activities or the discharge of mine water;
- changes in primary productivity within the lake which may affect invertebrates at higher levels of the food chain; and
- changes to the structure of vegetation fringing the lake.

These impacts will be highly localised and will not significantly affect the overall diversity or richness of the species inhabiting the lake and its surrounds. The Proponent's commitment to protecting the aquatic flora of the playas and ephemeral pools adjacent to Lake Lefroy will assist in minimising impacts on terrestrial invertebrate populations in these areas.

Aquatic Invertebrates

Data collected to date indicate that aquatic invertebrate productivity in Lake Lefroy proper is limited by the hypersaline conditions of the lake. The most productive habitats are the ephemeral pools and claypans that occur adjacent to the lake (rather than the lake itself). These habitats are productive because of the presence of the dense algal mats formed by *Schizothrix* sp. (as described above under "Aquatic Flora"). Invertebrate species recorded in these habitats include brine shrimps, ostracods and copepods.

The main impact on aquatic invertebrates associated with the proposed mining developments is loss of habitat due to disturbance of the playas and ephemeral lakes. The development of the Phoebe and Thunderer pits will result in the disturbance of approximately 2.4 ha of this habitat. This represents an insignificant portion of the total area of this habitat type in the Lake Lefroy area. Consequently, this impact is not considered to be significant.

Discharging mine water to the playas and claypans adjacent to Lake Lefroy could impact those invertebrate species inhabiting these areas as they may not be able to tolerate the physiochemical conditions that prevail at dewatering discharge sites. However, the Proponent is committed to ensuring that the discharge points for mine dewatering operations are located away from, and do not drain to, these areas. Therefore, the potential impact on aquatic invertebrate communities in the Project Area due to dewatering discharge is not considered to be significant.

Rehabilitation

Those areas disturbed by the proposed mining developments will be rehabilitated on a progressive basis using procedures developed by the Proponent to suit the conditions that exist at Lake Lefroy. These procedures will be modified as appropriate to suit the site-specific conditions of each of the sites to be rehabilitated. Planning for rehabilitation, and the progress made in rehabilitating Project disturbances, will be reported in the AEMP.

Research into the use of lake muds as a growth medium in rehabilitation and the feasibility of using overburden in dune reconstruction will also be conducted. The findings of these research programmes will be reported in the AEMP.

Particulates/Dust

Dust and other particulates will be generated by the Project primarily through:

- drilling and blasting;
- loading, transporting and dumping ore and overburden; and
- the movement of light vehicles, haul trucks, road trains, drill rigs and other vehicles.

Dust will also be generated from exposed surfaces such as ore stockpiles. Saline water will be used for dust suppression except on topsoil stockpiles (where fresh water will be used). Dust is not considered to be a significant issue for the Project.

Hydrocarbon Management

On-site hydrocarbon storage facilities for the proposed mining developments will be designed in accordance with AS1940-1993. Waste oil collected from the workshop area will be transferred to a collection tank for off site disposal.

Detailed hydrocarbon management audits will be carried out annually. A spill response plan and clean-up procedures will be implemented if required. No significant environmental impacts are expected to occur as a result of the storage and use of hydrocarbons in the Project Area.

Greenhouse Gas Emissions

The main source of greenhouse gas emissions for the proposed Project will be the use of diesel fuel during:

- mining and exploration activities;
- the transport of ore to the St Ives Gold Mill;
- the transport of overburden to an overburden management area; and
- pumping for mine dewatering.

The use of explosives will also result in some emissions. The release of carbon through vegetation clearing is not considered significant given the Project's location, and would be balanced by progressive rehabilitation.

The estimated generation of CO_2 over the ten year life of the Project is 906,000 t (based on the emission index for 1998 of 44 kg CO_2/tonne of ore milled). The following measures will be implemented to minimise the potential emissions of greenhouse gases:

- minimising, in the light of other environmental objectives, the haulage distances to either the processing facility or overburden management area; and
- reducing the haulage gradient (within the overall pit design criteria) so as to reduce engine loads and therefore fuel consumption.

The Proponent is committed to continuous improvement of performance in the efficiency of energy consumption, the prevention of energy wastage and abatement of greenhouse gas emissions, and will continue to report energy efficiencies through its annual reporting process.

Noise

Localised noise will be generated during the construction of the Project due to the use of earthmoving machinery, trucks and other equipment. The Project is located in a remote area and is an extension of existing gold mining operations. The increase in noise levels at the site due to proposed mining operations will not be significant.

Sewage and General Refuse

The waste from the offices and other facilities required for this Project will be disposed of by sanitary landfill disposal. The landfill is located adjacent to the St Ives Gold Mill and will accept all non-toxic wastes. Domestic sewage and sullage will be treated either by sewage treatment plant(s) or in septic systems. No significant impacts are expected to occur as a result of waste management and disposal techniques.

Visual Impacts

The proposed mining developments will alter the lakescape through the development of mine voids, additional islands and other infrastructure. However, the Proponent's commitment to progressively rehabilitate disturbed sites within the Project Area will reduce the visual impact of these changes to the lakescape. Therefore, the visual impact of the Project is not considered to be significant.

Aboriginal Heritage

A number of Aboriginal heritage studies have been conducted on and around Lake Lefroy on behalf of the Proponent. No archaeological or ethnographic sites have been identified in the Project Area. Contact between WMC's Community Relations Department and local Aboriginal groups and individuals is made on a regular basis (including regular liaison with the Native Title claimants) and has not identified any contemporary economic, recreational or cultural associations with Lake Lefroy.

It is concluded that the proposed mining developments will not directly or indirectly impact any Aboriginal heritage sites in the Lake Lefroy area.

CONCLUSION

The Proponent's commitment to sound environmental management is reflected in the implementation of its Environmental Policy, its EMS and the Australian Minerals Industry's Code for Environmental Management.

The Proponent has presented its EMS and environmental procedures in the PER to provide the EPA and the public with detailed information on the way in which the proposed mining developments will be managed. In addition, the Proponent has made a range of commitments specific to the environmental management of the Project. These commitments will be implemented to the satisfaction of the EPA.

The EPA and regulatory authorities will be advised of ongoing developments associated with, and the management of, the Project through the AEMP process.

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Table 2

Identification of Environmental Factors

Element	Environmental Factor	Work Required for the Environmental Review of the Project (as identified by the EPA Guidelines)	Environmental Conditions/Impacts	Proposed Mitigation and Management Measures	Predicted Outcome
BIOPHYSICAL					
Biodiversity	Lake Lefroy and its surrounds	The EPA Guidelines require that the Proponent demonstrate that biodiversity will not be compromised by this proposal.	Surveys have been conducted of the terrestrial flora and vegetation, aquatic flora, vertebrate fauna, terrestrial invertebrates and aquatic invertebrates of the Project Area. The results of these surveys are presented in Sections 3.8 to 3.12. The Project will not adversely affect the biodiversity of the Project Area.	No specific measures are required.	Biodiversity of Lake Lefroy and its surrounds will not be compromised.
Nature Conservation Values	Lake Lefroy and its surrounds	The EPA Guidelines require that the Proponent: • identify areas represented in local, regional, national and international reserves or agreements; and • assess the nature conservation values of the Project Area.	National parks, nature reserves, timber reserves and other areas included in the conservation estate in the Kalgoorlie area are shown on Figure 3.16. The Project Area is not included in conservation reserves or agreements and has no significant conservation values.	No specific measures are required.	No impacts on the conservation estate of the Goldfields region.
Terrestrial Flora	Vegetation	The EPA Guidelines require that the Proponent: • conduct baseline studies to identify existing plant communities; • assess potential impacts (direct and indirect) on vegetation (local and regional) as a result of mining and associated activities; • propose measures to manage impacts.	A flora and vegetation survey of the Project Area was completed in 1993 (see Section 3.8). Vegetation is only present in the Project Area on the islands and along the shorelines of Lake Lefroy. Flora and vegetation will be affected by clearing operations. Less than 3 ha of vegetation will be cleared during the development of the Phoebe and Thunderer pits. This comprises shrublands and woodlands on deep dunal sands and a halophytic complex dominated by chenopods and samphires. These communities have been disturbed previously by sand mining. Approximately 0.3 ha of woodland vegetation may be cleared during the development of the Delta Cutback. Most of the area to be developed for this pit has already been disturbed by previous mining operations. Vegetation may also be affected by the use of saline water for dust suppression and if inundated by hypersaline mine water discharge.	• SIG-EP 014: Vegetation and Topsoil Management. • Rehabilitate disturbed areas on a progressive basis. • Bund roads to prevent the egress of saline water to adjacent vegetation. • Use fresh water for dust suppression on topsoil stockpiles. • Position mine water discharge points away from, and will not draining to, fringing vegetation.	No significant impacts.
	Declared Rare and Priority Flora	The EPA Guidelines require that the Proponent: • conduct baseline studies to identify any Declared Rare and/or Priority Flora; • assess potential impacts (direct and indirect) on species as a result of mining activities and construction of infrastructure; • analyse the likelihood of occurrence of taxa not flowering at the time of survey; and • propose measures to manage impacts.	A flora and vegetation survey of the Project Area was completed in 1993 (see Section 3.8). *Acacia kalgoorliensis* (a Priority 3 species) has been recorded in the Project Area but will not be affected by the Project. A DRF species, *Pityrodia scabra*, is known to occur in the Lake Lefroy area but has not been recorded in the Project Area and will not be affected by the Project.	No specific measures are required.	No loss of DRF or Priority Flora species or individuals.
Terrestrial Fauna	Fauna Species	The EPA Guidelines require that the Proponent: • conduct baseline studies to identify existing fauna in the Project Area; • assess potential impacts (direct and indirect) on terrestrial and avian fauna (local and regional) as a result of mining and associated activities; and • propose measures to manage impacts.	Three vertebrate fauna surveys have been undertaken. The results of these surveys indicate that the long history of mining around Lake Lefroy has had little impact on the vertebrate fauna of the area. The fauna species known or likely to occur in the Project Area have also been recorded elsewhere in the Goldfields region. The Project will not result in the loss of any vertebrate fauna species or populations inhabiting the area. The main impact on fauna will be loss of habitat through vegetation clearing. However, the amount of clearing will be minimal (<4 ha) and this is not considered to be a significant impact.	• Minimise vegetation disturbance. • Cover open foundation holes, drill holes and trenches. • Inspect open holes and trenches regularly for trapped fauna and release trapped individuals. • Prohibit firearms and domestic pets in the Project Area. • Rehabilitate disturbed areas on a progressive basis to minimise loss of habitat. • Raise workforce awareness about fauna. • Avoid direct contact with fauna wherever possible. • Park vehicles and machinery only in designated locations to minimise habitat damage. • Discourage off-road recreational activities. • Continue the Proponent's current fauna monitoring programme and feral animal trapping programme.	No significant impacts on fauna habitats or species.

Table 2 (*cont'd*)

Element	Environmental Factor	Work Required for the Environmental Review of the Project (as identified by the EPA Guidelines)	Environmental Conditions/Impacts	Proposed Mitigation and Management Measures	Predicted Outcome
Salt Lakes	Lake Lefroy	The EPA Guidelines require that the Proponent: • assess the potential impacts on Lake Lefroy due to mining and exploration operations occurring on the lake and from construction of associated facilities. Specifically: – the potential impacts on the lake's hydrology and ecology arising from mining in the lake bed and abandonment of the pits; – potential impacts on the lake's ecology arising from construction of the overburden dumps, causeways and bunds; – assess the impacts on lake hydrology and ecology arising from discharges to the lake from dewatering during normal annual lake fluctuations and periodic flooding events known to be important triggers of biological activity; • evaluate the effects of the potential impacts on the functions and environmental values of Lake Lefroy; and • propose measures to manage impacts.	Exploration on the lake may result in: • drill hole collapse; • spillage of hydrocarbons from equipment; • visual impact of tracks and drill castings on the lake; • localised changes in micro-topography due to drill castings left on the lake's surface; • provision of additional fauna habitat and access for feral animals (causeways); • noise; and • dust generation from vehicle movement on unsealed tracks and causeways. Mining and the presence of new infrastructure on the lake will result in changes to the movement of water across the lake due to the creation of new landforms on the lake bed and along part of its shoreline (see Section 5.4.1). Movement of water across the lake surface is wind-driven, and water will flow around permanent features such as overburden dumps and abandonment bunds (where these are maintained). Temporary structures such as causeways will be removed when no longer required, so will not have any longterm effect on surface water flow. Therefore, the impact of the Project on surface water flow is not considered to be significant. There is little or no biological activity on the lake itself as this is limited by the hypersaline conditions of the lake. The habitats adjacent to the lake (i.e. the plant communities and playas that occur adjacent to the lake) are more productive (see Section 3.8-3.12 for further details). Less than 4 ha of vegetation and 2.4 ha of playas will be disturbed by the development of the Project. This is an insignificant portion of the total area of habitat available. Therefore, the impact is not considered to be of local or regional significance. The discharge of mine water to the lake bed may result in localised changes to the quality and quantity of water at the discharge sites. The discharge will be hypersaline and will have similar physical and chemical characteristics to the lake's surface water. The concentration of metals may vary as this is a function of aquifer geology. Localised hardening and discolouration of the salt crust may occur where the lake's surface water and the discharge water have different hydrochemical signatures. There will be a short term build-up of salt on the surface of the lake at the discharge point but this will be redistributed within the lake system during flood conditions. See Section 5.4.2 for further details. Lake Lefroy does not to experience the freshwater phase that occurs at the other lakes following significant rainfall events and that triggers biological activity. Therefore, the impact of dewatering discharge on this factor will not be significant.	• Complete the hydrological investigations by CSIRO. Report the results in the AEMP. • Monitor surface water flows, levels and quality using the existing monitoring network. • Backfill pits. Consider removing abandonment bunds from around final voids. • Remove causeways and other infrastructure when no longer required. • SIG-EP 007: Waste Dump Design, Construction and Water Management. • SIG-EP 008: Hydrocarbon Management Plans. • SIG-EP 013: Development and Review of Site Closure Plans. • SIG-EP 019: Planning, Construction and Maintenance of Access Tracks. • SIG-EP 015: Rehabilitation Objectives and Progress Criteria.	The impact of the Project on the surface water and groundwater of Lake Lefroy is an important issue. Surface water flow will be modified by the changes to the lakescape, but this is not considered to be a significant impact. The Project will not result in significant impacts on the ecology of the lake and its surrounds. Dewatering discharge will cause localised and short term changes to the quality and quantity of water at some discharge points. The salt crust may harden and become discoloured at some discharge points, but this will be highly localised. The impact of this on the hydrology and ecology of the lake is not considered to be significant.

Table 2 (*cont'd*)

Element	Environmental Factor	Work Required for the Environmental Review of the Project (as identified by the EPA Guidelines)	Environmental Conditions/Impacts	Proposed Mitigation and Management Measures	Predicted Outcome
Land	Landform	The EPA Guidelines require that the Proponent: • assess potential impacts of the proposal on the existing landforms; • describe the management of the waste dumps, causeways, bunds and final voids, with regard to their long term stability and potential for erosion; • investigate the stability of excavations and discuss options for their long term management; and • propose measures to manage impacts.	It is estimated that approximately 420 ha (0.7%) of the surface of Lake Lefroy will be converted to islands and that mine voids will cover approximately 155 ha (0.3%). The stability of these features depends primarily on the stability of the lake sediments. A number of studies have been conducted into the stability of lake sediments, and it has been demonstrated that, in sediments 5-15m thick, the potential failure surfaces for open voids would not extend to more than 30m behind the pit crest. The risk of slumping is reduced in those voids that fill with water. Though minor slumps may occur in the early stages of re-saturation, the stability of the sediments is unlikely to be compromised as the salt build-up at on the sediment surfaces would prevent further erosion. See Section 5.6 for further information. The risk of erosion from features such as overburden dumps will be minimised by rehabilitating disturbed areas on a progressive basis. Causeways and other infrastructure will be removed and rehabilitated when no longer required for the Project.	• Rehabilitate disturbances on a progressive basis. • SIG-EP 007: Waste Dump Design, Construction and Water Management. • Conduct further studies into the stability of pit slopes. • Complete the studies by CSIRO into the behaviour of final voids.	Surface water flow will be modified by the changes to the lakescape, but this is not considered to be a significant impact. The management of final voids may be modified depending on the findings of the studies into the behaviour of final voids and the stability of pit slopes.
	Rehabilitation	The EPA Guidelines require that the Proponent describe: • the measures proposed to rehabilitate the impacted areas to an acceptable standard that will integrate the post-mining landform with the surrounding environment; • revegetation programmes; • completion criteria; • rehabilitation programmes to include mining pits, overburden dumps, causeways, bunds and borrow pits; • the removal of infrastructure and clean-up of any contaminated areas.	Impacted areas will be rehabilitated on a progressive basis using the environmental procedures listed in the next column, and as described in Section 2. These procedures will be modified as appropriate to suit the site-specific conditions of each of the sites to be rehabilitated. Planning for rehabilitation and the progress made in rehabilitating Project disturbances will be reported in the AEMP.	• SIG-EP 007:Waste Dump Design, Construction and Water Management • SIG-EP 013: Development and Review of Site Closure Plans • SIG-EP 014: Vegetation and Topsoil Management • SIG-EP 015: Rehabilitation Objectives and Progress Criteria • SIG-EP 023: Rehabilitation Monitoring	Progressive rehabilitation of Project disturbances to meet the standards specified in the AEMP.
POLLUTION MANAGEMENT					
Air	Particulates/Dust	The EPA Guidelines require that the Proponent: • identify existing sources of dust; • assess potential increases in dust resulting from the construction and operation of the mine and associated activities; and • assess potential impacts of increased dust on surrounding vegetation from the construction and operation of the mine and associated activities.	Dust is generated by the existing mining operations through the movement of vehicles on unsealed haul roads and access tracks, and from exposed surfaces such as ore stockpiles. High levels of fugitive dust occur naturally in the region, particularly when high winds occur following dry periods. Dust will be generated during the construction and operation of the Project as a result of earthworks and the movement of vehicles.	• Use hypersaline water for dust suppression on haul roads and access tracks (water trucks). • Use hypersaline water sprays on ore pads and other exposed surfaces if required. • Use freshwater for dust suppression on topsoil stockpiles.	No significant impacts. The Proponent's existing DEP pollution control licence will apply to the proposal. This licence specifies management and limits to control dust generation.
	Greenhouse Gases	The EPA Guidelines require that the Proponent: • detail source(s) and amounts of greenhouse gases released as a result of mining activities; and • propose measures to minimise greenhouse gas emissions.	Total CO_2 emissions at St Ives in 1998 were 135,730 t. The main sources of greenhouse gas emissions for the Project will be the use of diesel fuel during: • mining and exploration activities; • the transport of ore to the St Ives Gold Mill; • the transport of overburden to an overburden management area; • pumping for mine dewatering; and • the use of explosives. The release of carbon through vegetation clearing is not considered significant. Approximately 44 kg of CO_2 is generated per tonne of ore milled. Therefore, it is estimated that 906,000 t of CO_2 will be generated over the 10 year life of the Project.	• Minimise the haulage distances to either the Mill or overburden management areas. • Reduce the haulage gradient (within the overall pit design criteria) so as to reduce engine loads and therefore fuel consumption. • Utilise the competitive tendering process to ensure the use of efficient machinery.	No significant increase in greenhouse gas emissions by St Ives Gold's overall operations as a result of the proposed mining developments.

Table 2 (*cont'd*)

Element	Environmental Factor	Work Required for the Environmental Review of the Project (as identified by the EPA Guidelines)	Environmental Conditions/Impacts	Proposed Mitigation and Management Measures	Predicted Outcome
Water	Groundwater quality	The EPA Guidelines require that the Proponent: • describe the groundwater abstraction for the mining development; • describe the fate of water abstracted in any on-site mine operations; and • propose measures to manage impacts.	The proposed mining developments will be dewatered using in-pit sumps and/or bores, as per current practice. Further investigations are required to determine the dewatering requirements of the proposed pits but it is anticipated that these will be similar to the requirements of the existing in-lake pits. Mine water will be discharged to Lake Lefroy. Four options exist for dewatering discharge, as discussed in Section 2.5.	• Conduct further studies to determine the dewatering requirement for the individual pits. • Direct mine water to settlement ponds prior to discharge. • Monitor discharge quality and quantity.	Localised impacts may occur where the hydrochemical signature of the discharge water is different to that of the receiving water. The conditions of the Proponent's DEP licence include a requirement to conduct water quality monitoring on a three or six monthly basis (depending on the parameter being measured).
	Surface water quality	The EPA Guidelines require that the Proponent: • describe the water requirements for the mining development and other associated operations; • describe the fate of water used in any on-site and mine operations; • discuss options for disposal of runoff to ensure the surface water quality is maintained; • identify contaminants (such as hydrocarbons) discharged to Lake Lefroy; and • propose measures to manage impacts.	Water is required for dust suppression and for drilling. This requirement will be met using hypersaline water from dewatering operations. Potable water for domestic consumption and dust suppression on topsoil stockpiles will be obtained from the Proponent's existing water supply. Hydrocarbons will not be discharged to the lake.	• Bund roads to prevent the egress of saline water to adjacent vegetation. • Use fresh water for dust suppression on topsoil stockpiles. • Contain and collect run-off from workshop areas and washdown bays, and direct it through an oil-water separator. Recycle water through the washbay with no discharge to the lake. Recycle waste oil or disposal by other suitable means. • SIG-EP 008: Hydrocarbon Management Plans. • SIG-EP 003: Spill Response Preparedness. • SIG-EP 005: Emergency Spill Response.	No significant impacts.
SOCIAL SURROUNDINGS					
Public health and safety	Risk and hazard	The EPA Guidelines require that the Proponent describe the methods proposed to manage the final voids, overburden dumps and access causeways.	Addressed under the factors of Landform and Rehabilitation.	Addressed under the factors of Landform and Rehabilitation.	Addressed under the factors of Landform and Rehabilitation.
Social	Road transportation	The EPA Guidelines require that the Proponent describe the transport requirements for the proposal, including anticipated impact on local authority roads.	Ore and overburden will be transported within the Project Area via haul trucks. Ore is transported to the St Ives Mill via road trains. Light vehicle use will also occur. Vehicle movements will be restricted to haul roads and access tracks within the Project Area, and to the St Ives Causeway.	• Restrict vehicle use to haul roads and access tracks. • Discourage off-road vehicle usage.	No significant impacts.
	Recreation	The EPA Guidelines require that the Proponent: • establish the recreational values of Lake Lefroy; and • propose measures to manage impacts.	Recreational users of Lake Lefroy include motorbike riders, walkers and photographers. These users will not be affected by the Project. The Project Area is of limited recreational value due to access limitations. See Section 3.13.2 for further information.	No specific measures required.	No significant impacts.
Culture and heritage	Aboriginal culture and heritage	The EPA Guidelines require that the Proponent: • identify Aboriginal cultural and heritage sites of significance through archaeological and ethnographic surveys of the Project Area and through consultation with local Aboriginal groups and the Department of Aboriginal Affairs; • consult with the Aboriginal people of the area to determine potential impacts of the proposal on cultural associations with the Project Area; and • propose measures to manage impacts.	A number of Aboriginal heritage studies have been conducted in the Lake Lefroy area on behalf of the Proponent (as described in Section 3.13.4). In addition, contact is made with local Aboriginal groups and individuals (including the Native Title claimants) on a regular basis. No sites of significance or importance to Aboriginal people have been identified in the Project Area as a result of these investigations and consultation. The proposed mining developments will not directly or indirectly impact any Aboriginal heritage sites in the Lake Lefroy area.	The Proponent will continue to liaise with Aboriginal groups and individuals on a regular basis.	Aboriginal heritage sites will not be affected by the proposal.

PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY
for
WMC Resources Ltd (St Ives Gold)

1. INTRODUCTION

1.1 THE PROPOSAL

WMC Resources Ltd (WMC) owns and operates gold and nickel exploration, mining and processing operations on and adjacent to Lake Lefroy (and to the east and southeast of Kambalda), Western Australia (Figure 1.1). The gold operations are conducted by St Ives Gold (a wholly owned subsidiary of WMC) and comprise:

- exploration of lake-based and land-based deposits;
- lake-based mining operations comprising:
  - two active mines (Intrepide[1-1] and Santa Ana); and
  - four inactive mines (Revenge, Redoubtable, Delta and South Delta);
- land-based mining operations comprising:
  - four active mines (the Leviathan complex, North Orchin, Africa and Junction); and
  - six inactive mines (Orchin, Lifeboat, Pinnace, Argo, Clifton, Blue Lode);
- a gold treatment plant (the St Ives Gold Mill); and
- administration facilities and other supporting infrastructure.

The nickel operations are conducted by Kambalda Nickel Operations (KNO), which is also a wholly owned subsidiary of WMC. Until early in 1999, KNO operated eight nickel mines in the Kambalda area but currently operates only two mines (Coronet and Lanfranchi/Schmitz) and a treatment plant. The remainder of KNO's mining operations have either been closed or placed on care and maintenance. The treatment plant is currently scheduled to produce 10,000 tonnes per annum (tpa) of nickel concentrate operating on a campaign basis of eight days per month.

The location of the gold and nickel operations is shown on Figure 1.2.

As the Santa Ana and Intrepide gold reserves become depleted, St Ives Gold (hereafter referred to as the Proponent) proposes to develop additional pits on Lake Lefroy to ensure a continuous supply of ore to the St Ives Mill. The location of the proposed mining area is shown on Figure 1.3. To date, 13 potential deposits have been identified within this area, as follows:

- North Shore;
- Formidable;
- Bahama;
- West Intrepide;
- Intrepide South;
- East Yacht Club;
- LT17/Lute;

[1-1] Operations at the Intrepide pit were suspended in April 1999 but are scheduled to recommence in September 1999. Therefore, for the purposes of this report, Intrepide is considered to be an active mine site.

- North Revenge;
- South Revenge;
- West Revenge;
- Delta Cutback;
- Phoebe; and
- Thunderer.

The majority of the pits will be small and will produce approximately 0.3 to 1.0 million tonnes (Mt) of ore, though there is potential for a number of larger pits that will produce around 3.0 Mt of ore (Table 1.1). Overburden will be removed during the mining process at an average strip ratio of 20:1, and will be placed in mined-out pits or overburden dumps.

Table 1.1

Proposed Mining Developments

Deposit	Indicative Timing	Estimated Volume of Ore (Mt)	Estimated Volume of Overburden (Mt)	Estimated Total Volume (Mt)
Bahama	Year 1-3	1.0	20.0	21.0
North Revenge	Year 1-3	3.0	60.0	63.0
Delta Cutback	Year 3-6	0.5	10.0	10.5
Formidable	Year 3-6	0.3	6.0	6.3
South Revenge	Year 3-6	3.0	60.0	63.0
Phoebe	Year 3-6	0.5	10.0	10.5
Thunderer	Year 4-8	1.0	20.0	21.0
West Revenge	Year 5	1.0	20.0	21.0
West Intrepide	Year 5-8	0.4	8.0	8.4
Intrepide South	Year 5-8	3.0	60.0	63.0
North Shore	Year 6-9	1.0	20.0	21.0
East Yacht Club	Year 6-9	3.0	60.0	63.0
LT17/Lute	Year 6-9	3.0	60.0	63.0
Total		**20.7**	**414.0**	**434.7**

The proposed mining developments will also require dewatering operations, access causeways and other infrastructure. The Project will be supported by the Proponent's existing administration, workshops, contractors' compounds and processing facilities. Additional workshop facilities and contractors' compounds may also be established.

Approximately 480 hectares (ha) or 0.9% of the lake's surface have been disturbed by WMC's mining operations to date. At the end of the Project's 10 year life, the additional area of disturbance due to the proposed gold mining developments is estimated to be 254 ha (0.4%). Therefore, the total extent of disturbance that will exist on the lake at the end of the Project's life is estimated to be 734 ha, which represents approximately 1.3% of the lake's surface.

1.2 PURPOSE AND STRUCTURE OF THIS REPORT

Mining developments on Lake Lefroy have, in the past, been assessed and approved on a mine-by-mine basis. Both the Proponent and the Environmental Protection Authority (EPA) recognised that this approach did not adequately address the cumulative impacts which might occur through successive mining developments on the lake and did not give the Proponent the level of certainty it requires for long term planning of its operations on the lake.

Discussions were subsequently held between the EPA, the Department of Environmental Protection (DEP) and the Proponent to determine the approach that would best meet the EPA's requirements for environmental protection and also provide the Proponent with certainty of process. It was determined that the existing formal environmental impact assessment process could be used to establish a framework for future mining developments on Lake Lefroy. It was agreed that the assessment would:

- provide sufficient detail regarding the proposed mining development to enable the relevant environmental factors to be identified and evaluated by the EPA through the environmental impact assessment process;
- identify specific areas on Lake Lefroy that are likely to be targeted for future mining, even though the exact details associated with mining these areas may not be fully understood. The environmental impact assessment process and subsequent environmental conditions published by the Minister for the Environment would provide the framework for consideration and subsequent approval of mining in those areas identified in the assessment but for which specific detail is not available;
- describe the Environmental Management System (EMS), and Environmental Management Plan (EMP) and decommissioning and rehabilitation plans for the Proponent's operations on Lake Lefroy;
- provide for a reporting process by which the EPA and regulatory authorities could be provided with additional detailed documentation on the precise locations and impacts of the proposed mining developments as this information becomes available. This documentation would describe the proposed development and its impacts within the context of the advice provided by the EPA through the formal assessment process and other relevant background documentation. It would be integrated within a revised EMP, and decommissioning and rehabilitation plans would be modified accordingly; and
- accept that the EPA would reserve the right to subject any future proposals to formal environmental impact assessment should it consider this necessary.

To trigger this process, the Proponent referred its proposal for gold mining developments on Lake Lefroy to the EPA in November 1998. The EPA elected to formally assess the proposal as a Public Environmental Review (PER) and issued Guidelines for the preparation of this document (Appendix A). The environmental factors that the EPA believes should be addressed in the PER are listed in Part A of these Guidelines.

The PER is structured as follows:

Section 1	Introduction	Provides background information relevant to the environmental assessment of the proposed mining development.
Section 2	Project Description	Describes the key characteristics of the proposed gold mining developments on Lake Lefroy. The Proponent's current operations at Lake Lefroy are also described to facilitate the assessment of the proposed developments.
Section 3	Existing Environment	Describes the physical, biological and social characteristics and values of the Project Area.
Section 4	Community and Government Consultation Programme	Describes the community and government consultation programme conducted by the Proponent during the preparation of this PER.
Section 5	Environmental Impacts and Management	Describes the environmental impacts associated with the proposed development of individual pits, the cumulative impacts of successive mining developments on the lake and the environmental management procedures that will be implemented to mitigate or manage these impacts.
Section 6	Summary of Environmental Management Commitments	Summarises the Proponent's environmental management commitments.
Section 7	References	Provides a list of references cited in this document.

Technical data and other relevant information are provided in Appendices B to K. The Proponent's EMS is described in Appendix G. The Environmental Procedures relevant to the management of the proposed Project are provided in Appendix J.

1.3 HISTORY

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

The small township of St Ives was established on the St Ives Peninsula in 1920 in an area adjacent to the Proponent's current Mill site. Ore was treated in a State Battery located to the north of this site. Land yachts (dinghies with wheels and sails) were used by the early miners to transport supplies across the lake. The route used by the land yachts closely follows the alignment of the existing causeway. Alternative transport routes were located between Lake Lefroy and Lake Randall, or via

Widgiemooltha. By 1927, all major mining activity had ceased, and the town of St Ives was abandoned (Gresham, 1991).

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

In 1980, exploration on the eastern side of Lake Lefroy (in an area approximately 15 kilometres (km) southeast of Kambalda) revealed a substantial gold ore reserve. Open-cut mining commenced at the Victory mine (now incorporated in the Leviathan complex) in April 1981, and a 0.5 million tonnes per annum (Mtpa) Carbon-in-Pulp (CIP) plant was commissioned in October of the same year. The plant was subsequently expanded to 1 Mtpa. From 1982 to 1988, further exploration drilling resulted in the discovery of other reserves north of Victory along the Lefroy Fault.

The construction of a 3 Mtpa Carbon-in-Leach (CIL) plant began at St Ives in mid-1987 and the plant was commissioned in May 1988. It currently produces approximately 400,000 ounces of gold per annum.

1.4 THE PROPONENT

The Proponent of this Project is:

WMC Resources Ltd (St Ives Gold)
c/- Kambalda Post Office
KAMBALDA WA 6442
ACN 004 184 598

WMC was incorporated as a gold exploration, mining and management company in 1933. Since the 1950s, the company has diversified and expanded the size, range and geographical spread of its operations to become a significant producer and exporter of processed minerals and metals (Figure 1.4).

St Ives Gold is a wholly owned subsidiary of WMC and is currently the third largest gold producing site in Australia. WMC is currently Australia's fourth largest gold producer.

Further information on WMC's operations is available on its web page (www.wmc.com.au).

1.5 OBJECTIVES AND BENEFITS OF THE PROJECT

The objectives of the Project are to:

- develop, operate and rehabilitate the lake deposits in such a way that the environmental impacts associated with these developments are minimised;
- ensure a continuous supply of ore to the St Ives Mill; and
- provide a sufficient resource to secure future investment in the St Ives area.

The proposed gold mining developments will result in:

- funding for scientific research into the ecology of Lake Lefroy (see Section 3.2 of this PER);
- continued employment for approximately 140 WMC permanent employees, 400 contractors, 30 casual employees plus the multiplier effect of their continued employment; and
- revenue for the State and Federal Governments in the form of royalties, taxes and other charges.

The Project is essential to the long-term viability of the Proponent's operations.

1.6 ALTERNATIVE ORE SUPPLIES

The Proponent has evaluated, and will continue to evaluate, alternative ore supplies. The principal alternative to this Project is to increase the amount of ore generated by the land-based operations. Although additional land-based pits are planned or being developed, these alone will not be able to provide an adequate quantity or quality of ore for the St Ives Gold Mill. In order to maintain adequate plant throughput and head grade, the mill utilises a blend of ores from both land- and lake-based pits.

1.7 THE "NO PROJECT" OPTION

The "no project" option would significantly reduce future development options for St Ives Gold and consequently the life of the overall operations. This would in turn reduce employment opportunities with local and regional communities, and State and Commonwealth revenue.

1.8 TIMING OF THE PROJECT

An indicative timing for the development of the gold deposits is provided in Table 1.1. The criteria that will be used to determine the timing and sequence of pit development are:

- ore quantity, grade and characteristics required for optimal mill operation;
- the availability of access infrastructure; and
- the availability of materials for the construction of other supporting infrastructure.

Based on the above, it is anticipated that the Bahama pit and North Revenge series of pits will be the first to be developed.

It is unlikely that more than three pits will be producing ore simultaneously. However, the nature of the operations preceding and following mining will mean that the development and/or rehabilitation of more than three pits could be occurring at any one time.

1.9 MINING TENURE

A range of exploration licences, mining leases and other tenements have been granted on Lake Lefroy (Table 1.2, Figure 1.5). The Proponent's tenements in the Lake Lefroy area comprise:

- Prospecting, Exploration and Miscellaneous Licences administered under the *Mining Act* 1978;
- Mining Leases administered under the *Mining Act* 1978; and

- Mineral Leases administered under the *Nickel Refinery (WMC) Agreement Act* 1968 (the Agreement Act).

The proposed gold mining developments will be located on Mineral Leases administered under the Agreement Act (Figure 1.5).

Table 1.2

Mining Tenements over Lake Lefroy

Tenement Holder	Tenement Type	Area Covered by the Tenements (ha)	Proportion of Lake Area Covered by the Tenements[1] (%)
Acacia Resources Ltd	Exploration Licences	12,907	21.5
Australian Gold Resources Ltd	Exploration Licences	9,394	15.7
Border Resources NL	Prospecting Licence	127	0.2
	Exploration Licence	8,389	14.0
	Mining Lease	127	0.2
I.J. Buchhorn	Prospecting Licence	828	1.4
	Mining Lease	828	1.4
Capella Holdings Pty Ltd	Mining Lease	612	1.0
Central Kalgoorlie Gold Mines NL	Prospecting Licence	127	0.2
	Exploration Licence	8,389	14.0
	Mining Lease	127	0.2
Connaught Mining NL	Exploration Licences	2,350	3.9
Consolidated Gold NL	Exploration Licence	4,691	7.8
Croesus Mining NL	Exploration Licences	7,633	12.7
M.R. Dallacosta	Exploration Licences	3,389	5.6
	Mining Leases	4,014	6.7
R.G. Elms	Mining Lease	759	1.3
Geographe Resources Ltd	Exploration Licences	4,772	8.0
	Mining Leases	3,425	5.7
Insofaras Pty Ltd	Exploration Licence	1,763	2.9
Interbac Australasia Pty Ltd	Mining Lease	958	1.6
Kanowna Consolidated Gold Mines NL	Exploration Licence	3,819	6.4
	Mining Leases	2,351	3.9
Kilkenny Gold NL	Exploration Licence	765	1.3
M.J. McDonald	Mining Lease	759	1.3
Resolute Ltd	Exploration Licence	4,772	8.0
	Mining Leases	3,425	5.7
Sovereign Resources Australia NL	Exploration Licence	8,581	14.3
	Mining Leases	2,353	3.9
The Readymix Group Australia Ltd	Mining Leases	166	0.3
	Miscellaneous Licence	52	0.1

Table 1.2 (*cont'd*)

Tenement Holder	Tenement Type	Area Covered by the Tenements (ha)	Proportion of Lake Area Covered by the Tenements[1] (%)
WMC Resources Limited	Prospecting Licences	1,265	2.1
	Exploration Licences	14,725	24.5
	Mining Leases	25,018	41.7
	Mineral Leases	15,836	26.4
	Miscellaneous Licences	105	0.2
Yamarna Goldfields NL	Exploration Licence	1,566	2.6
A.J. Young	Prospecting Licences	428	0.7

Note: 1. The proportion of Lake Lefroy covered by these leases is an estimate only as some leases include areas adjacent to Lake Lefroy. The total is greater than 100% as some leases overlap other leases.

1.10 REGULATORY FRAMEWORK

The Proponent's proposal for gold mining developments on Lake Lefroy is being assessed as a PER under Part IV of the *Environmental Protection Act* 1986 (as amended). If the Project is approved, the Minister for the Environment will issue a statement that lists the environmental conditions under which the Project will be implemented.

In addition to obtaining approval from the Minister for the Environment, the Proponent will also take into account the legislation and regulations administered by a range of State and Federal Government bodies. Relevant legislation includes those acts and regulations listed in Table 1.3.

Table 1.3

Regulatory Framework

Acts	Regulations	Standards and Codes
• *Nickel Refinery (WMC) Agreement Act* 1968 • *Environmental Protection Act* 1986 • *Mining Act* 1978 • *Mines Safety and Inspection Act* 1994 • *Explosives and Dangerous Goods Act* 1961 • *Health Act* 1911 • *Occupational Safety and Health Act* 1984 • *Occupational Safety and Health Legislation Amendment Act* 1995 • *Rights in Water and Irrigation Act* 1914 • *Conservation & Land Management Act* 1984 • *Wildlife Conservation Act* 1945 • *Soil & Land Conservation Act* 1945 • *Land Act* 1933 • *Bush Fires Act* 1954 • *Agriculture and Related Resources Protection Act* 1976 • *State Planning Commission Act* 1985 • *Australian Heritage Commission Act* 1975 • *Aboriginal Heritage Act* 1972-1980 • *Native Title Act* 1993	• Environmental Protection Regulations 1987 • Environmental Protection (Ozone Protection) Policy 1993 • Mining Regulations 1981 • Mines Safety and Inspection Regulations 1995 • Dangerous Goods Regulations 1992 • Explosives Regulations 1963 • Occupational Health and Safety Regulations 1988	• Australian Minerals Industry Code for Environmental Management • Australian Code of Practice for the Transport of Dangerous Goods by Road and Rail 1992 • Draft Code of Practice for Rural Landfill Management • Australian Standard (AS 1940-1993): The Storage and Handling of Flammable and Combustible Liquids

1.11 ENVIRONMENTAL ASSESSMENT AND MANAGEMENT PROCESS

The environmental assessment process is designed to provide information to the EPA, DEP and other regulatory authorities, as well as the public, about proposed developments with the potential to impact on the natural and social environment. The main stages of this process associated with the assessment of the proposed Project are illustrated on Figure 1.6.

The Proponent referred the proposal for the gold mining developments on Lake Lefroy to the EPA on 2 November 1998. The EPA elected to formally assess the proposal as a PER and has issued Guidelines for the preparation of this document (Appendix A). The environmental factors that the EPA believes should be addressed in the PER are listed in Part A of these Guidelines.

This PER is a public document and will be subject to an eight-week public review period during which time government agencies, private organisations and the public are invited to make submissions to the EPA. The EPA will then assess the proposal with consideration of:

- issues raised by the public;
- the Proponent's response to those issues;
- specialist advice from government agencies;
- the EPA's own research; and
- research undertaken by other expert agencies, if required.

The EPA will then submit its report and recommendations to the Minister for the Environment. This will comprise the EPA's report on the environmental acceptability of the Project and its recommendations regarding the environmental conditions that should apply if the Project is to proceed. The EPA will publish its report and the public may appeal to the Minister against the content of the report or its recommendations.

The final decision on whether the Project may proceed will be made by the Minister for the Environment. Only after the Minister has set the environmental conditions of approval may other regulatory authorities give approvals and construction is allowed to commence.

The Proponent's environmental performance, and its compliance with the Ministerial conditions of approval and the environmental management commitments made for this Project, will be reviewed on an annual basis. The mechanism through which this will be achieved is an Annual Environmental Management Plan (AEMP) that will:

- review the development of the Project in the previous 12 months;
- provide a detailed description of the mining developments proposed for the next 12 months (including the environmental management measures incorporated into the design of the mines and associated infrastructure located on Lake Lefroy); and
- provide a summary of projected activities for the next three years.

Those items for the year in review that will be addressed in the AEMP are:

- the mining activities conducted during the reporting period;
- environmental management activities (including rehabilitation works);
- the findings of environmental investigations and monitoring programmes; and
- environmental incidents, audit findings and corrective actions.

Those items for the forthcoming year that will be addressed in the AEMP are:

- the location and design of the mine pits that will be developed during the 12 month period;
- overburden management techniques;
- the location and layout of any new support infrastructure (such as ore pads, contractor compounds, workshops and offices);
- the alignment and design of any new access causeways and haul roads (including measures for the management of surface water movement);
- the type of mine dewatering operations to be implemented, the location of any new mine water discharge point(s) and the volume and quality of water to be discharged;
- the environmental management and monitoring programmes that will apply to the development of the above components of the Project. Any changes to these made as a result of audits, studies and practical experience will be highlighted;
- the objectives and scope of new environmental studies;
- the closure and rehabilitation activities planned for the year ahead, including:
  - the options considered and the decisions made on the closure and rehabilitation of open voids on the lake;
  - management measures for the open voids (if these are required); and
  - progressive rehabilitation of areas disturbed by the Project to meet the identified post-mining land use(s).

The AEMP will be submitted to the DEP, the Department of Resources Development (DRD), the Department of Minerals and Energy (DME), the Department of Conservation and Land Management (CALM) and the Water and Rivers Commission (WRC) on an annual basis for review and comment.

Two years prior to the completion of the life of the Project, the Proponent will review its planning for the closure, decommissioning and rehabilitation of the Project. This review will address, but will not necessarily be limited to, the following:

- the removal or, if appropriate, retention of plant and infrastructure developed as a result of this Project;
- the rehabilitation of any remaining disturbances in the Project Area;
- the development of a "walk away" solution[1-2] for pits, overburden dumps, causeways, borrow pits, haul roads and other associated infrastructure; and
- identification and remediation of any contaminated areas, including provision of evidence of notification to the relevant statutory authorities.

The findings of this review will be reported through the AEMP process.

[1-2] A "walk away" solution means that the site shall either no longer require management at the time the Proponent ceases operation or, if further management is deemed necessary, the Proponent shall make adequate provision so that the required management is undertaken with no liability to the State.

2. PROJECT DESCRIPTION

This section describes the proposed gold mining developments on Lake Lefroy. A brief description of the Proponent's existing operations on Lake Lefroy is also provided. Whilst these operations have been subject to previous approvals processes, it is considered appropriate to provide this information to set the current proposal in context and to facilitate the assessment of the proposed Project.

2.1 OVERVIEW

The proposed Project comprises the construction, operation and closure of:

- a series of gold mines on Lake Lefroy and its shoreline within the area shown on Figure 1.3;
- overburden dumps;
- dewatering operations for these mines and the discharge of the mine water;
- flood protection bunds;
- access causeways;
- an alternative haulage causeway; and
- supporting infrastructure (such as powerlines and pipelines).

The pits will be mined using open-cut methods though underground mining may be conducted at some of these deposits. This mining development will be supported by existing administration, workshop, power generation and processing facilities at the St Ives Gold Mill. Additional workshop facilities and contractor compounds may also be developed. These facilities will be located on existing disturbed areas (such as backfilled pits or overburden dumps) where possible. No facilities will be constructed on Gamma, Oyster or Coral Islands.

The current layout of the Project Area is illustrated on Figure 2.1 (northern portion) and Figure 2.5 (southern portion). Indicative layouts for the Project based on the development of the 13 deposits are provided as Figures 2.2 to 2.4 (northern portion) and Figures 2.6 to 2.8 (southern portion). The actual layout of these operations during the life of the Project will vary depending on the results of further exploration and resource delineation as well as the results of monitoring and research programmes. Changes to the Project layout will be addressed in the AEMP.

The disturbances that result from the proposed mining developments and associated activities will be rehabilitated on a progressive basis, as described in the following sections. The procedures, completion criteria and monitoring programme relevant to rehabilitation of each component of the Project will also be described in the AEMP.

The key characteristics of the proposed mining developments are summarised in Table 2.1.

Table 2.1

Key Characteristics Table

Element	Description			
Life of Project	Approximately 10 years.			
Size of Orebodies	Approximately 435 Mt of ore and overburden.			
Mining Rate	Approximately 21 Mt of ore and 414 Mt of overburden will be mined during the 10-year life of the Project (see Table 1.1). The annual mining rate will vary.			
Mining Method	Open pit mining using conventional drilling, blasting, loading and hauling techniques. Underground mining may also be conducted at some deposits.			
Depth of Mining	30 – 150 m.			
Strip Ratio	Approximately 20:1.			
Estimated Area of Disturbance[1] (ha)	Current Project Layout	Project Layout at Year 2	Project Layout at Year 6	Project Layout at Year 10
Mine pits	50	105	240	180
Overburden dumps	270	270	400	480
Bunds, causeways and roads	142	150	130	72
Ore pads, settlement ponds and other infrastructure	18	20	35	2
Total	480	545	805	734
Depth to Water Table	At or near surface.			
Mine Dewatering and Discharge	Further investigations are required to determine the volume of mine water to be abstracted from each pit but is likely to be similar to the volume abstracted from existing pits (5,004 ML was abstracted from June 1997 to June 1998).			

Note: 1. The area of disturbance that will result from the proposed mining developments has been estimated using the indicative project layout maps presented as Figures 2.1 to 2.8. The actual layout of the Project will vary depending on the results of further exploration and resource delineation as well as the results of ongoing monitoring and research.

2.2 MINING

2.2.1 Current Mining Operations on the Lake

Mining is conducted using conventional drilling, blasting, loading and hauling methods. The majority of the material mined is either lake sediments or oxidised rock. Blasting is limited and usually confined to the final stages of the mining operations. Flood protection bunds are constructed to prevent surface water inflow (see Section 2.4). The mines are dewatered using in-pit pumps and/or external bores (see Section 2.5).

The Proponent currently conducts gold mining operations on Lake Lefroy at the Santa Ana and Intrepide pits, and previously operated the Redoubtable, Revenge/Delta and South Delta mines (Table 2.2, Plates 2.1 to 2.4). There are no nickel mines on the lake, though the underground workings associated with Beta/Hunt and Victor extend under the lake. These mines are currently inactive or have been closed.

Table 2.2

Summary of Existing Gold Mining Operations on Lake Lefroy

Deposit	Life of Mine	Description of Operations	Total Production to date (Mt of ore)	Approximate Area of Disturbance[1] (ha)
Redoubtable	Open-cut mining was conducted at Redoubtable from 1996 to 1997.	The development of the Redoubtable pit included the construction of a 2.1 km haulage causeway (which also provides access to Intrepide), overburden dumps and other supporting infrastructure. Dewatering operations were conducted at this site for a period of approximately 15 months. The discharge was initially directed to a settling dam and then used for dust control for the lake-based operations. The pit is currently being backfilled with overburden from the Intrepide and Santa Ana pits (Plate 2.2). Prior to backfilling, the northern portion of the pit was about 55 m deep while the southern portion of the pit was about 70 m deep. Approximately 2.2 million bulk cubic metres (Mbcm) of ore and overburden were removed from the pit during construction and operations.	1.38	38
Intrepide	Operations at Intrepide commenced in January 1997 but were suspended in April 1999 as a result of cyclones Elaine and Vance. Mining is currently scheduled to recommence in September 1999.	The pit will be excavated to a depth of up to 100 m, requiring the removal of about 5 Mbcm of ore and overburden. The latter is disposed of to an overburden dump to the west of Alpha Island. Dewatering operations are conducted using in-pit pumps and external bores. Mine water is contained in a settlement pond prior to discharge to Lake Lefroy.	1.66	134
Santa Ana	Mining commenced in February 1998. Santa Ana is an active mine.	Mining at Santa Ana will reach a depth of approximately 100 m. The development of the pit required the construction of 1.75 km long causeway (linking the Intrepide operation with the Santa Ana operation) and a 36 ha overburden dump (Santa Ana Island). Dewatering was conducted prior to and during mining with discharge onto the lake via a settlement pond.	0.36	102

Table 2.2 *(cont'd)*

Mine	Life of Mine	Description of Operations	Total Production to date (Mt of ore)	Approximate Area of Disturbance[1] (ha)
Revenge/Delta	Open cut mining at the Revenge and Delta pits commenced in 1989. Portal development commenced at the Delta pit in 1992 to access the deeper resources at Revenge. The Revenge underground mine operated from 1992 to 1998.	Mine water abstracted during dewatering operations was hypersaline and was discharged to Lake Lefroy via a series of settling dams. The Proponent closed the Revenge underground mine in November 1998. No dewatering has occurred after closure. It is estimated that flooding of the underground workings will take approximately 12 months, with a further five years for the pit to fill to an equilibrium water level.	0.84	138
South Delta	Mining at South Delta pit commenced during 1990 and ceased early in 1995.	Overburden from the open cut operations at South Delta was used to construct Epsilon Island (Plate 2.5). These operations were expanded in 1993 with a southern expansion of the mine.	0.72	55

Note: 1. Area of disturbance includes the mine, overburden dumps, haul roads, causeways, flood protection bunds, ore stockpiles and other disturbances associated with the construction and operation of those sites located on Lake Lefroy.

2.2.2 Design of the Proposed Mine Pits

The dimensions of the proposed mine pits will be determined using pit optimisation software. Factors that will affect the final pit size and shape include:

- the gold price and other economic considerations;
- the gold content (grade) of the ore;
- the ratio of ore to overburden; and
- geotechnical considerations.

The proposed pits will be designed to conform to the WMC's Major Hazard standards which address slope stability, inrushes, ground control and the operation of surface machinery. The results of site-specific geotechnical and hydrogeological investigations will be incorporated into the pit design.

Once the parameters of the optimum pit design have been determined, the design will be drafted and a Project Management Plan will be developed. These will be provided to the DME for approval as per normal approval processes for mine pit design.

When mining is completed, the depth of the pits will vary from approximately 30 m to 150 m below the surface of the lake (depending on the depth of the ore).

2.2.3 Mining Schedule

To date, approximately 21 Mt of gold-bearing ore have been identified within the Project Area. Mining will initially focus on the 13 deposits listed in Table 1.1, but other resources within this area could also be developed following the completion of further exploration drilling.

It is unlikely that more than three pits will produce ore simultaneously. However, the nature of the activities that precede and follow mining may mean that the development of more than three pits could occur at any one time. Mine scheduling will be conducted so as to maximise opportunities for the backfilling of mined-out pits.

2.2.4 Mining Operations

Conventional drilling, blasting, loading and hauling methods will be used in the mining operations. Bench heights will depend on the size of the equipment employed in the various pits. Selective blasting practices will be used within the ore zones to minimise dilution and maximise recovery.

Once the ore has been excavated, it will be loaded onto haul trucks and transported to an ore pad. The ore will then be hauled to the St Ives Gold Mill via road trains.

Mining operations will be conducted on a continuous basis, seven days a week. Blasting will be limited to daylight hours. Flood protection bunds will be constructed to prevent water from entering the pit and creating unsafe working conditions (see Section 2.4).

2.2.5 Pit Closure and Rehabilitation

A decision tree for the assessment of closure options for the mine pits has been developed with consideration of the work by Mallett and Mark (1996) and is presented as Figure 2.9.

Mining operations at a pit generally cease for one or more of the following reasons:

- no mineral resources remain in the pit (i.e. the pit has been mined out);
- operating conditions at the pit significantly constrain, or prevent, mining (e.g. as a result of flooding following a cyclone); and
- the viability of the operations are adversely affected by changes in market conditions.

Those pits that close due to changes in operating and/or market conditions may re-open if these conditions improve. If this happens during the life of the Project, then the pit will be closed temporarily and placed under care-and-maintenance. An inactive pit will also be placed under care-and-maintenance if there are additional mineral resources that could be mined at a later date during the life of the Project or if the pit will be used to gain access to other resources through underground mining. Dewatering operations may continue if further development of the pit is likely to occur within a reasonable timeframe.

Pits that have been closed temporarily or that are under care-and-maintenance will be re-evaluated periodically to determine whether plans for future development are still viable, and whether the current management procedures remain appropriate to the environmental and safety conditions that exist at the pit. Two years prior to the completion of the life of the Project, the Proponent will review its closure and rehabilitation planning to ensure that a "walk away" solution is developed for any mine voids remaining in the Project Area at the end of the life of the Project.

Pits that have been mined out and are not required to provide access for underground mining will be closed. A pit will be backfilled in order to minimise the area of disturbance on the lake if suitable material is available (such as overburden from an adjacent active pit or causeways that are no longer required to provide access). Once a pit has been backfilled, the flood protection bund will be removed and the salt crust allowed to reform. Alternatively, an overburden dump may be developed on a backfilled pit. The dump will be designed to mimic the features of natural islands in the area (see Section 2.3).

A pit will be left as an open void if there is no available source of material suitable for backfilling. In the event that this option is selected, the integrity of the pit's flood protection bund will be reviewed to determine its suitability as an abandonment bund (to minimise the risk of inadvertent access by the public). Remedial work will be conducted if required, and the bund will be landscaped and rehabilitated. Consideration will be given to removing the bunds from around a pit where it can be demonstrated that public safety will not be compromised by doing so.

Pits that are left as open voids (in the short term or long term) may be used to contain discharge from mine dewatering options. The main benefit of this option is that it allows mine water to be discharged without increasing the area of disturbance on the lake.

A closure and rehabilitation plan will be prepared for each pit and will describe:

- the closure option selected for the pit;
- how the closure and decommissioning will be implemented;
- the rehabilitation objectives and completion criteria relevant to the closure options; and
- the monitoring programme that will be implemented to determine progress made in achieving the rehabilitation objectives.

This plan will be included in the AEMP that will be submitted to the regulatory authorities on an annual basis.

2.3 OVERBURDEN MANAGEMENT

Priority will be given to using overburden to backfill mine voids. Overburden may also be used in the construction of causeways, haul roads and ore pads or as foundation material for workshops and contractors' compounds. The remaining overburden will be placed in overburden dumps which will be designed and managed in accordance with SIG-EP 007 in Appendix J. These dumps will be placed on top of backfilled pits in preference to disturbing additional areas on the lake bed. At this stage in the development of the Project, it is estimated that approximately 420 ha (0.7%) of the surface of Lake Lefroy will be converted to islands.

Indicative overburden dump locations for Year 2, 6 and 10 of the Project life are provided on Figures 2.2 to 2.4 (northern portion of the Project Area) and Figures 2.6 to 2.8 (southern portion of the Project Area). The overburden dumps will be designed to complement the geomorphological features of the lake's natural islands. This process has previously been used successfully by the Proponent in the development of Epsilon Island (Plate 2.5) and Omega Island (Plate 2.6), and is described below.

Prior to the commencement of mining, the island's conceptual shape, height and orientation is determined using geomorphic models of natural islands such as Oyster Island (Figure 2.10). The final landform may contain small, internally draining, clay-based saline areas similar to those found on natural islands in the area. These areas were included in the design of Omega Island (Figure 2.11). Elsewhere on the island, surface drainage will be directed to permeable rock areas or down low-angle slopes to assist in the leaching of saline material and to minimise erosion.

The placement of overburden during the construction of a dump will take into consideration the need to encapsulate and isolate any deleterious materials such as acid-generating rock. However, this is unlikely to be a concern in the design of most overburden dumps as the overburden has little or no sulphide content (see Section 3.4.3).

Once the general shape of the island has been determined, a rehabilitation plan will be developed that addresses the following aspects:

- **The micro-topography of the island and direction of sand movement**. While the prevailing winds are from the east and southeast, the strongest winds generally originate from the north and west. Strong westerlies associated with frontal systems move sand and clay particles across Lake Lefroy. These accumulate at locations where their movement is obstructed, resulting in the formation of mounds, dunes and islands. Islands developed from overburden will be designed to trap some of the sand particles being blown across the lake, while at the same time preventing it from sand-blasting newly-established vegetation.

- **The likely source of free-draining sands or other suitable growth media for 'topsoiling' the island**. The Proponent is investigating the suitability of using lake sediments to cap the overburden dumps to enhance their appearance and potentially provide a better growth medium (see Section 5.13). Preliminary observations at the Revenge pit area indicate that the lake sediments provide a suitable growth medium once leached of salt.

- **Selection of plant species to be used in the revegetation of the island**. The floristic composition of the natural islands has been recorded (see Section 3.8) and the results will be used to facilitate the selection of species suitable to the conditions that are likely to exist on the new island. The characteristics of each island's terrain will play a determining role in the type of vegetation to be established on the island. For example, Delta Island consists of a rock core with a veneer of transported dune material developed in well-defined longitudinal (east-west) belts. The central belt comprises red siliceous clay sands supporting low eucalypt woodlands and hummock grasses (*Triodia* spp.) with low scrublands dominated by acacias on the outer gypsiferous dunes.

Details on the design of overburden dumps will be included in the AEMP (see Section 1.11).

2.4 FLOOD PROTECTION

Open pits and portals to underground mines will be bunded to prevent water from entering these areas and creating unsafe working conditions. The bunds around a lake pit are generally placed 50 m to 100 m from the crest of the pit.

The flood protection bunds are currently constructed by the Proponent using lake sediments excavated from within the area proposed for mining (Plates 2.2 and 2.4). The sediments are loaded onto dump trucks and dumped outside of the proposed pit-shell. To prevent equipment from becoming bogged, hard rock is used to sheet both the excavation site and the bund alignment. Haulage routes are sheeted with a layer of hard rock approximately 1 m deep.

As per current practice, any water that collects within the bunded area will be removed through v-drains or trenches that channel water to in-pit sumps or sumps within the circumference of the bund. Water from the sumps will be pumped to settling ponds located on the outside of the bund wall (Plate 2.7). Dewatering bores situated within the bund will also be used as required.

The bunds will remain in place until the completion of mining. If a pit is to be backfilled, the bund will be removed at the end of the backfilling process. The bund will be maintained around those pits that will remain open due to potential for further mining and those mined-out pits that will not be backfilled. The integrity of the bund will be checked on a regular basis and remedial works conducted if required.

2.5 MINE DEWATERING

2.5.1 Dewatering Requirements

Water will enter the proposed mine pits through:

- direct precipitation;
- surface water inflow; and/or
- groundwater inflow.

The pits will be dewatered using in-pit sumps and/or bores. The volume of water to be abstracted from each pit will be determined through further hydrological and hydrogeological investigations, and will be reported in the AEMP. However, it is expected that the dewatering requirements of the proposed pits will be similar to those of existing pits (as described below). The water abstracted from the pits will be hypersaline and will have physical and chemical properties similar to those of the natural lake waters (see Section 3.7.4). However, some variation may occur as water quality is primarily a function of aquifer geology. Mine water will be directed to settlement ponds to remove sediment loads prior to discharge to Lake Lefroy (Plate 2.7).

St Ives Gold currently uses these methods to dewater the Junction, Santa Ana, Intrepide and Argo pits as well as the Leviathan complex, and previously used these methods at Revenge and Redoubtable (Table 2.3). The current location of the discharge points is shown on Figure 2.12.

Table 2.3

St Ives Gold Dewatering Discharge Volumes from June 1997 to June 1998

Mine	Dewatering and Discharge Method	Dewatering Volume
Argo	Operations at Argo have been currently suspended but dewatering is continuing in preparation for further mining in 2000. Dewatering is conducted using an in-pit sump and an external bore. Mine water is discharged directly to Lake Lefroy. The discharge point is located on the shoreline of Lake Lefroy, approximately 1.5km west of Argo.	940 ML
Junction	From 1987 to 1993, groundwater from the mine was discharged to Lake Finn for evaporation. Following increased water production from the mine, a pipeline was installed from Lake Finn to Lake Lefroy. Since April 1993, mine water has been discharged to Lake Finn for settling prior to being discharged to Lake Lefroy.	382 ML
Leviathan Complex	Mine water has previously been discharged to Lake Victory, a playa adjacent to Lake Lefroy and the Thunderer Bund (Plate 2.8). Dewatering is currently being conducted only at North Orchin.	450 ML
Santa Ana	Dewatering was conducted prior to, and is being conducted during, mining with discharge onto Lake Lefroy via a settlement pond.	1,555 ML
Revenge	Revenge closed in 1998. Dewatering during operations comprised underground pumping to surface settlement ponds prior to discharge to Lake Lefroy.	830 ML
Redoubtable	Dewatering operations were conducted for a period of approximately 15 months, with discharge direct to Lake Lefroy. The mine was closed in 1997.	148 ML
Intrepide	Dewatering operations are conducted using in-pit pumps and external bores. Mine water is contained in a settlement pond prior to discharge to Lake Lefroy.	699 ML
TOTAL		5,004 ML

Source: Halpern Glick Maunsell (HGM) (1998a).

St Ives Gold abstracted a total of 5,004 ML of water during dewatering operations in 1997/98, which represents less than 0.7% of the total volume of natural inflow received by Lake Lefroy each year (HGM, 1998a).

KNO previously conducted dewatering operations at the Silver Lake, Otter/Juan, Hunt/Beta, Long and Victor mines (Figure 1.2). From June 1997 to June 1998, approximately 864 ML of water was abstracted from these mines (Table 2.4). Approximately 750 ML of this volume was discharged to Lake Lefroy with the remainder used in the KNO Mill or elsewhere. This represents less than 0.1% of the total volume of natural inflow received by Lake Lefroy each year (HGM, 1998a).

Table 2.4

KNO Dewatering Discharge Volumes from June 1997 to June 1998

Mine	Dewatering and Discharge Method	Dewatering Volume
Silver Lake	Dewatering operations comprised direct discharge from underground workings to Lake Lefroy.	400 ML
Otter/Juan	Water from the underground workings was pumped to an underground settlement pond prior to discharge to Lake Lefroy and an evaporation pond.	< 174 ML
Hunt/Beta	Mine pondage with overflow to Lake Lefroy.	110 ML
Long	Water was pumped from the underground workings to a settlement pond before being reused underground and on the surface. Intermittent discharge to Lake Lefroy also occurred.	86 ML
Victor	Water from the underground workings was pumped to Victor Dam, which acted as a settlement pond prior to intermittent discharge to Lake Lefroy. Most water was re-used by the KNO Nickel Mill.	94 ML
TOTAL		< 864 ML

Source: HGM (1998a)

The discharge of mine water to Lake Lefroy by St Ives Gold and KNO is licensed by the DEP. The licence conditions relevant to dewatering discharge include a requirement to conduct water quality monitoring on a regular basis. The results of the water quality monitoring indicate that discharge water from the nickel and gold mines is similar to the lake water (see Section 5.4.3 for further details).

2.5.2 Discharge Options

Some of the mine water abstracted from the proposed mine pits will be used for dust suppression on the lake but there will be a surplus of water that will require disposal. There are four options for the discharge of mine water to Lake Lefroy, as follows:

- **Discharge to an unconfined area on the lake-bed**. Mine water will be pumped to a settling pond before being transported via a pipeline to the lake and allowed to disperse freely across the surface of the lake. The discharge point will be located sufficiently far from the shoreline so that the brine does not flood the fringing vegetation. This type of discharge is currently being used for the disposal of mine water from Argo and Junction (Figure 2.12, Plates 2.9 and 2.10).

- **Discharge to a bunded area on the lake bed.** Mine water is pumped to a settlement pond located on the lake bed and allowed to seep onto the lake through or under the bund walls. The location of the bunded area will be selected primarily on the basis of proximity to the source of the mine water and the hydrological characteristics of the discharge site. This type of discharge was previously utilised at Revenge.

- **Discharge to a bunded or unbunded area on the lake bed that will be used for mining in the future.** This disposal method is the same as the options listed above but the discharge site will be located in an area proposed for mining in the future. The benefit of this option is that it assists in minimising the area of disturbance associated with the development of the proposed Project. This type of discharge is currently being utilised by the North Orchin pit and the Leviathan complex which discharge to the Thunderer bund, an area that will be mined as part of the development of the Thunderer pit (Figure 2.12).

- **Discharge to an inactive mine pit located on or adjacent to Lake Lefroy.** This will minimise the extent of disturbance and allow the final water level in a mined-out pit to be reached more quickly. For example, mine water was discharged into Orchin pit for a short period prior to the pit being backfilled as part of the North Orchin development.

The preferred option for each of the proposed pits will be selected following consideration of the following factors:

- the environmental risks associated with the use of the potential discharge site;
- visual impacts;
- proximity of the site to an inactive pit or future mine site with sufficient capacity to contain the volume of discharge;
- decommissioning and rehabilitation requirements; and
- the cost of construction and operation (including pumping costs).

Details of the mine dewatering option selected for each pit will be provided in the AEMP (see Section 1.11).

2.6 WATER REQUIREMENTS AND SUPPLY

Water will be required by the Project for dust suppression on haul roads and for drilling. This requirement will be met using hypersaline water pumped from the proposed and existing mine pits. Potable water will be obtained from the existing pipeline located adjacent to the main causeway.

2.7 ACCESS

2.7.1 Causeways and Haul Roads

Existing Access

Access from Kambalda to St Ives is via a 13 km long causeway (Plates 2.3 and 2.5) that was constructed in 1968 to service nickel mines on the southern shores of Lake Lefroy. The causeway was designed to minimise the obstruction of water flow across the lake surface. It incorporates two multi-barrelled culverts located 7.5 km apart and positioned at the two lowest points along the route

(Halpern Glick, 1977). Other causeways are also used to provide access between the lake pits and the main causeway.

Proposed Access

Access to the proposed pits will be through an extension of the existing network of haul roads and causeways. Existing infrastructure will be used where possible but it is likely that new causeways will be required to access most of the proposed pits and support facilities.

Experience has shown that causeways constructed from hard waste rock are best suited to allow vehicles (such as haul trucks) to gain access to the immediate area of the proposed pit excavations. Culverts will be installed in all causeways more than 500 m long. The culverts will have a diameter of 900 mm to allow the movement of hypersaline water around the lake.

Once a causeway is no longer required it will be removed. The material used in the causeway will be disposed of to a mined-out pit or overburden dump. The salt crust will reform as the lake's natural wetting and drying cycle continues.

Numerous narrow causeways were established on the lake during early exploration programmes. These will be removed progressively during the life of the Project.

2.7.2 Alternative Haulage Route

The proposed Project also includes provision to re-route the southern end of the St Ives causeway around the Revenge series of pits. The alignment of this alternative haulage route is shown on Figures 2.3 and 2.7. The portion of this route traversing the lake will comprise a causeway that will generally follow the alignment of the existing powerline corridor and causeway to the west of Delta Island.

This option will only be implemented if further resource delineation at the Revenge deposit identifies a large resource beneath the existing causeway.

2.8 SUPPORT FACILITIES

As indicated in Section 2.1, the Project will be supported by existing administration, workshop and processing facilities at the St Ives Gold Mill. Additional workshops and contractor compounds may also be developed adjacent to some of the lake-based pits. These facilities will be located on existing disturbed areas (such as backfilled pits or overburden dumps) where possible. The natural islands in the area will not be used for these facilities.

Workshop areas and washdown bays will be concreted and bunded so that any runoff is directed to lined sumps and through an oil-water separator. The water is recycled through the washbay, with no discharge to the lake. Waste oil retrieved by the oil-water separator and from equipment servicing will be collected and transported off-site for recycling or disposal by other suitable means, as per the Proponent's current practice.

Waste materials and other refuse will be contained on-site and then disposed of to an approved landfill (see SIG-EP 006 and SIG-EP 018 in Appendix J). Waste reduction, re-use practices and recycling will be implemented where possible. Domestic waste will be treated by the existing on-site sewage treatment plant or septic tanks. Used tyres will be disposed of in accordance with the procedures outlined in SIG-EP 011 (in Appendix J).

All supporting infrastructure (such as buildings and workshops) will be removed from the lake once they are no longer required or at completion of mining. The sites will then be rehabilitated. The decommissioning and rehabilitation of these components of the Project will be addressed in the AEMP (see Section 1.11).

2.9 WORKFORCE

The personnel required for the Project will be drawn from the existing St Ives Gold workforce (which comprises contractors and direct employees) and will be accommodated within the existing facilities at Kambalda or in the region.

Prior to commencing work on the Project, all employees and contractors will be required to complete an induction programme that covers the relevant environmental and occupational health and safety aspects of the Project. A comprehensive competency-based training programme is currently utilised by the Proponent.

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3. EXISTING ENVIRONMENT

3.1 OVERVIEW OF THE PROJECT AREA

Lake Lefroy is one of the many elongated, medium-sized salt lakes that occur in chains on the Yilgarn Craton of Western Australia (Clarke, 1994a). It occurs within the Lefroy Palaeodrainage, a river valley excavated into the Archaean Yilgarn Craton during the Jurassic period and which historically drained from the southwest to northeast (Clarke, 1994a; Handley, 1991) (Figure 3.1).

Lake Lefroy is arc-shaped with an axial length of 59 km and a maximum width of 16 km (Clarke, 1994a). Clarke (1991) reports that the lake has a surface area of approximately 554 km^2 (55,400 ha) and a total catchment of 4,528 km^2 (452,800 ha). Water levels vary seasonally and can be more than 1 m deep after heavy rainfall (Reddell and Dusci, 1997). The lake bed is flat and has a well-developed halite crust that varies in thickness from location to location. It has been estimated that more than 94 Mt of salt is present in the halite crust and shallow aquifer (Clarke, 1994a).

It has been estimated that the lake's surface is completely dry for 25% of the year, and that less than 50% of the lake becomes flooded each year. Typically the depth of water within the lake does not exceed 30 cm, though heavy rain can lead to deeper and more extensive flooding of the lake. Evaporation over the months following a major rainfall event causes the larger surface pools to disaggregate into smaller pools. The location of these pools varies according to the wind direction. As evaporation exceeds precipitation by a factor of 10, eventually all water on the lake's surface will evaporate (Clarke, 1991).

Lake water is hypersaline and neutral to weakly acid with a dominant sodium-chloride signature. Salinities of up to 462,000 mg/L have been recorded in the surface water (Clarke, 1993). The high salinity promotes the settlement of any sediment suspended in the water column. These sediments are mantled with the salt that crystalises out onto the lake floor as the surface water evaporates (CSIRO, 1999b).

The Phoebe and Thunderer pits will be located on the eastern shoreline of the lake (Figure 1.3). This area is characterised by parallel ridges of dunes separated by narrow playas or claypans. The dunes are vegetated by a mosaic of woodland and shrubland communities, and have been disturbed previously by sand mining (see Section 3.8). The playas and mudflats are biologically more productive than Lake Lefroy itself due to the presence of algal mats formed by the filamentous cyanobacteria, *Schizothrix* sp. These algal mats provide an important food source for macroinvertebrates and protozoans, and help to reduce erosion by binding sand particles together. The development of the Phoebe and Thunderer pits will disturb approximately 12ha of playa habitat, but this impact is not considered to be significant as the algal mats are common throughout the samphire region and playas that occur over extensive areas adjacent to Lake Lefroy. Further information on these mats in provided in Section 3.9.

The Delta Cutback will be developed on Delta Island. The island comprises gypsum and siliclastic dunes on a basement outcrop and is vegetated mainly by open eucalypt woodlands (see Section 3.8). Gold mining has been conducted on Delta Island since 1989 and two new islands (Omega Island and Epsilon Island) have been developed in adjacent areas using overburden from these mining operations.

The remainder of the pits will be located on the surface of Lake Lefroy. This salt-encrusted area is devoid of flora species and has a low biological productivity. Some terrestrial invertebrates such as ants, beetles and spiders have been recorded on the lake bed, but tended to be more abundant towards the edge of the lake and in the playas adjacent to the lake (see Section 3.12). The discharge of mine water to the lake surface may change the species composition of invertebrate communities in the immediate area of the discharge but the area affected by the discharge of mine water is likely to be small (~5 ha per discharge point) in comparison to the area of available habitat for these species over the lake and will be recolonised when the discharge ceases.

3.2 LAKE LEFROY STRATEGY

The Lake Lefroy Strategy (the Strategy) was developed as a concept and initiated in 1991 to:

- assess the nature and scope of impacts associated with the development of mineral deposits on Lake Lefroy;
- develop environmental guidelines for exploration and subsequent project development on the lake; and
- determine the type and level of environmental investigations required to support the development and implementation of these guidelines.

In summary, the Strategy provides a framework for undertaking environmental studies on Lake Lefroy and for the development of guidelines for the management of exploration and mining activity on the lake.

From 1991 to 1996, a significant number of studies were undertaken at Lake Lefroy, as summarised in Table 3.1. The findings of these studies have been used to further understand, classify and manage the natural processes of Lake Lefroy and its catchment.

Table 3.1

Summary of Environmental Studies (1991-1996)

Date	Study	References
1991	A comprehensive study of the evolution of the palaeodrainages in the Kambalda region.	Clarke (1991, 1993, 1994a, 1994b, 1994c)
1991	A comparative study of the biota of inland salt lakes of the Kambalda region and coastal lakes of Esperance.	Handley (1991)
1992	Modelling initiatives in the design of waste rock dumps at Kambalda.	Woolard and Valent (1992)
1993 - 1994	Vertebrate fauna monitoring survey in 1993 (Kambalda area) and 1994 (Widgiemooltha area).	Ninox Wildlife Consulting (1995)
1995	Surveys of the invertebrate fauna of Lake Lefroy, Lake Zot and other salt lakes in the vicinity of Lake Zot.	Hudson (1995)
1995	Hydrological investigation for the Kambalda Stormwater Harvesting Project.	Novaplex (1995)
1995 - 1996	Palaeomagnetic dating on the onset of playa sedimentation in Lake Lefroy.	Zheng (1996a)
1995 - 1996	Investigation into the stratigraphy of the Cainozoic sequences encountered in the vicinity of Lake Lefroy and Lake Cowan.	Zheng (1996b)
1996	Review of the waterfowl species likely to occur on the WMC TSFs and development of potential deterrent strategies.	Ninox Wildlife Consulting (1996)
1996	Flora and vegetation studies in the Kambalda area.	E.M. Mattiske and Associates (1996)

In January 1997, a review of the Strategy was conducted by the Proponent in association with representatives from CSIRO, CALM and the University of Adelaide. The objectives of the review were to:

- refine the original objectives of the Strategy;
- review the studies that had been undertaken to date; and
- identify areas where further research and/or investigations would be required.

Those topics identified as requiring further research predominantly related to:

- the biota of Lake Lefroy and its surrounds; and
- surface hydrology and groundwater interactions.

Subsequently, a number of additional studies were commissioned to address these issues (Table 3.2). The studies by CSIRO and Curtin University are on-going. Available findings from these studies and earlier studies have been used to describe the environmental characteristics of the Project Area and its surrounds.

Table 3.2

Summary of Environmental Studies (1997-1999)

Date	Study	References
1997	Characterisation of mine dewatering discharge	WMC Resources Ltd (1997b)
1997	Preliminary inspection of sediment discharge from the Junction mine dewatering discharge line.	WMC Resources Ltd (1997c)
1997	Review of vegetation and flora on the SIG Peninsula.	HGM (1997a)
1997	Assessment of fauna on the SIG Peninsula.	HGM (1997b)
1997	Survey of the natural resources of the rangelands near Kambalda.	Payne et al. (1998)
1998	Assessment of mine dewatering and discharge by KNO and SIG.	HGM (1998a)
1998	Environmental assessment of Lake Lefroy.	HGM (1998b)
1998	Vertebrate fauna monitoring survey at Kambalda and Widgiemooltha.	Ninox Wildlife Consulting (1999)
1998 – current	Studies into the hydrology of Lake Lefroy.	CSIRO (1998, 1999a, 1999b)
1998 – current	Ecological studies of Lake Lefroy.	Brearley (1999), John (1999), Chaplin (1999), Brennan (1999)

A number of project-specific studies were also initiated to support the development of significant deposits identified by the Proponent's continuing mineral exploration program. The results of these studies were reported in the NOIs submitted to the DEP and DME for review prior to the commencement of mining (Table 3.3). These NOIs also described the ongoing development of the Proponent's environmental management concepts and practical experience in undertaking mineral developments in salt lake environments (such as overburden dump design and construction).

Table 3.3

Notices of Intent Prepared for the Proponent's Existing Operations

Report Date	Project	Reference
1989	Revenge Open Pit	Western Mining Corporation Limited (St Ives Gold Mines) (1989)
1991	Revenge Underground Development Proposal	Western Mining Corporation Limited (St Ives Gold Mines) (1991)
1993	Southern extension to the Delta Pit (South Delta Pit)	Western Mining Corporation Limited (St Ives Gold Mines) (1993)
1995	Redoubtable-Intrepide Open Pit Project	Western Mining Corporation Limited (St Ives Gold Mines) (1995)
1997	Amendments to the Redoubtable-Intrepide Open Pit Project	Western Mining Corporation Limited (St Ives Gold) (1997d, 1997e)
1997	Santa Ana Open Pit Project	Western Mining Corporation Limited (St Ives Gold) (1997a)

3.3 CLIMATE

Data from meteorological recording stations at Kalgoorlie and Norseman have been used to describe Lake Lefroy's climate as these are the principal recording stations in the region.

Lake Lefroy has a semi-arid climate with cool winters and hot, dry summers. The mean daily maximum temperature is about 24.5°C and the mean minimum temperature is about 11.0°C. January is the hottest month with a mean daily maximum temperature of approximately 34°C. The mean minimum temperature in summer is around 17°C. During the winter months, the mean daily maximum temperature is approximately 17°C, whilst the mean daily minimum temperature is around 5°C. Frost may occur during the winter months.

The region receives a mean annual precipitation of 264 mm. Yearly rainfall is highly variable, with a 10% probability of rainfall not exceeding 134 mm in any given year (Figure 3.2). The total potential evaporation from Lake Lefroy is estimated to be about 2,700 mm per annum (CSIRO, 1999b).

An analysis of rainfall records by CSIRO (1999b) revealed that the distribution of rainfall in the Kalgoorlie region has two distinct seasons. In winter there are light but consistent showers between April and October, whereas in summer there is heavy but irregular rainfall.

Wind roses for Kalgoorlie indicate generally low wind speeds and a low percentage of calms (Figure 3.3). Winds in summer and autumn are mainly northeasterlies and southeasterlies, whilst winter is dominated by westerlies and northwesterlies. Wind speeds generally do not exceed 30 km/hr, though wind speeds up to 50 km/hr are recorded occasionally. Newbey (1984) reports extreme wind gusts of 138 km/hr (November 1979) and 132 km/hr (October 1955) which were probably related to storm activity.

3.4 GEOLOGY

3.4.1 Regional Geology

The potential of the Lake Lefroy area to host significant gold mineralisation has long been known with historical gold workings located immediately north and south of the salt lake and on Delta Island. Gold mineralisation is known to occur in all rock types in the Kambalda-St Ives area. The more favourable host rocks include dolerite, basalt and interflow sediments such as the Kapai Slate (Reddell and Dusci, 1997).

The Kambalda-St Ives corridor is located in the south-central part of the Norseman-Wiluna Greenstone Belt within the Yilgarn Craton. The corridor forms part of the Kambalda Domain, a structural-stratigraphic rock package within the Kalgoorlie Terrane (Swager et al., 1990). The Kambalda Domain is bound by two major north-northwest trending regional structures; the Zuleika Shear to the west and the Boulder Lefroy Fault to the east (Reddell and Dusci, 1997).

Structures hosting gold mineralisation in the Kambalda-St Ives area are generally oriented north-northwest to north-northeast and are interpreted as third or fourth order shears. They have a limited strike length (up to 1 km) and intersect the main north-northwest fault zones to form a network of shears and faults (Reddell and Dusci, 1997).

The region has undergone multiple deformations and is metamorphosed, with metamorphic grades ranging from upper greenschist facies to lower amphibolite facies (Reddell and Dusci, 1997).

3.4.2 Local Geology

There is a common theme to all of the gold deposits in the Kambalda-St Ives area in terms of structural/metamorphic setting and the alternation style associated with mineralisation. The deposits are generally hosted in structures that include quartz vein arrays, quartz breccia zones and the mylonitic parts of shear zones. The Archaean host stratigraphy does not outcrop and is blanketed by 5 m to 15 m of clastic lake sediments (WMC, 1997d) (Figure 3.4).

The group of gold deposits (including Victory, Defiance, Britannia, Sirius, Orchin, Thunderer, Phoebe, and Revenge) near the southern edge of Lake Lefroy occur adjacent to the Playa Shear zone. The deposits are complex quartz-vein shear zone systems contained within the compressional regime created by flexures on the Playa Shear zone. Gold deposits located toward the northern part of Lake Lefroy (Redoutable, Formidable, Intrepide, Bahama, and Santa Ana) are associated with felsic/intermediate intrusive rocks, and their sheared contacts between mafic and ultramafic lithologies (Figure 3.5) (Reddell and Dusci, 1997).

3.4.3 Acid Generation Potential

Geochemical and mineralogical analysis of ore and waste rock is routinely undertaken by St Ives Gold in order to identify any potential for acid generation. Data collected to date indicate that the overburden has little or no sulphide content and a low potential for acid generation. Any sulphide minerals such as pyrite that do occur are generally associated with zones of mineralisation and are volumetrically very small. These zones also often contain relatively high levels of acid-consuming carbonate minerals.

Confirmation of the low acid-generating potential has been provided by the results of analytical testwork for the existing mines (e.g. Ammtec Ltd, 1998a, 1998b) and by previous waste characterisation studies by Campbell and Associates (1994). It is recognised that the distribution of sulphide and carbonate minerals within fresh Archaean bedrock can be quite variable so acid generation testwork is conducted as part of routine metallurgical testwork. The results of this testwork are used to develop strategies to monitor and isolate any high sulphide material as part of the day-to-day mining operations (see Section 5.8).

Table 3.4 presents typical results for acid generation testwork conducted on the Victory Basalt and Intrepide ultra hard rock ore (Ammtec Ltd, 1998a, 1998b).

Table 3.4

Summary of Results for Acid Generation Testwork for Victory Basalt and Intrepide Ultra Hard Ore Samples

Parameter	Rock Type			
	Victory Basalt (Sample No. 1)	Victory Basalt (Sample No. 2)	Intrepide Ultra Hard Ore (Sample No. 1)	Intrepide Ultra Hard Ore (Sample No. 2)
Total sulphur (%)	1.06	1.06	1.15	1.15
Total Acid Production Potential (kg/t H_2SO_4)	32.6	32.6	35.4	35.4
Acid Neutralisation Capacity (kg/t H_2SO_4)	373.0	396.0	11.2	10.4
Net Acid Production Potential (kg/t H_2SO_4)	-340.4	-363.4	24.2	25.0
Net Acid Generation (kg/t H_2SO_4)	0.0	0.0	18.6	18.7

Source: Amtecc Ltd (1998a,1998b)

The proposed pits will generally not be deep enough to expose fresh, sulphide-bearing ore. Where such material is encountered, it will be mined. Pits will be backfilled where possible (as discussed in Section 2.2 and 2.3). Any voids that remain after mining are expected to flood to above the natural, in-situ base of oxidation relatively quickly, thus further reducing the already low potential for acid generation from the pit walls. In addition, the hypersaline nature of the water will strongly buffer any tendency for changes in pH (K. Berry, pers. comm.).

3.5 PHYSIOGRAPHY

The description of the physiographic units of Lake Lefroy presented in Sections 3.5.1 – 3.5.3 is from Clarke (1994a).

3.5.1 Lake Shores

Erosional processes dominate along the western and northern shores of Lake Lefroy (Figure 3.5, Plate 3.1). Consequently, cliff outcrops of Archaean and occasional Tertiary rocks are characteristic of these areas. The bedrock exposures are interspersed by deltas where streams discharge into the lake. A rock platform covered by sediment veneer from zero to 5 m thick extends for up to 1 km from the lake shore. Islands and rocky knobs protrude above the lake bed from the rock platform.

Such rock platforms or shelves are characteristic of playa lakes on the Yilgarn Craton (Jutson, 1934; Clarke, 1994a).

In contrast, deposition processes dominate along the southern and eastern lake shores (on which the Phoebe and Thunderer deposits are located). Parallel dune ridges, some separated by inter-dune playa lakes, demonstrate how these deposits have accreted through time. Stream courses are either lost in the dune system or have strongly re-entrant estuaries in contrast to the deltas present along the western and northern shore. Most dunes are partly or completely stabilised by vegetation (Plate 3.2 and 3.3). The inter-dune lakes consist of muddy playas, often with microbial mats. The beds of some lakes have been colonised by samphire vegetation. Halite efflorescence is common on the small lakes during summer. Inter-dune lakes exhibit a range of morphologies, but tend to be oval, elliptical or circular in shape (Clarke, 1994a).

The smaller lakes also tend to occur in chains, sometimes within inter-dune swales. This is particularly evident in those inter-dune lakes farthest from the present lake shore (Clarke, 1994a).

Beaches along the shoreline of Lake Lefroy are well defined, and are often characterised by a microrelief resulting from halite and gypsum crystalisation. The asymmetry of the lake shores is a feature recognised by Jutson (1934) who coined the term "billiard table" surface for the rock shelves on the northern and western sides (Clarke, 1994a).

3.5.2 Lake Islands

Islands are common on Lake Lefroy and consist of four types:

- islands that result from outcropping basement, such as the islands that lie immediately south of the mouth of Moorebah Creek;
- islands that comprise relict gypsum dunes, the margins of which may have been eroded to form cliffs (e.g. Alpha, Beta and Gamma Islands, Plate 3.4);
- islands that consist of mixed clay-sand dunes, the largest of which is Landmark Island. These are most common at or near stream estuaries; and
- islands which are a combination of the previous three types, with gypsum and siliciclastic dune accretion onto a basement outcrop. Delta Island is an example of this type (Plate 3.5).

Island shorelines exhibit the same asymmetry as the shorelines of Lake Lefroy, with eroded northern and western shores, and accreted southern and eastern shores (Clarke, 1994a).

Alpha, Beta, Delta and Gamma Island have been disturbed by previous and current mining operations. Oyster, Coral and Landmark Island are relatively undisturbed.

3.5.3 Lake Bed

The bed of Lake Lefroy is flat and corresponds to the top of the capillary fringe of the groundwater table. The mean elevation of the lake bed in the vicinity of the St Ives Causeway is 286 m and topographic relief is less than 2 m. The southern end of Lake Lefroy at Widgiemooltha is slightly lower with an elevation of 281 m. No accurate altimetric data exist for the northeastern end of the lake, but the elevation is probably less than 296 m (Clarke, 1994a).

The bed of Lake Lefroy exhibits several types of microrelief. Bare surfaces of clastic sediment along the northern and western shores of the lake are locally fretted by wind action during summer with deflated material deposited as clay pellet dunes and ripples, particularly in the lee of obstacles such as causeways. Local areas of bedrock are also present in the same areas, commonly eroded to the level of the lake bed but occasionally projecting above it as small knobs. A halite crust up to 10 cm thick, but often no more than 1 cm to 2 cm in thickness, covers approximately 64% of the lake bed. The crust becomes thinner towards the lake shore and lake islands. Tepees, polygons and blisters of halite are common where the crust is thin. Small salt volcanoes 1 cm to 4 cm high develop around vents releasing gases rich in H_2S from sediments beneath the crust, indicating that sulphate reduction is occurring (Clarke, 1994a).

The halite crust partly dissolves during winter flooding and re-crystalises as the water evaporates. Halite crystalising in the water column is reworked by waves into small ripples and very low amplitude megaripples. Rapid cementation of detrital halite occurs through precipitation of interstitial halite crystals (Clarke, 1994a).

3.6 LAND SYSTEMS

A land system is defined as an area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation (Christian and Stewart, 1953). Land systems consist of smaller land units. The relative proportions of constituent land units and their spatial arrangement relative to each other form characteristic patterns on aerial photography and may also be recognisable on satellite imagery (Pringle et al., 1994).

The land systems of the Kambalda region were mapped for WMC by a team from Agriculture Western Australia's Natural Resource Management Services (Payne et al., 1998). The area surveyed by this team covers about 4,910 km^2 of rangelands near the town of Kambalda and is centered on, and includes, Lake Lefroy. 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.

The proposed gold mining developments will occur within the Lefroy Land System (Figure 3.7). This system comprises salt lakes and fringing saline plains, sandy plains and dunes with halophytic shrublands (Table 3.5). These are generally level or have gently inclined slopes. Areas of alluvial plains are subject to sheet flow on the boundary of this land system with other systems (Payne et al., 1998).

Table 3.5

Land Units of the Lefroy Land System

Land Unit	Landform	Soil	Vegetation
Unit 1: Lake Bed	Lake floors.	Highly saline and/or gypsiferous sediments.	Unvegetated.
Unit 2: Saline Plains	Level, highly saline lower plains often adjacent to Unit 1.	Red/brown non-calcareous clays.	Very scattered to scattered low shrublands, *Halosarcia* spp. (samphire) and *Frankenia* spp.
Unit 3: Alluvial Plains	Level saline alluvial plains, marginally higher than Unit 2.	Red deep duplex soils.	Scattered to moderately close halophtic low shrublands with *Atriplex vesicaria, Frankenia* spp., *Maireana* spp., *Cratystylis subspinescens* with sparse taller shrubs such as *Acacia masliniana*.
Unit 4: Sandy Banks	Banks and low rises with uneven surfaces, up to 2 m above surrounding plains (Units 2 and 3).	Red deep sands.	Scattered shrublands with very variable mixtures of halophytic and non-halophytic shrubs.
Unit 5: Loamy Plains	Level plains on the landward margins of the system.	Red deep duplex or red sandy earths.	Very scattered to scattered eucalypt woodlands with *Eucalyptus lesouefii* and *Eucalyptus longicornis*, with many species in shrub layers but dominated by *Eremophila* spp.
Unit 6: Kopi Dunes	Low dunes with gently undulating linear crests and uneven surfaces, gentle side slopes and up to 8 m above the lake beds (Unit 1) and saline plains (Unit 3).	Encrusted gypsiferous sediments with shallow red sand in pockets.	Scattered woodlands or tall shrublands with *Eucalyptus, Casuarina* and *Callitris* spp. and patchy low shrubs such as *Lawrencia helmsii, Frankenia* spp., *Atriplex vesicaria* and *Halosarcia* spp.
Unit 7: Dunes	Generally linear, aeolian deposits up to 10 m high fringing lake beds (Unit 1).	Red deep sands.	Scattered woodlands or tall shrublands comprising *Callitris preissii* subsp. *verrucosa, Eucalyptus platycorys, Acacia ligulata, Dodonea viscosa, Grevillea* spp. with low halophytic and non-halophytic shrubs which occasionally include the spinifex *Triodia scariosa*.
Unit 8: Drainage Zones	Drainage lines, drainage foci and claypans.	Red/brown non-cracking clays.	Low halophytic shrublands in drainage lines; drainage foci with variable halophytic and non-halophytic communities, commonly *Meuhlenbeckia* sp. in centres with dense margins of *Melaleuca* spp. Claypans are unvegetated.

Source: Payne et al. (1998)

The lack of slope means that most of the units within this land system are generally not susceptible to soil erosion. However, the loss of stabilising perennial shrubs may exacerbate wind erosion of the lake margins. The vegetation of this land system is highly preferred for grazing by native and introduced fauna but the survey by Payne et al. (1998) found that the vegetation in the survey area was generally in good condition (except where disturbed by previous or current sand, gold or other mining activities).

3.7 LAKE HYDROLOGY

3.7.1 Hydrological Studies

CSIRO (1999a) reports that early investigations into the hydrology of Lake Lefroy include those of Barnes (undated, 1972, 1974), which were concerned principally with design of safe structures (causeway, dams, mine workings) on Lake Lefroy. The potential for harvesting of stormwater for re-use in mining operations was investigated in a three-volume report by David Flavell of Novaplex Pty Ltd (1995), while a further report by Flavell (1996) assessed the potential yield of selected catchments. In his honours thesis, Johnson (1993) described the use of satellite imagery in the study of the flooding and drying cycle in Lake Lefroy (amongst others).

In 1998, HGM conducted an environmental assessment of Lake Lefroy which summarised existing information on the lake (HGM, 1998b), and also produced a report on the nature of harmless discharge to Lake Lefroy (HGM, 1998a).

A comprehensive study of the evolution of the palaeodrainages in the region was conducted by Clarke from 1987 to 1991. The results of these studies are reported in an internal report to WMC (Clarke, 1991) and published in a series of papers that describe:

- the stratigraphy of the Lefroy and Cowan palaeodrainages (Clarke, 1993);
- the physiography, sediments and hydrology of Lake Lefroy (Clarke, 1994a);
- palaeodrainage evolution (Clarke, 1994b); and
- regional geomorphology (Clarke, 1994c).

CSIRO is currently conducting a two-year study into the hydrology of Lake Lefroy. The objectives of this study include:

- to review and assess the existing knowledge of the surface hydrology of Lake Lefroy;
- to design and implement an environmental monitoring programme to assess the key surface hydrological characteristics of the lake;
- to investigate and determine the groundwater-surface water interaction in the lake;
- to investigate the water balance elements of the lake's hydrology (including evaporation, direct rainfall, surface run-off, groundwater relations and lake storage);
- to review existing data on lake-bed elevation and upgrade the database; and
- to investigate the hydraulic relationship between the surficial aquifer in Lake Lefroy, the deeper aquifer within the palaeochannel, the bedrock aquifer(s) and surface waters within the lake.

CSIRO is also assessing the hydrology of post-mining voids and the impacts of mine dewatering and discharge of mine water onto the lake surface. This study is on-going, with preliminary results presented below.

3.7.2 Surface Water

It has been estimated that the lake bed is completely dry for 25% of the year (Clarke, 1994a). When present, surface water on the lake comes from two main sources:

- direct precipitation; and
- surface runoff (sheet flow) and stream discharge following significant rainfall events.

In addition to the above sources of water, minor inputs to the lake come from groundwater inflow (see Section 3.7.3) and mine water discharge (see Tables 2.3 and 2.4). Water is lost from the lake primarily via evaporation, though some water is lost to Lake Randall via the Lefroy Palaeochannel and through the shallow aquifer (Figure 3.8).

A number of surface watercourses drain into Lake Lefroy, including the Newtown Dam, Compton Dam and Moorebar Dam catchments, Merougil Creek, Yilmia Creek, Muldolia Creek, Ingham's Inlet, Irwan's Inlet and a number of unnamed creeks. Several of these catchments have been investigated previously to determine their potential for stormwater harvesting and preliminary catchment mapping was developed by Novaplex (1995) (Figure 3.9). Additional catchment mapping is being developed as part of the current hydrological studies and will be reported in the AEMP. Flow gauging data has historically been collected in the Newtown, Compton Dam and Moorebar Dam catchments. The regional surface water monitoring network has recently been supplemented by the installation of a network of ultrasonic flow velocity meters (CSIRO, 1998).

The catchments that drain the western and northern shores of Lake Lefroy generally have steeper topography and a higher proportion of rock outcrop than the gentler catchments that drain the eastern and southern shores of the lake. Vegetation in these catchments comprises woodland interspersed by broad plains of saltbush and bluebush, with native pines along creek lines and the lake shore (Novaplex, 1995). Runoff characteristics of the catchments vary considerably: in general, higher proportions of runoff occur from steeper, more rocky catchments, whereas catchments with gentler topography, less outcrop and more poorly developed stream systems (such as Ingham's Inlet) only produce significant runoff after major rainfall events (Novaplex, 1995). The volume of run-off which enters Lake Lefroy from some catchments has been limited by the construction of water storage facilities such as the Moorebar, Newtown and Compton dams.

Water is most likely to flow into Lake Lefroy during widespread heavy rains, when extensive runoff occurs (Clarke, 1994a), though the frequency of runoff as a result of rainfall events depends on a number of factors including:

- rainfall intensity and duration;
- soil moisture conditions;
- catchment area;
- topography;
- vegetation type and density; and
- soil types.

Rainfall events of greater than 30 mm in total and with an intensity of more than 5 mm per day are most likely to produce partial to complete inundation of salt lakes (CSIRO, 1999b). Records indicate that two rainfall events of this magnitude or greater are likely to occur in the Kalgoorlie area each year (Johnson, 1993; Turner et al., 1996). It is predicted that the probability of a maximum daily rainfall event of 160 mm (which is comparable to cyclones Elaine and Vance) is about 5% (CSIRO, 1999b) (Figure 3.2).

The cyclonic events in March 1999 allowed Lake Lefroy's response to a direct rainfall-runoff event to be measured for the first time. Most previous runoff estimates have been based on an assumed runoff coefficient of 0.5 (Halpern Glick, 1967) but preliminary analysis of the lake's response to cyclones Elaine and Vance by CSIRO (1999b) indicates an event-based runoff coefficient of about 0.21. It is estimated that these cyclones introduced approximately 222,000 ML of water to Lake Lefroy as a result of direct rainfall recharge (89,000 ML) and runoff from the surrounding catchments (133,000 ML) (CSIRO, 1999b). This compares to the 5,004 ML of mine water discharged to the lake by St Ives Gold during 1997/98.

Typically the depth of water within the lake does not exceed 30 cm, though heavy rain can lead to flooding of the lake. On the basis of remote sensing imagery, it has been estimated that 10-50% of the lake bed is flooded each year and that the lake is completely dry for 25% of the year (Clarke, 1994a).

Evaporation over the months following a major rainfall event causes the larger surface pools to disaggregate into smaller pools. Wind seiche effects cause the migration of these pools across the surface of the lake, and a cycle of coalescence and disaggregation occurs. The pools become permanently separated as water levels decline, and eventually evaporate completely (Clarke, 1991; CSIRO, 1999b).

3.7.3 Groundwater

Three distinct types of aquifer system have been identified within the Lake Lefroy area:

- a perched water table which forms in bedded gypsum, sand and salt within 2 m of the surface;
- aquifer zones associated with sub vertical porphyry dykes and faults; and
- the major aquifers in the region are palaeodrainage systems such as those intersected by the Argo and Intrepide pits.

Mound springs are absent, but marginal springs are present at:

- Hogans Lagoon, where "low salinity" alkaline water with a pH of 9.4 and a sodium carbonate signature seeps from the lagoon through the confining dune; and
- Loves Find, where highly saline acidic water with a pH of 3.2 seeps from a spongolite outcrop (Clarke, 1994a).

The location of these areas is shown on Figure 3.6.

It is important to recognise that the surface and groundwater systems of Lake Lefroy are in dynamic equilibrium and that water moves between the lake surface and the shallow groundwater system. The primary mechanisms which facilitate the transfer of water (and dissolved salt) between these two systems are:

- infiltration of surface water and mine water discharge though the halite crust; and
- groundwater seepage to surface.

Salama et al. (1992) attributes the salt crust on Lake Deborah East to hydrological barriers preventing the flow of brine from the lake. This does not appear to be the case with Lake Lefroy as groundwater sapping has formed blind gullies in sand dunes along the shore of Lake Randall closest to Lake Lefroy. This indicates that ongoing flow of shallow groundwater from Lake Lefroy to Lake Randall is occurring (Clarke, 1994a).

3.7.4 Lake Water Quality

An analysis of water samples from the Kambalda area was conducted by KNO and reported in Clarke (1994a). Typically, water from the surface of Lake Lefroy and within the Roysalt Formation was found to comprise sodium chloride brines (see Samples 1 to 3 in Table 3.6). Clarke (1994a) reports that these results are similar to those of the more regional surveys reported by Williams and Buckney (1976), Geddes et al. (1981) and De Deckker (1988). These brines become diluted following significant rainfall events, but the salinity rapidly recovers (Figure 3.10).

Clarke (1994a) reports that the pH of the surface waters varies from neutral to weakly acid. Samples from the underlying fractured bedrock aquifers are similar to those from Lake Lefroy but are slightly more acid (Sample 7, Table 3.6). Springs discharging from Tertiary sediments along the lake shore near Loves Find are both highly saline and acid (Sample 10) (Clarke, 1994a).

Water from marginal lagoons is more variable, presumably representing the composition of surface runoff and shallow groundwater away from the lake. For example, water from Hogan's Lagoon is dominated by sodium and carbonate (Sample 6, Table 3.6), while magnesium and chloride ions dominate the water from an eastern shoreline lagoon (Sample 5). Typically, such lagoons are weakly to strongly alkaline and far less saline that either Lake Lefroy or the bedrock aquifers. Low salinity was also recorded in creek water (Clarke, 1994a).

Clarke (1991) reports that surface water samples from Lake Eaton North and Lake Zot were found to be enriched in chloride and sodium and were weakly alkaline (pH 7.2 and 7.1, respectively), but were otherwise broadly similar to Lake Lefroy's surface water.

3.7.5 Sediment Load

Rainfall events such as cyclones Elaine and Vance deliver substantial sediment loads to Lake Lefroy (Plate 3.6) as well as remobilising the salt stored in the halite crust. Photographic records and anecdotal data indicate that the sediment load of runoff following these major storm events is high. CSIRO (1999b) suggests that values in the order of 250 mg/L to 500 mg/L would not be unreasonable. If it is assumed that these events generated a runoff volume of 133,000 ML with a TSS of 250mg/L, this indicates that 33,250 t of sediment were introduced to Lake Lefroy as a result of this single event.

The high salinity of the lake promotes rapid coagulation and settlement of suspended sediments from the standing water column. The sediments are covered by the halite crust that forms as the salts crystalise out onto the lake floor due to surface water evaporation (CSIRO, 1999b). During the inundation following cyclones Elaine and Vance, the salt crust was still evident under 0.75 m of water (B. McDougall, pers. comm.).

Table 3.6

Chemistry of Selected Water Samples from the Kambalda Area

Parameter	Sample[1]										
	1	2	3	4	5	6	7	8	9	10	11
TDS (mg/L)	327,500	462,000	252,100	371,300	75,750	562	303,600	215	20	244,900	34,507
Cl (mg/L)	182,280	182,000	128,000	196,000	37,240	162	157,000	95	9	137,200	18,800
Na (mg/L)	116,000	100,000	69,000	106,000	21,000	140	87,000	54	7	75,250	10.770
SO_4 (mg/L)	10,000	32,400	17,400	21,200	4,900	30	24,200	-	-	9,700	2,715
Mg (mg/L)	2,900	19,500	9,500	14,000	3,150	12	14,000	7	<1	7,175	1,290
Ca (mg/L)	820	275	1,350	330	390	6	340	20	2	1,025	412
K (mg/L)	600	1,900	680	88-0	4,100	4	700	4	1	690	380
CO_3 (mg/L)	22	142	126	28	72	210	-	<1	<1	195	140
Fe (mg/L)	<5	<5	<5	<5	<1	<1	1	-	-	<1	-
pH	6.8	6.8	7.0	6.5	8.2	9.4	6.1	-	-	3.2	-

Source: Clarke (1994a)

Sample details:
1. Lake surface water.
2. Residual pool, NE culvert.
3. Pits in lake at South Widgiemooltha.
4. Revenge test pit
5. Westernmost inter-dune lagoon, eastern end of the causeway.
6. Surface water, Hogan's Lagoon.
7. Orion N percussion hole VD720.
8. Newtown Creek after large flow.
9. Rainwater.
10. Lake shore spring at Loves Find.
11. Seawater (Krauskopf, 1979).

3.7.6 Salt Budget

Lake Lefroy has a well-developed halite crust that is typically 1 cm to 2 cm thick (but can be up 10 cm thick) and which, according to Clarke (1994a), covers approximately 64% of the lake. This crust partially dissolves with the re-introduction of surface water following significant rainfall events, but subsequently recrystalises as the water is lost to evaporation (CSIRO, 1999b). During the inundation following the cyclones Elaine and Vance, the salt crust was still evident under 0.75 m of water (B. McDougall, pers. comm.).

The salt in the halite crust comes from three possible sources (Figure 3.11):

- salts contained in rain and surface run-off (sheet flow and stream discharge);
- windblown dust (including salts deflated from the surface of Lake Lefroy or other playas such as Lake Cowan, or from soils adjacent to the lakes); and
- groundwater (including salts derived from the weathering of bedrock and the inflow of meteoric salts from groundwater aquifers).

There are no data available on the rate, composition or source of windblown dust or on the recharge rate of saline groundwater. However, Clarke (1994a) estimates that approximately 13,000 t of salt is deposited into Lake Lefroy on an annual basis as a result of direct precipitation and precipitation-induced runoff. An average of 5.1 t/km^2 of salt is deposited each year by rainfall alone (based on the salt content of the Kambalda rainwater sample given in Table 3.6). This compares well with the data of Hingston and Gailitis (1976) who calculated that 5.52 t/km^2 of salt was deposited in the Norseman area each year as a result of rainfall.

The amount of salt stored in the halite crust of Lake Lefroy was estimated by Clarke (1994a) to be 15.3 Mt. This estimate assumed that the salt crust covers an area of 354 km^2 (64% of the total area of the lake bed), has an average thickness of 2 cm, and a density of 2.16 t/m^3. If this salt was supplied solely from rainfall and run-off, it would have taken approximately 1,100 years to accumulate.

Salt stored in the near-surface aquifer of Lake Lefroy was estimated by assuming:

- a mean salinity of 356,680 ppm TDS;
- a mean thickness of the Roysalt Evaporite Formation of 1 m;
- a lake area of 554 km^2, and
- a porosity of 0.4.

Using these assumptions Clarke (1994a) estimates that 79 Mt of halite is stored in the shallow aquifer. By adding this total to the amount of salt present in the halite crust, it can be calculated that the total salt mass in Lake Lefroy is 94.3 Mt (Figure 3.11). The actual solute mass could be larger if the near-surface brine pool of Lake Lefroy is connected to those of other lakes in the Lefroy palaeodrainage channel (Clarke, 1994a).

The unknown factors in these calculations include the contribution of saline dust, the amount of salt deflated from the lake surface and removed from the lake floor and the amount of salt lost by groundwater flow east into Lake Randall. However, these order-of-magnitude calculations clearly demonstrate that the salt repository of Lake Lefroy has been a dynamic feature since the inception of evaporite conditions in the Early Pliocene (Clarke, 1994a).

The salt balance of the lake is dynamic, with salt being transferred between the lake surface and the shallow groundwater system as a result of infiltration through the halite crust and groundwater seepage. When considering the "salt budget" of Lake Lefroy, it is therefore important to recognise the dynamic equilibrium that exists between the surface water and shallow groundwater systems, which indicates that the salt balances of these systems should not be considered in isolation from one another.

3.7.7 Mine Void Lakes

Final pit void lakes have been created in mined-out voids at North Orchin and Revenge. With the cessation of mining (and associated dewatering), the water level in these voids have approached close to surface within a period of less than five years. The North Orchin pit has recently been cut back and dewatered to facilitate renewed mining activity.

The water level in the North Orchin void prior to the resumption of dewatering had stabilised at 272m RL. This level was significantly lower than the lake bed and was considered to reflect the effects of ongoing dewatering from the underground Victory complex (Berry, 1999) which has since ceased.

Reconnaissance profile sampling undertaken during November 1998 showed that the North Orchin void water body had the following characteristics:

- no apparent thermal stratification;
- uniform pH and dissolved oxygen profiles throughout the water body; and
- TDS concentrations were between 327,000 mg/L and 333,000 mg/L, with a slight increase towards surface (which may have reflected evaporative concentrations and/or wall rock interactions). These values were approximately 40% higher than the TDS of groundwater in the surrounding aquifers (Berry, 1999).

On the basis of this dataset, it was concluded that no acid generation was taking place in the North Orchin pit and that the potential for metals mobilisation was therefore low.

Water level recovery of the Revenge pit is not yet complete, but the observed rate of inflow indicates that the water level will reach a steady state condition at a level about 290mRL, which is 5m below lake level (Berry, 1999). It is predicted that recovery to steady state conditions in the Revenge pit will take between five and ten years (CSIRO, 1999b; Berry, 1999). The geology and hydrogeology of the North Orchin and Revenge pits are similar (Berry, 1999) and it is therefore expected that the final void water body which develops in the Revenge pit will exhibit similar characteristics to those observed in the North Orchin water body during 1998.

3.8 TERRESTRIAL FLORA AND VEGETATION

3.8.1 Baseline Survey

A baseline flora and vegetation survey of the Lake Lefroy area was conducted in April and August 1993 by E.M. Mattiske & Associates. The objectives of the survey were to:

- collect and identify all vascular plants in the survey area;
- review the conservation status of the vascular plants;

- define and map the plant communities in the survey area;
- define the local and regional significance of the plant communities in the survey area; and
- establish a set of representative monitoring sites.

The methodology utilised for this survey is summarised below.

The vegetation survey comprised a reconnaissance of the survey area and the establishment of monitoring plots measuring 20 m x 20 m (Figure 3.12). The plots were pegged and their locations were recorded using a Global Positioning System. A site description was recorded for each plot and included notes on soil colour, degree of disturbance and the condition of the vegetation.

The information recorded at each plot included detailed line intercept data. The vascular plant species within each plot were recorded by noting the line intercepts with a diagonal of the plot (southeast to northwest for vascular species and southwest to northeast for non-vascular species). These were then expressed as a percentage of the total diagonal distance. Total percentages of live and dead material were calculated to provide a quantitative baseline for future monitoring. Measures of species richness for the vascular species were expressed as the total number of species recorded in each community (Mattiske & Associates, 1996).

Opportunistic collections of flora specimens were made, and time was allocated to searching for rare, threatened or geographically restricted species. All plant specimens collected during the field programmes were dried and fumigated in accordance with the requirements of the Western Australian Herbarium. The specimens were identified in consultation with botanists and plant taxonomists from the Herbarium. Consultation was also conducted as required with botanists and taxonomic specialists based in other States who have expertise in the identification of certain plant families or genera.

3.8.2 Vegetation

The plant communities present on the islands and along the shorelines in the Project Area are described below. The vegetation types present within this area are listed in Table 3.7 and mapped on Figure 3.13.

The lake bed is devoid of vegetation. Vegetation within the lake is restricted to the islands. The same vegetation types are found on Alpha, Beta, Gamma, Oyster and Coral islands, and comprise:

- Community S1 – very open woodland of *Callitris glaucophylla, Acacia ligulata* and *Jacksonia arida* with occasional *Eucalyptus griffithsii* on deep aeolian silica sands (Plate 3.7). *Triodia scariosa* and *Zygophyllum iodocarpum* dominate the sparse ground cover; and
- Community S12 – very open woodland of *Eucalyptus gracilis* and *Eucalyptus trichopoda* with occasional *Casuarina pauper* over sparse mixed shrubs (including *Grevillea acuaria*) and relatively dense cover of spinifex dominated by *Triodia scariosa* on deep aeolian silica sands and gypsum dunes (Plate 3.8).

Communities S1 and S12 also occur on Delta Island, but the main vegetation type on this island is Community S6 – an open woodland of *Eucalyptus platycorys, Eucalyptus salicola* and *Eucalyptus trichopoda* over *Triodia* species on deep dunal sands (Plate 3.9). A small area of Community S3 has also been recorded on the island. This community occurs on disturbed sites adjacent to the salt lake on coarse sands that become wet periodically. It comprises low open scrub of regenerating shrubs including *Melaleuca* species over chenopod species, mixed shrubs and succulents.

The portion of eastern shoreline occurring within the Project Area is characterised by a mosaic of woodland and shrubland communities and small playa lakes. The main plant communities occurring in the vicinity of the Phoebe and Thunderer deposits are communities S1, S3 and S12. A small area of Community S7 (open woodland of *Eucalyptus platycorys* over very sparse mixed shrubs and *Triodia scariosa* on deep dunal red sands) occurs to the west of Phoebe in association with Community S2 (open shrubland dominated by *Jacksonia arida* and *Darwinia* aff. *diosmoides* on pale gritty sands) (Plate 3.10). Other species present in Community S2 include *Calandrinia* spp. and a range of species from the Asteraceae and Poaceae families. This community also supports populations of the Priority Flora species, *Acacia kalgoorliensis* (see Section 3.8.5). These populations will not be affected by the proposed mining developments.

Community S2 also occurs along the fringe of the lake to the northeast of the Thunderer deposit. Communities S6 and H2 are also present in this area. Community H2 is a halophytic complex dominated by chenopod species and *Frankenia pauciflora* that occurs on the seasonally inundated fringes of the playa lakes (Plate 3.11). Other species present in this community include *Maireana pyramidata, Atriplex vesicaria* and *Disphyma crassifolium. Wurmbea dioica* and a range of annual species from the Asteraceae and Poaceae families dominate the plant cover beneath the shrub layer.

Communities S1, S6 and S12 also occur in the Project Area along the western shoreline in the vicinity of Kambalda. However, this area is more hilly than the eastern shoreline, and also supports Community R2 (low mixed shrubland over mixed open herblands on the upper slopes of the banded ironstone hills), Community R7 (open woodland of *Eucalyptus lesouefii* and *Eucalyptus griffithsii* over mixed shrubs and herblands on the rocky hillslopes) and Community F1 (tall open woodland of *Eucalyptus salmonophloia* and *Eucalyptus salubris* with pockets of *Eucalyptus lesouefii* over mixed low chenopod species and sparse shrubs on red clays on broad valley floors). These communities will not be affected by the proposed mining developments.

Communities H1 and H2 (halophytic complexes of *Halosarcia* species) are present over reasonably large, low-lying areas of the western shoreline. Community H1 is dominated by *Halosarcia halocnemoides, Disphyma crassifolium* and *Maireana atkinsiana* (Plate 3.12), whilst Community H2 is dominated by *Maireana pyramidata, Atriplex vesicaria, Frankenia pauciflora* and *Disphyma crassifolium* (Plate 3.11). Annual species from the Asteraceae and Poaceae families also occur beneath the shrub layer of these vegetation types. These communities will not be affected by the proposed mining developments.

Table 3.7

Vegetation Types in the Project Area

Vegetation Type	Description[1]	Alpha Island	Beta Island	Delta Island	Gamma Island	Oyster Island	Coral Island	Western Shoreline	Eastern Shoreline
Shrublands and Woodlands on Deep Dunal Sands									
Community S1	Very open woodland of *Callitris glaucophylla*, with occasional *Eucalyptus griffithsii* over patchy shrubs of *Acacia* species and *Jacksonia arida* ms over a sparse ground cover of *Triodia* species on deep aeolian silica sands.	✓	✓	✓	✓	✓	✓	✓	✓
Community S2	Open shrubland dominated by *Jacksonia arida* ms and *Darwinia* aff. *diosmoides* on pale gritty sands on the fringes of large salt lake systems.								✓
Community S3	Open low scrub of regenerating shrubs including *Melaleuca* species over chenopod species, mixed shrubs and succulents on disturbed aeolian silica sands.			✓	✓				✓
Community S6	Open woodland of *Eucalyptus platycorys*, *Eucalyptus salicola* and *Eucalyptus trichopoda* over *Triodia* species on deep dunal sands.			✓				✓	✓
Community S7	Open woodland of *Eucalyptus platycorys* over very sparse mixed shrubs over *Triodia* species on deep dunal red sands.								✓
Community S12	Very open woodland of *Eucalyptus gracilis* and *Eucalyptus trichopoda* with occasional *Casuarina pauper* over sparse mixed shrubs and relatively dense cover of *Triodia* species on deep aeolian silica sands and gypsum dunes.	✓	✓	✓		✓	✓	✓	✓
Halophytic Communities									
Community H1	Halophytic complex of *Halosarcia* species on the fringes of playa lakes.							✓	
Community H2	Halophytic complex dominated by chenopod species and *Frankenia pauciflora* on the fringes of the playa lakes							✓	✓
Eucalypt Woodlands on the Flats and Low-lying Areas									
Community F1	Tall open woodland of *Eucalyptus salmonophloia* and *Eucalyptus salubris* with pockets of *Eucalyptus lesouefii* over mixed low chenopod species and sparse shrubs on red clays on broad valley floors.							✓	
Shrublands and Woodlands on Rocky Slopes									
Community R2	Low mixed shrubland over mixed open herbland (including annual Asteraceae, Poaceae and Goodeniaceae species) on upper hillslopes.							✓	
Community R7	Open woodland of *Eucalyptus lesouefii* and *Eucalyptus griffithsii* over mixed shrubs and herblands (annual Asteraceae and Poaceae species) on shallow soils on rocky basaltic and quartzite hillslopes.							✓	

Note: 1 As described by Mattiske & Associates (1996).

3.8.3 Local and Regional Significance of Plant Communities

The significance of the plant communities in the Project Area was determined by Mattiske & Associates (1996) with consideration of a range of factors including:

- representation of rare and endangered species;
- local and regional spatial extent of the communities; and
- the number of processes/activities in the area that may affect the condition of the community (such as clearing activities or grazing).

Community S2 (open shrubland dominated by *Jacksonia arida* and *Darwinia* aff. *diosmoides*) is considered to be important as it supports the Priority Flora species, *Acacia kalgoorliensis* (see Section 3.8.5).

The plant communities fringing the salt lakes (communities H1, H2, S1, S2, S3 and S12) are relatively site-specific and therefore restricted in their distribution within the region. The occurrence of Community S7 within the Project Area is limited but this community is well represented in the region.

3.8.4 Vascular Flora Species

Lake Lefroy is located in the Southwestern Interzone (Coolgardie Botanical District) as defined by Beard (1990). The dominant plant families in this region are the Myrtaceae (myrtles), Asteraceae (daisies), Chenopodiaceae (salt bushes) and Poaceae (grasses).

The flora species present on the islands and along the shoreline in the Project Area are listed in Appendix B. These species mainly come from the following families:

- Myrtaceae – 20 species;
- Chenopodiaceae – 20 species;
- Asteraceae – 17 species; and
- Poaceae – 12 species.

Species richness varies between communities due to habitat type and the degree of disturbance (Mattiske & Associates, 1996) (Table 3.8).

The species known to occur in the Project Area are known to occur elsewhere in the Goldfields, such as those locations listed in Appendix C.

Although the proposed Project will result in the clearing of some areas of vegetation, the diversity of vascular flora species in the Project Area will not be adversely affected.

Table 3.8

Flora Species Richness

Plant Community		Total Number of Species Recorded in the Community
S1:	Very open woodland of *Callistris glaucophylla, Acacia ligulata* and *Jacksonia arida* with occasional *Eucalyptus griffthsii* on deep aeolian silica sands.	27
S2:	Open shrubland dominated by *Jacksonia arida* and *Darwinia* aff. *diosmoides* on pale gritty sands on the fringes of large salt lake systems.	20
S3:	Open low scrub of regenerating shrubs including *Melaleuca* spp. over Chenopodiaceae spp., mixed shrubs and succulents on disturbed areas of aeolian silica sands.	19
S6:	Open woodland of *Eucalyptus platycorys, Eucalyptus salicola* and *Eucalyptus trichopoda* over *Triodia* spp. on deep dunal sands.	7
S7:	Open woodland of *Eucalyptus platycorys* over very sparse mixed shrubs over *Triodia* spp. on deep dunal red sands.	30
S12:	Very open woodland of *Eucalyptus gracilis* and *Eucalyptus trichopoda* with occasional *Casuarina pauper* over sparse mixed shrubs and a relatively dense cover of spinifex on deep aeolian silica sands and gypsum dunes.	16
H1:	Halophytic complex of *Halosarcia* spp. on the fringes of playa lakes.	18
H2:	Halophytic complex dominated by Chenopodiaceae spp. and *Frankenia pauciflora* on the fringes of playa lakes.	16
F1:	Tall open woodland of *Eucalyptus salmonophloia* and *Eucalyptus salubris* with pockets of *Eucalyptus lesouefii* over mixed low Chenopodiaceae spp. and sparse shrubs on red clays on broad valley floors.	26
R2:	Low mixed shrubland over mixed open herbland on upper hillslopes.	42
R7:	Open woodland of *Eucalyptus lesouefii* and *Eucalyptus griffthsii* over mixed shrubs and herblands on shallow soils on rocky basaltic and quartzite hillslopes.	31

3.8.5 Priority Flora

One of the plant species recorded in the Project Area, *Acacia kalgoorlienisis*, is listed in the Declared Rare and Priority Flora Database as Priority Three – Poorly Known Taxa. Priority Three taxa are known from several populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declation as 'rare flora' but are in need of further survey.

Acacia kalgoorliensis has been recorded in Community S2 (open shrublands of *Jacksonia arida* and *Darwinia* aff. *diosmoides*) at the western end of the southern shoreline in the Project Area. This species has also been recorded elsewhere in the Kambalda area in *Eucalyptus salubris* var. *salubris* woodlands on a variety of soil types (Mattiske & Associates, 1996) and is known to occur in the Broad Arrow, Mt Hunt, Kalgoorlie, Kanowna, Marvel Loch, Laverton and Lake Carey areas as well as on Hampton Hill Station. The populations in the Project Area will not be disturbed by the proposed mining developments.

One Declared Rare Flora (DRF) species, *Pityrodia scabra*, is known to occur in the Lake Lefroy area but has not been recorded within the Project Area. Nine populations comprising approximately 940 plants occur at the southern end of Lake Lefroy and are managed by the Proponent in accordance with a management plan prepared by WMC Resources Limited (1998).

3.9 AQUATIC FLORA

3.9.1 Methodology

A baseline survey of the aquatic flora of Lake Lefroy was undertaken by Curtin University of Technology in February 1999 (John, 1999). The objectives of the survey were to:

- describe the aquatic flora of Lake Lefroy, Lake Cowan and Lake Zot, with emphasis on algal mats (micro- and macro-algae) and submerged and emergent macrophytes; and
- establish a series of representative monitoring sites.

Two reference sites and four monitoring sites were established at Lake Lefroy (Figure 3.12). The reference sites corresponded to the two references sites established by CSIRO in 1999 (referred to as the Northeast and Southwest Reference Sites).

As there was no standing water at these sites at the time of the survey, sampling at these sites was restricted to the collection of sediment cores up to 10 cm deep and samples of the cryptogamic crust. Additional samples of the cryptogamic crust were collected in the peripheral and samphire zones of Lake Lefroy. Sediment cores and cryptogamic crusts were also collected from sites at Lake Zot and Lake Cowan.

3.9.2 Results

The results of the study by John (1999) indicate that the salt-encrusted region of Lake Lefroy is generally lacking in aquatic flora. However, a wide range of species (bacteria, cyanobacteria, diatoms and ciliates) can be found during the wet period in the ephemeral pools and playa lakes adjacent to Lake Lefroy. These species are adapted to a hypersaline environment and a regime of wetting and drying.

The dominant feature of the algal flora in these habitats is the filamentous cyanobacteria, *Schizothrix* sp. which forms algal mats (Plates 3.13 and 3.14). These mats have two important functions in the playa ecosystem. Firstly, the mucilaginous sheaths of the trichomes bind sand particles together and prevent sand erosion. Secondly, the mats provide the basis of the food chain within playas and ephemeral lakes. Bacteria utilising the organic materials provided by the mucilage multiply rapidly and provide a food source for macro-invertebrates and protozoans further up the food chain (John, 1999). Some macro-invertebrates, such as brine shrimp, may also graze the mat surfaces directly (Chaplin, 1999).

The algal mats formed by *Schizothrix* sp. are common throughout the samphire regions and playas that occur along the shoreline of Lake Lefroy, but do not occur on the halite crust of the lake itself. Consequently, the only impacts on these mats that are likely to occur will be associated with the development the Phoebe and Thunderer pits on the shoreline of Lake Lefroy. However, the loss of a small area of suitable habitat for the algal mats is not considered to be significant as there is a great deal of homogeneity of ecological conditions within the playas and ephemeral lakes adjacent to Lake Lefroy.

Other cyanobacteria common in the samples from Lake Lefroy were *Oscillatoria earlie*, *Chroococcus* sp., *Spirulina* sp., *Phormidium* sp. and *Anabaena* sp. The monitoring sites along the causeway are also characterised by two colonial coccoid cyanobacteria, *Gomphosphaerium* and *Caelosphaerium*. Diatom assemblages were generally dominated by *Amphora coffeaeformis* (Plate 3.15). Other species of diatoms were *Navicula durrenbergiana, Amphora ventricosa, Nitzschia palea* and *Hantzschia virgata.*

Two varieties of ciliates were recorded at the Northeast Reference Site. Ciliates were only sparsely distributed through, or absent from, samples from the remainder of the sites.

The survey of the aquatic flora of Lake Lefroy conducted by John (1999) found that the aquatic flora species present in the Project Area were recorded elsewhere at Lake Lefroy and also at Lake Cowan and Lake Zot. For example, *Schizothrix* was present at Southwest and Northeast Reference Sites, Lake Cowan and Lake Zot (though it was less abundant at Lake Cowan). A small coccoid bacteria identified as *Synecoccus* was common in the samples from Lake Zot, as were the diatoms *Amphora coffeaeformis* and *Amphora ventricosa*. Two species of the filamentous cyanobacteria *Oscillatoria* were common in samples from Lake Cowan and diatoms were represented in moderate numbers.

The study concluded that the aquatic flora species present in the Project Area are well represented elsewhere within the Lake Lefroy system and other lake systems in the region. Consequently, disturbances associated with the proposed mining developments will not reduce the diversity of these species at Lake Lefroy or in the region.

3.10 VERTEBRATE FAUNA

3.10.1 Baseline Surveys

Three vertebrate fauna surveys have been undertaken in the Project Area. The first survey was conducted by Ninox Wildlife Consulting (Ninox) in 1993, with a follow-up survey in 1998. In addition, a vertebrate fauna habitat assessment was undertaken by HGM (1997b).

Vertebrate Fauna Species Inventory

The objectives of the 1993 survey by Ninox included the following:

- establish and sample a series of representative fauna monitoring sites;
- produce a comprehensive inventory of the vertebrate fauna of the study area;
- provide an assessment of the regional and local conservation significance of the fauna (with reference to earlier published and unpublished studies);
- review the relationship between fauna communities and the major vegetation and soil types of the study area (based on their relative species richness and abundance);
- assess the impact of operations on fauna;
- assess rehabilitation areas; and
- develop habitat indices for use in impact assessment (see Section 5.10).

Sampling was conducted from 28 April to 6 May 1993 and seven monitoring sites were established within the study area (Table 3.9, Figure 3.10). Four of these sites (KFS1, KFS2, KFS3 and KFS5) are located within the proposed mining area. The three remaining sites are located to the southeast of this area.

Two of these sites (KFS3 and KFS5) were chosen as representative of disturbed areas. KFS3 had been used for sand extraction with minimal natural regeneration. KFS5 had been impacted by alluvial gold mining between 1896 and 1916, but has regenerated. All of the other sites exhibited relatively low levels of disturbance (Ninox, 1995).

Table 3.9

Fauna Monitoring Sites

Fauna Site Code [1]	Description
KFS1	Delta Island. Supports an Open Woodland of *Eucalyptus gracilis* and *Eucalyptus playtcorys* with occasional *Callistris glaucophylla* over a mixed shrub layer *of Grevillea acuaria, Acacia ligulata, Acacia hermiteles, Senna artemisoides* ssp. *filifolia* and *Eremophila* species with a relatively dense ground cover of *Triodia scariosa* on deep aeolian silica sands and gypsum. Sparse leaf litter, numerous logs. Relatively low disturbance.
KFS2	Foredune adjacent to Lake Lefroy supporting an Open Woodland of *Callistris glaucophylla* with an occasional *Eucalyptus* over a patchy low shrubland of *Acacia ligulata, Grevillea acuaria* and *Jacksonia arida*. Patchy ground cover of *Triodia scariosa* on deep aeolian silica sands. Some flow-on of fauna from contiguous littoral zone of chenopod shrublands. Patchy deep *Callistris* leaf litter, few logs. Low disturbance.
KFS3	Lake Lefroy foredune and littoral zone supporting a habitat originally equivalent to KFS2 (above) but exploited for sand extraction. Small remnants of the original vegetation present, but patchy regeneration of *Acacia ligulata, Jacksonia arida* and *Darwinia* aff. *diosmoides* and chenopod species on deep aeolian silica sands. The site is dominated by bare ground with pavement exposed in parts. Some flow-on of fauna from adjacent woodland and littoral zone of chenopod shrubland. Minimal leaf litter, some logs. Extremely disturbed, original habitat wholly transformed.
KFS4	Tall Open Woodland of *Eucalyptus salubris* and occasional *Eucalyptus salmonophloia* over a mixed shrub layer of *Eremophila scoparia* and other *Eremophila* species, *Santalum acuminatum, Dodonaea lobulata*, grasses and ephemeral plants on deep, loamy, silica sands with a high clay content and calcareous nodules. Patchy leaf litter, numerous logs. Low disturbance.
KFS5	Low granite/basalt hill, moderate in-situ weathering. Open Woodland of *Eucalyptus lesouefii* and occasional *Eucalyptus griffithsii* over a very mixed shrub layer of *Eremophila* species, *Acacia* species, *Dodonaea lobulata, Santalum acuminatum* and *Santalum spicatum* as well as chenopods (including species of *Atriplex* and *Maireana*) on shallow rocky soil. Some bare rocky ground and occasional thickets of mixed shrubs in sheltered gullies with deeper soils. Patchy leaf litter, some logs. Relatively high disturbance with exposed mining shafts pre-dating WMC activity.
KFS6	Open Woodland of mallee *Eucalyptus platycorys* and *Eucalyptus leptophylla* over sparse low shrubs of *Eremophila* species, *Westringia rigida* and *Grevillea heugelii* over relatively dense *Tridoia scariosa* on deep silica sands. Patchy leaf litter, some logs. Low disturbance.
KFS7	Low basalt hill, high in-situ weathering. Closed shrubland of *Eremophila scoparia* and other *Eremophila* species, *Acacia erinacea, Atriplex* and *Maireana* species, *Westringia rigida* and *Exocarpus aphyllus* with emergent *Eucalyptus torquata* and occasional *Casuarina cristata* on loamy soils with somew rocky areas. Patchy leaf litter, numerous logs. Relatively low physical disturbance despite proximity to a haul road.

Source: Ninox (1995)

Note: 1 See Figure 3.12 for the location of these sites.

Ninox collected data using both systematic and inventory sampling techniques. Systematic sampling is the collection of data over a fixed period of time in an area of known size and of a discrete vegetation type. The resulting data were used as a standardised base for site comparisons within each area. Inventory sampling includes all opportunistically gathered, non-systematic data such as that recorded during site reconnaissance or whilst the survey team traversed the study area. The same methodology was applied during the 1998 follow-up survey.

The total sampling effort is summarised in Tables 3.10 and 3.11. The combined results of the systematic and inventory sampling were used to produce a comprehensive inventory of both resident and nomadic fauna.

Table 3.10

Total Systematic Sampling Effort for Fauna Monitoring Sites

Sampling Method	Number of Trap Nights	
	1993	1998
Systematic Sampling		
Pit traps	560	420
Elliott traps	672	420
Cage traps	-	126
Total number of trap nights	**1,232**	**966**

Source: Ninox (1995, 1999)

Table 3.11

Total Inventory Sampling Effort for Fauna Monitoring Sites

Sampling Method	Minimum Number of Hours	
	1993	1998
Bird area search	31.5	26.25
Hand foraging	28	26.25
Total number of hours	**59.5**	**52.5**

Source: Ninox (1995, 1999)

Vertebrate Fauna Habitat Assessment

Mapping of the vertebrate fauna habitats of the St Ives Peninsula was conducted by HGM (1997b). Preliminary identification of these habitats was conducted using aerial photography of the site. Ground truthing was then undertaken with data recorded on the characteristics of the vegetation, landform, soil features and microhabitats at each site.

Broadly speaking, vertebrate fauna habitats are aligned with landform features. Therefore, the habitat mapping was based largely on vegetation associations that are dependent on the underlying landforms and soils. HGM (1997b) notes that the exactness of this relationship is unclear as the requirements of most species are not fully understood and the three primary terrestrial vertebrate groups (avifauna, mammals and herptofauna) respond differently to the various elements of their habitat. For example, reptiles tend to be more substrate-specific than do the highly mobile non-passerine birds.

The habitat assessment also included the compilation of species lists for each of the habitat types using data from Ninox (1995), the Western Australia Museum, Birds Australia (formerly the Royal Australasian Ornithological Union) and CALM.

3.10.2 Fauna Habitats

HGM (1997b) recognised six fauna habitats on the St Ives Peninsula (Figure 3.14). These are:

- playa lakes and claypans;
- halophytic shrublands;
- lake foredunes and surrounding flats;
- lakeside shrublands;

- open mallee woodland over moderately dense spinifex; and
- moderately dense mallee woodland over open shrubs and spinifex.

The description of these habitats provided below is from HGM (1997b). The fauna species known, or likely, to utilise these habitats are listed in Appendix D.

Salt Lakes and Claypans

Numerous isolated salt lakes and claypans occur adjacent to Lake Lefroy. These lakes, together with Lake Lefroy, provide habitat that could support waterbirds on a seasonal basis. These species include the Australian Shelduck (*Tadorna tadornoides)*, Grey Teal (*Anas gracilis)*, Pink-eared Duck (*Malacorhynchus membranaceus*), Black-tailed Godwit (*Limosa limosa*) and Common Greenshank (*Tringa nebularia*). All of these species are known, or could be expected, to occur at other salt lakes in the Goldfields region as indicated by the results of an assessment of waterfowl usage of wetlands in the south east interior of Western Australia by Chapman and Lane (1997) (Table 3.12, Figure 3.15).

Very few other bird species and no reptile, amphibian or mammal species utilise this habitat.

Halophytic Shrublands

Halophytic shrublands occur on seasonally inundated clay loam soils and on low-lying saline areas along the shores of Lake Lefroy. This habitat is generally restricted to the fringes of Lake Lefroy and other salt pans, and is often represented by a narrow (2 m to 5 m wide) band of *Halosarcia* which correlates to vegetation type H1. This habitat also includes:

- low shrublands of *Frankenia pauciflora* and of low shrublands of *Maireana pyramidata* over a moderately dense cover of *Frankenia pauciflora* (vegetation type H2); and
- a mixed halophytic shrubland to 1.5 m tall and dominated by an open cover of *Eremophila scoparia* above moderately dense *Maireana sedifolia* and *Ptilotus obovatus* (vegetation type H3).

This habitat is structurally the least complex in the Project Area with few microhabitats, an absence of logs and other debris, and virtually no leaf litter. Consequently, it supports the lowest number of fauna species. However, they may be utilised by some specialist species such as the White-winged Fairy-Wren (*Malurus leucopterus*) and the White-fronted Chat (*Epthianura albifrons*) (HGM, 1997b).

Table 3.12

Waterfowl Occurrence on Wetlands in the Eastern Goldfields

Bird Species	Wetland Name and Type(s)[1]																							
	Lake Lefroy	Firtzgerald Lagoon	Lake Wannaway	Lake Cowan	Lake Arrow	Lake Douglas	Lake Hannans	Canegrass Swamp	Lake Miranda	Rowles Lagoon	King of the West	Lignum Swamp	Brown Lagoon	Lake Carnage[2]	Malcolm Dam	Black Flag Lake	Lake Barlee	Galah Rock Lake	Lake Ballard	Lake Raeside	Lake Noondie	Pinnacles St/n Lake	Lake Walton	Lake Mason
	B10	B8	B12	B8	C2	B8	B10	B8	B6, 13, 14	B8	B13	B6	B6, 14	C2	B8	B8	B8	B8	B8	B8	B8	B8	B8	B8
Blue-billed Duck										✓			✓	✓										
Musk Duck										✓			✓	✓										
Freckled Duck										✓		✓	✓	✓										
Black Swan	✓		✓		✓		✓		✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
Aust. Shelduck	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Aust. Wood Duck	✓		✓	✓				✓		✓				✓		✓	✓					✓		
Pacific Black Duck	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓	✓		✓	✓		✓					
Australasian Shoveler	✓		✓	✓	✓			✓	✓			✓												
Grey Teal	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Chestnut Teal		✓		✓			✓																	
Pink-eared Duck	✓		✓	✓						✓		✓	✓	✓		✓	✓							
Hardhead			✓					✓	✓	✓			✓	✓										
Australasian Grebe										✓														
Hoary-headed Grebe	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓						✓
Little Pied Cormorant										✓														
Little Black Cormorant	✓									✓														
White-faced Heron	✓		✓	✓	✓	✓	✓			✓			✓	✓		✓	✓	✓	✓	✓	✓		✓	
White-necked Heron	✓			✓	✓	✓	✓	✓							✓	✓				✓				
Great Egret					✓																			
Straw-necked Ibis					✓		✓												✓	✓				
Yellow Billed Spoonbill	✓					✓				✓														
Aust. Spotted Crake								✓				✓												
Black-tailed Native Hen	✓		✓	✓		✓		✓		✓		✓		✓	✓	✓	✓							✓

Table 3.12 (*cont'd*)

Bird Species	Wetland Names and Type(s)[1]																							
	Lake Lefroy	Firtzgerald Lagoon	Lake Wannaway	Lake Cowan	Lake Arrow	Lake Douglas	Lake Hannans	Canegrass Swamp	Lake Miranda	Rowles Lagoon	King of the West	Lignum Swamp	Brown Lagoon	Lake Carnage[2]	Malcolm Dam	Black Flag Lake	Lake Barlee	Galah Rock Lake	Lake Ballard	Lake Raeside	Lake Noondie	Pinnacles St/n Lake	Lake Walton	Lake Mason
	B10	B8	B12	B8	C2	B8	B10	B8	B6, 13, 14	B8	B13	B6	B6, 14	C2	B8	B8	B8	B8	B8	B8	B8	B8	B8	B8
Erasian Coot	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓	✓		✓						✓		
Black-tailed Godwit	✓			✓						✓														
Common Greenshank	✓		✓	✓			✓							✓										
Black-winged Stilt	✓				✓		✓		✓		✓		✓	✓	✓	✓								✓
Banded Stilt	✓				✓						✓					✓	✓		✓	✓				
Red-necked Avocet	✓				✓		✓		✓		✓				✓	✓	✓				✓			✓
Red-capped Plover	✓				✓		✓		✓					✓	✓	✓	✓							✓
Black-fronted Dotterel			✓							✓			✓	✓										
Hooded Plover	✓				✓												✓		✓					
Red-kneed Dotterel					✓		✓			✓														
Gull-billed Tern	✓								✓															✓
Whiskered Tern	✓								✓	✓			✓	✓	✓	✓								

<u>Source</u>: Ninox (1995, 1999) for Lake Lefroy data, Chapman and Lane (1997) for the remainder of the data.

<u>Notes</u>:

1. B8 – Intermittent saline lake; B12 – seasonal saline marsh; B6 – seasonal freshwater lake; B10 – intermittent freshwater marsh; B13 – shrub-dominated freshwater marsh; B14 – seasonally-flooded freshwater wooded swamp; C2 – man-made dams of less than 8 ha in area (as defined by ANCA, 1996).
2. Includes data from Clear Lake and Muddy Lake.

Lake Foredunes and Surrounding Flats

This habitat is similar to the lakeside halophytic shrublands, but is structurally more complex with a tree stratum that includes *Eucalyptus* species and *Callitris glaucophylla* over a shrub layer including *Acacia ligulata* and *Jacksonia arida*. A moderately dense cover of spinifex or a sparse cover of herbs and soft grasses occurs at ground level. This habitat correlates to vegetation types S1 and S7, and encompasses fauna monitoring sites KFS2 and KFS3 established by Ninox (1995) (Figure 3.12).

The *Eucalyptus* species provide suitable habitat for many gleaning avifauna such as Weebills, Gerygones and some of the Honeyeaters. Older trees provide hollows which are potential roosting spots for bats and birds such as the Spotted Nightjar (a Priority 4 species – see Section 3.10.5) and the Owlet Nightjar. Dense leaf litter provides suitable habitats for fossorial species such as members of the reptile genus *Lerista* and invertebrate species. The deep silica sands would provide suitable habitats for burrowing species.

The patchy distribution and the small size of the lake's foredunes suggests that this habitat is unlikely to support a unique assemblage of native mammals. Mammal species utilising this habitat type would probably represent a flow-on from neighbouring habitats. The Southern Ningaui (*Ningaui yvonneae*), Little Long-tailed Dunnart (*Smithopsis dolichura*) and the Western Pygmy Possum (*Cercartetus concinnus*) were recorded in this habitat type by Ninox (1995). The House Mouse (*Mus musculus*) and Rabbit (*Oryctolagus cuniculus*) have also been recorded. Up to ten other native species and three other introduced species could also occur in this habitat (Appendix D).

Lakeside Shrublands

The lakeside shrublands occur on the pale coarse sands adjacent to Lake Lefroy. This habitat is characterised by open to moderately dense shrublands to 1 m in height and dominated by *Jacksonia arida* and *Darwinia* aff. *diosmoides.* It correlates to vegetation types S2 and S3, and is similar to the lake foredune and flats habitat, but lacks a tree stratum.

The fauna species occurring in these shrublands will be similar to those occurring in the lake foredunes and surrounding flats. Microhabitats present include the dense shrub layer, deep silica sands and the leaf litter that accumulates at the base of shrubs.

The lakeside shrublands could potentially support 26 species of herpetofauna, though only five species were observed by HGM (1997b). The species likely to occur in this habitat type include those typically associated with a sandy substrate such as the skinks *Ctenotus atlas* and *Lerista picturata* (HGM, 1997b). Nine native and five introduced mammal species could also be expected to occur (Appendix D) but no mammals have been recorded in this habitat to date.

Open Mallee Woodland over Moderately Dense Spinifex

This habitat comprises an open woodland of mallees over a moderately dense (and more or less continuous) cover of the spinifex *Tridoia scariosa.* The dense ground cover provides suitable habitats for a variety of reptile species while the open woodland would be utilised by a number of birds. The larger eucalypts provide good hollows for nesting and roosting as well as perches for aerial predators such as falcons and owls.

This habitat type is likely to support the highest number of reptile and amphibian species of the habitat types in the St Ives area. Within the Project Area, this habitat occurs only on Delta Island and as such would only be expected to support a subset of the fauna potentially occurring in this habitat in the region (Appendix D). The species recorded at this site include the gecko *Diplodactylus maini* and the skinks *Ctenotus schomburgkii*, *Lerista muelleri* and *Mentia greyii*. None of these species are restricted to this habitat type (HGM, 1997b).

Approximately 17 mammal species could occur in this habitat. However, only one native species (the Southern Ningaui, *Ningaui yvonneae*) and three introduced species (the House Mouse, Fox and Rabbit) have been recorded (Appendix D).

Moderately Dense Mallee Woodland over Open Shrubs and Spinifex

This habitat comprises a moderately dense mallee woodland over an open cover of shrubs of various heights. Ground cover comprises an open and often patchy cover of *Triodia scariosa*. This habitat is similar to the open mallee woodlands described above, but the ground cover is more sparse than in that habitat suggesting that fewer reptile species would be present.

Fifty two bird species, 38 reptile and amphibian species and 22 mammal species could occur in this habitat type, but none have been recorded to date (Appendix D).

3.10.3 Fauna Assemblages

The results of the monitoring surveys by Ninox Wildlife Consulting indicate that the long history of mining around Kambalda and Lake Lefroy appears to have had little impact on the vertebrate fauna of the general area (Ninox, 1999). A reduction in species and abundance has occurred in mined areas (compared to unmined areas), though it considered that this reduction is a product of physical habitat disturbance rather than secondary impacts such as noise, light and vibration. For example, the low shrubland at site KFS7 is situated in close proximity to a busy haulage route but recorded the second highest species richness (Ninox, 1995).

The fauna species known or likely to occur in the Project Area have also been recorded elsewhere in the Goldfields region (Appendix E). The Project will not result in the loss of any of the vertebrate fauna species or populations inhabiting the area.

3.10.4 Significant Fauna Species

Four fauna species known, or likely, to occur in the Project Area are protected under Schedule 1 or Schedule 4 of the *Wildlife Conservation Act* (Table 3.13). Schedule 1 lists fauna species that are rare or likely to become extinct and are declared to be in need of special protection. Species listed under Schedule 4 are also in need of special protection.

Table 3.13

Significant Fauna Species Known, or Likely, to Occur in the Project Area

Species	Common Name	Classification[1]	Comments
Dasyurus geoffroii	Chuditch	Schedule 1	Now considered to be rare in this part of the Goldfields region. The last positive recorded sighting in the Kambalda area was in 1976 though more recent unconfirmed sightings have been recorded.
Cereopsis novaehollandiae grisea	Cape Barren Goose	Schedule 1	This species was recorded near Widgiemooltha in 1979 but is rarely located this far inland.
Leipoa ocellata	Mallee Fowl	Schedule 1	The Mallee Fowl has declined considerably since settlement. They are still found throughout the area but occur in low densities. The most recent sighting for the area was at Yallari Sandalwood Reserve in 1995.
Neophema slendida	Scarlet-chested Parrot	Schedule 1	This species may occur as a nomad or occasional visitor.
Falco hypoleucos	Grey Falcon	Schedule 1	Inhabits lightly timbered plains of the arid interior and is one of Australia's rarest hawks.
Falco peregrinus	Peregrine Falcon	Schedule 4	Widely distributed across Australia but not common anywhere. It is regarded as a rare visitor (mostly in Autumn and Winter) (Storr, 1986).
Caprimulgus gattatus	Spotted Nightjar	Schedule 4	This uncommon to moderately common species usually occurs singly. It prefers sparsely vegetation stony country such as breakaways and outcrops.
Morelia spilota imbricata	Carpet Python	Schedule 4	A cryptic species which could be widespread in the woodland habitats of the Goldfields.
Charadrius rubricollis	Hooded Plover	Priority 4	Occurs in small numbers around the margins of salt lakes throughout the southern Goldfields and further south.
Falcunculus fronataus leucogaster	Crested Shrike-tit	Priority 4	Favours salmon gum and gimlet woodlands and mulga country. It is a cryptic species and may well be widespread in much of the woodland habitat in the Goldfields.

Source: HGM (1998b)

Note: 1. Species listed in this table are protected under Schedule 1 or Schedule 4 of the *Wildlife Conservation Act* or listed under Priority 4 in CALM's Rare Fauna Database.

Two other fauna species that may occur in the Project Area (the Hooded Plover and the Crested Shrike-tit) are listed on CALM's Rare Fauna Database under Priority 4: taxa in need of monitoring (Table 3.13). These taxa are considered to have been adequately surveyed or for which sufficient knowledge is available. They are not currently considered to be threatened or in need of special protection. These taxa are usually represented on conservation lands and are declining significantly but are not yet threatened.

No species with distributions restricted to the region were recorded or are expected to occur within the Project Area.

3.11 AQUATIC INVERTEBRATES

3.11.1 Methodology

Two surveys of the aquatic invertebrates of Lake Lefroy were conducted in 1999. The first survey was undertaken by Curtin University of Technology in February 1999. As the lake was dry at the time of this survey, samples were collected of macroinvertebrate cyst banks (encysted embryos of invertebrate fauna species which are resistant to desiccation). Sampling was conducted at the Northeast Reference Site and Southwest Reference Site, and a range of sites around the causeway and mining area in February 1999. Some ephemeral pools on the margins of Lake Lefroy were also sampled as these areas reportedly have a high primary productivity compared to the main lake basin (see Handley, 1990). The location of the sample sites is shown on Figure 3.10. Samples were also taken at Lake Zot and Lake Cowan. The results of this survey are presented in Chaplin (1999) and summarised in Section 3.11.2.

The second survey was conducted following Cyclones Elaine and Vance in March 1999, with live organisms collected at regular intervals from April to June 1999. The results of this sampling period will be reported in the AEMP.

3.11.2 Results

The study by Chaplin (1999) found that Lake Lefroy sediments contain lower numbers of brine shrimp (*Parartemia* sp.) and ostracod cysts than sediments from Lake Cowan and Lake Zot. Two species of brine shrimp hatched from sediments collected from Lake Lefroy. An undescribed species resembling *Parartemia informis* was hatched from sediments collected from an ephemeral pool at the northeast reference site (Plate 3.16). *Parartemia serventyi* was hatched from a site near the causeway. *Parartemia informis* was also hatched from sediments from Lake Zot and *Parartemia serventyi* from Lake Cowan.

Three ostracod species were identified from Lake Cowan (*Australocypris* sp., *Diancypris dictyote* and *Diacypris fodiens*). *Diacypris fodiens* was also recorded from Lake Zot but no ostracods emerged from Lake Lefroy sediments during the hatching trials.

One calanoid copepod species (*Calamoecia* sp.), a cladoceran (*Bosmina meridionalis*), and the rotifer *Filinia perjleri,* were found preserved in the open lake salt-crust at the Southwest Reference Site. The salt crust was up to 3 cm thick at this site. Calanoid copepods were also found at four other sites in Lake Lefroy.

The data collected during this survey indicate that the ephemeral pools and claypans that support the dense algal mats are the most productive habitats of those sampled. In the basin of Lake Lefroy proper, invertebrate productivity is limited by high salinity (Colburn, 1980; Williams et al., 1990). Other chemical factors such as ionic composition may also be unsuitable for high macro-invertebrate productivity within the basin of Lake Lefroy.

The zooplankton species found preserved in the salt crust at some sites within Lake Lefroy were most likely transported to the lake from surrounding water-bodies via ephemeral creeks. In the open water at the southwest reference site, where the highest densities were found, numerous drainage lines feed into the lake. The species collected, *Bosmina meridionalis* and *Filinia perjleri*, are normally found in fresh waters (Egborge, 1994; Shiel, 1995).

3.12 TERRESTRIAL INVERTEBRATES

3.12.1 Methodology

Terrestrial invertebrates are classified as non-aquatic animals without backbones and comprise groups such as chelicerates (e.g. scorpions and spiders) and insects (ants, beetles, bugs and flies). Terrestrial invertebrates play an important role in the structure and maintenance of ecosystems as they are fundamental to processes such as decomposition, herbivory, parasitism and pollination (Brennan, 1999).

A number of studies on the terrestrial invertebrates of Lake Lefroy have been conducted to date, including:

- taxonomic and natural history studies on two species of salt lake wolf spider (*Lycosa alteripa* and *Lycosa salifodina*) by McKay (1976);
- research into the taxonomy of tiger beetles (including three species that inhabit Lake Lefroy) by Sumlin (1987, 1992a, 1992b and 1997);
- the preparation of a census of all terrestrial invertebrate groups inhabiting Lake Lefroy and many other smaller lakes including Golf Lake, Lake Zot, Lake Why, Lake Eaton North and Lake Eaton South (Hudson, 1995); and
- the use of allozyme electrophoresis to examine the genetic relationships of salt lake wolf spiders from a number of salt lakes in southern Australia including Lake Lefroy (Hudson and Adams, 1996).

A survey of the terrestrial invertebrates of Lake Lefroy was conducted by Curtin University of Technology in February 1999 (Brennan, 1999). The objectives of this survey were to:

- re-survey Lake Lefroy's terrestrial invertebrate fauna;
- develop a preliminary understanding of Lake Lefroy's terrestrial invertebrate fauna in both a local and regional context;
- establish two monitoring sites and undertake initial baseline monitoring; and
- determine the way in which terrestrial invertebrate communities may have been altered as a result of dewatering discharge onto the lake (see Section 5.12).

Sampling was conducted at the Northeastern and Southwestern Reference Sites, and at the discharge points along the causeway at Lake Lefroy (Figure 3.10). Samples were also collected at Lake Cowan and Lake Eaton South to provide a regional comparison of the terrestrial invertebrate fauna. Sampling was undertaken by pitfall trapping, systematic and non-systematic spotlighting and black lighting, diurnal ground searches, excavation of burrows and inspection of surface debris.

3.12.2 Results

More than 160 species of terrestrial invertebrates were collected during this survey (Appendix F). The most abundant species were the ants (49 species), spiders (41 species) and beetles (20 species). Most of the species collected in this survey had also been collected previously by Hudson (1995). However, several species collected by Hudson were not collected during this survey. These were:

- the salt lake wolf spider (*Lycosa* sp. nov. aff. *alteripa*);
- four species of tiger beetles (*Cicindela salicursoria, Cicindela* sp. nov., *Megacephala blackburni* and *Megacephala oleadorsa*); and
- the staphylinid beetle *Ochthephilum* sp.

A number of species were recorded at Lake Lefroy for the first time. These species include:

- the spiders Amaurobiidae sp. C and Theridiidae sp. A;
- the staphylinid beetle Staphylinidae sp. A;
- the tiger beetles *Megacephala pulchra* and *Megacephala castelnaui*; and
- the pseudoscorpion *Austrohorus* sp. A.

Austrohorus sp. A is considered to represent a salt lake specialist due to its highly unusual morphology (Brennan, 1999).

Most of the terrestrial invertebrates recorded at Lake Lefroy by Hudson (1995) and Brennan (1999) have been recorded at other salt lakes in the Goldfields region (Appendix F). Some species (such as a species of comb spider and two species of tiger beetles) are currently considered to be endemic to Lake Lefroy as they have not been recorded elsewhere because few other surveys have been conducted in the region.

Ants

The most common invertebrates collected during the 1999 survey were ants with 49 species from five families. The most species-rich genera were *Iridomyrmex, Melophorus, Camponotus* and *Monomorium*. Ant species tend to be the least abundant on the lake floor and more abundant towards the edge of the lake.

The genus *Iromyrmex* is one of the largest and most common genera of ants in Australia (Greenslade, 1979; Shattuck, 1999). Species from this genus are characteristic of open sunny areas (Andersen, 1991) and most are general scavengers (Shattuck, 1999). They interact strongly with many other invertebrates and can limit the number of other ant species inhabiting an area (Brennan, 1999).

Melophorus is also an abundant and species-rich genus. These are often the only ants active on the surface during the hottest part of the day (Andersen, 1991; Shattuck, 1999). They are general predators and scavengers, and display a wide range of feeding types (Brennan, 1999). *Camponotus* spp. are also general scavengers and predators. In addition, these species collect nectar and other plant secretions and tend *Hemiptera* (sap-sucking bugs) for honeydew (Briese and Macauley, 1981). Most species are nocturnal, but a few forage during the day (Shattuck, 1999).

Beetles

Twenty beetle species from 11 families were collected in the pit fall trapping. The most abundant species were the tiger beetles (Cicindelidae) *Megacephala pulchra* and *Megacephala castelnaui*, and the staphylinid beetle Staphylinidae sp. A. These species demonstrated distinct habitat preferences. *Megacephala pulchra* and *Megacephala castelnaui* were most abundant in the lake, beach and ephemeral pool habitats. Staphylinidae sp. A occurred only in the lake and beach habitats at the Northeastern Reference Site.

Important limiting resources for tiger beetles are food and oviposition sites. Tiger beetles are vertically burrowing ambush predators (Lawrence and Britton, 1994). Adults and larvae prey on arthropods though some species also scavenge dead organisms. They plug their burrows and become inactive during dry periods, but larvae will leave the burrow and relocate in extreme conditions of desiccation or flooding. Larvae have narrower habitat requirements than adult beetles, possibly as they tolerate less variation in physical factors such as soil moisture, composition of the soil and temperature (Pearson, 1988; Brennan, 1999).

The jewel beetle *Themognatha conspicillata* was also recorded at Lake Lefroy. This species, along with all jewel beetles, is protected under the *Wildlife Conservation Act* to prevent over-exploitation by insect collectors. *Themognatha conspicillata* inhabits mallee vegetation and is known to occur at other localities within Western Australia. Its presence in the Project Area is not considered to be significant.

Spiders

Forty species of spiders from 19 families were recorded during the 1999 survey. The families with the highest species richness were the jumping spiders (Salticidae - 10 species), lynx spiders (Oxyopidae - four species) and comb spiders (Theridiidae - four species) (Appendix D). Jumping spiders are small and widely distributed throughout Australia. They are diurnal hunters and are found throughout bushland, often upon rocks, logs, tree trunks and foliage. Some species have distinct territories while others are vagrants (Simon-Brunet, 1994). Lynx spiders are also diurnal hunters and prey on insects (Preston-Mafham and Preston-Mafham, 1984; Wise, 1993).

The most abundant families were the Amaurobiidae, Lyscosidae (wolf spiders, see Plates 3.18 and 3.19) and Zodariidae. Few spiders were recorded at sites with a salt crust. Most spiders were collected in habitats with small rocks and dense vegetation between 40 cm and 80 cm tall. Amaurobiid spiders were also recorded in association with sand/clay habitats but were seldom recorded in dense vegetation up to 40 cm high (Brennan, 1999).

3.13 SOCIO-ECONOMIC ENVIRONMENT

3.13.1 Demographic Profile

The Project Area is located in the Shire of Coolgardie. The Shire covers an area of 30,400 km^2 and has a population of approximately 5,600 people (Australian Bureau of Statistics, 1996). The average age of residents in the Shire is 27 years. The Shire includes the localities of Coolgardie, Kambalda and Widgiemooltha. Local industries include gold and nickel mining, pastoral and tourism.

The nearest settlements to the Project Area are Kambalda and Kambalda West, which have a population of approximately 3,500 people. Housing primarily comprises permanent dwellings though a number of non-permanent dwellings (such as transportable homes and caravans) are also used. Community facilities include a medical centre, police station, general stores, a child health centre, public library, schools and recreational facilities.

3.13.2 Other Land Uses

The Lake Lefroy area has been subject to exploration for, and mining of, minerals since the 1890s. However, there are currently no active exploration or mining activities on Lake Lefroy other than those activities conducted by the Proponent and sand mining conducted periodically by the Readymix Group at the northern end of the Lefroy Peninsula (see Table 1.2).

Salt mining has been conducted previously on Lake Lefroy, with operations concentrated at the southern end of the lake at Widgiemooltha and Lefroy Peninsula. Salt was collected at Widgiemooltha during the 1940s (and possibly earlier) through the use of scrapers drawn by camels (Clarke, 1991). Graders were also used to harvest the salt, and up to 400 t/month was extracted using this method. The salt was transported to Perth for domestic use and export (Sofoulis, 1966).

Lake Lefroy Salt Pty Ltd commenced the harvesting of salt from evaporation ponds at the northern end of the Lefroy Peninsula in 1968 (Figure 1.2). In 1970, the company started to export salt to Japan via Esperance, and by 1975 had exported 568,000 t of salt (Carter, 1976). Some salt was also exported from Perth. Salt production ceased in 1982, by which time 1.2 Mt of salt had been produced (Griffin, 1989). The remains of some buildings and infrastructure associated with the salt works are still present at the site.

The pastoral industry is also active in the Kambalda region. The Project Area is located adjacent to the Woolibar and Mt Monger pastoral stations.

Recreational users of Lake Lefroy include motorbike riders, walkers and photographers. However, the Project Area is of limited recreational value because of the access constraints required by the Proponent for safety reasons. The lake has been used for land sailing and a club house is located on Beta Island (Plate 3.19). The club hosted the Land Sailing World Championships in 1996 but is currently inactive.

3.13.3 European Heritage

A search of the databases of the Australian Heritage Commission, the Heritage Council of Western Australia and the National Trust was conducted to determine if any significant sites of European heritage are known to occur in the Project Area. No sites were listed as occurring in the Project Area.

The Red Hill lookout, which is located in Kambalda East and provides a view of the Project Area, forms part of the Eastern Goldfields Heritage Trail. Red Hill is often used by tourists and visitors to observe the mining operations at Lake Lefroy, though the view from the lookout itself is somewhat limited (see Section 5.15).

3.13.4 Aboriginal Heritage

A number of archaeological and ethnographic assessments of WMC's tenements in the Lake Lefroy area have been conducted in consultation with members of local Aboriginal communities with appropriate knowledge under Aboriginal tradition. These include:

- an archaeological and ethnographic assessment by Anthropos Australis Pty with the Gubrun Native Title claimants in September and November 1995 (Anthropos Australis Pty, 1996);

- an archaeological survey conducted by Archae-aus Pty with the Gubrun Native Title claimants in February 1997 (Archae-aus Pty, 1997);
- an ethnographic assessment by Daniel de Gand with the Murdeeu Native Title claimants in February 1997 (de Gand, 1997a);
- an ethnographic assessment by Daniel de Gand with the Ngadju Native Title claimants in March 1997 (de Gand, 1997b);
- an ethnographic assessment by Macintyre Dobson and Associates with the Ngadju Native Title claimants in June 1997 (Macintyre Dobson and Associates, 1997); and
- ethnographic field inspections by John Gleason with the Kalaako Native Title claimants in February 1998 (Gleason, 1998a), the Karonie Native Title claimants in July 1998 (Gleason, 1998b) and the Mardeeu in October 1998 (Gleason, 1998c).

The registered claimants of the Kabul Native Title claim participated in ethnographic assessments of the Proponent's tenements as representatives of the Gubrun (de Gand, 1997b) and the assessment by Anthropos Australis in 1995 (Anthropos Australis Pty, 1996).

No sites of significance or importance to Aboriginal people have been identified in the Project Area as a result of these investigations. However, Hogan's Lagoon (a fresh water soak located on the northern shoreline of Lake Lefroy, Figure 3.5) was identified as an important source of fresh water and game animals for the Karonie prior to the establishment of the Mt Monger pastoral station. This site is not located within the proposed mining area and will not be disturbed by the Project.

Frequent contact between WMC's Community Relations Department and local Aboriginal groups and individuals (including regular liaison with the Native Title claimants) has not identified any contemporary economic, recreational or cultural associations with Lake Lefroy.

3.14 COMPARISON WITH OTHER LAKES

A comparison of hydrologic parameters of Lake Lefroy and other salt lakes in Australia is provided in Table 3.14. Following a review of these data (and other data on Australian salt lakes presented in Bowler, 1981 and 1986), Clarke (1994a) concluded that Lake Lefroy is in transition between an ephemeral lake and a salt pan, as evidenced by the presence of a well-developed halite crust. In effect, Lake Lefroy combines the surface hydrology of relatively pluvial lakes such as Lake Tyrrell or Lake Gregory with the potential evaporative concentration index of saline playas such as Lake Frome or Lake Amadeus (Clarke, 1991).

Table 3.14

Hydrologic Characteristics of Selected Australian Salt Lakes

Lake	Characteristic[1]									
	% Dry	**Amp**	**E**	**P**	**F**	**E-P**	**PEC**	**E/P**	**(E/P)el**	**Delta el**
Lefroy	75	7.17	2,702	261	0.150	1,900	1,425	8.28	1.93	-76.7
Tyrell	75	6.00	1,200	356	0.150	884	633	1.75	-92.00	-92.0
Gregory	40	85.70	2,040	330	0.050	1,710	684	6.18	5.24	-17.9
Frome	92	9.00	2,000	210	0.150	1,790	1,646	9.52	2.20	-332.0
Gairdner	94	2.47	2,000	178	0.200	1,922	1,712	11.24	1.29	-771.0
Torrens	93	4.80	2,040	178	0.150	1,862	1,731	11.46	1.57	-629.0
Amadeus	95	3.00	2,240	178	0.200	2,062	1,960	12.58	1.40	-798.0
Eyre	90	140.00	2,640	220	0.025	2,490	2,241	13.20	4.48	-194.0

Source: Data from Bowler (1986) as reported by Clarke (1991).

Notes: 1. % Dry – percentage dryness of lake floor
Amp – basin amplificates factor
E – lake evaporation
P – average precipitation
F – run-off co-efficient
E-P – evaporation-precipitation
PEC – potential evaporative conservation
E/P – present climatic parameter
(E/P)el – lacostral climate needed to support steady state lake
Delta el – disequilibrium factor

The Directory of Important Wetlands in Australia (Australian Nature Conservation Agency [ANCA], 1996) indicates that there are 19 types of wetlands in inland Australia. Of these, seven types are present in the south-east interior of Western Australia, as follows:

- B8 – intermittent saline lake;
- B12 – seasonal saline marsh;
- B6 – seasonal freshwater lake;
- B10 – intermittent freshwater marsh;
- B13 – shrub-dominated freshwater marsh;
- B14 – seasonally-flooded freshwater wooded swamp; and
- C2 – man-made dams of less than 8 ha in area.

The six natural types of wetlands usually occur as systems. For example, saline marshes always occur on the margins of saline lakes (Chapman and Lane, 1997).

Saline wetlands are more common than freshwater wetlands, both numerically and in area. Examples of saline wetlands include Lake Lefroy, Lake Marmion, Lake Ballard and Lake Barlee. These lakes have similar physical and hydrological features (Table 3.15) but Lake Lefroy tends not to experience the freshwater phase that occurs at the other lakes following significant rainfall events. This freshwater phase is considered to be significant in triggering the hatching and growth of aquatic invertebrates that are in turn an important resource for breeding waterbirds. Consequently, Lake Lefroy is not an important breeding area for waterbirds whereas Lake Marmion, Lake Ballard and Lake Barlee are considered to be major breeding grounds for species such as the Banded Stilt.

Nearly all saline wetlands in Western Australia's Goldfields region occur either within pastoral leases or as Vacant Crown Land, so there are few statutory mechanisms for their protection though the *Wildlife Conservation Act* protects all species irrespective of land tenure. Only Lake Walton, part of Lake Goongarrie and the southern portion of Lake Marmion occur within lands managed for conservation purposes (Chapman and Lane, 1997) (Figure 3.16).

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Table 3.15

Environmental Characteristics of Selected Wetlands in the South-East Interior

Lake	Location	Shire	Natural Region[1]	Area	Elevation	Wetland Type[2]	Physical Features		
							Climate	Geological Setting	Landform
Lake Lefroy	7 km southeast of Kambalda.	Coolgardie	South-western Interzone (Coolgardie)	55,470 ha	286 m	B8	Semi-arid with mean annual rainfall of 242 mm. Bimodal rainfall distribution with peaks in February and June. Average annual evaporation is 2,700 mm.	Situated in the Yilgarn Craton in lacustrine valley fill deposits; part of the Lefroy Palaeodrainage. Islands are common and of four types: • emergent bedrock; • relict gypsum dunes, the margins of which have eroded to form cliffs; • mixed clay-sand dunes which are common at or near stream estuaries; and • gypsum and siliciclastic dune accretion onto a basement outcrop.	Irregular sumpland with an axial length of 59 km and a width of 16 km. The southern end of the lake is bifurcated by the Lefroy Peninsula.
Rowles Lagoon System	65 km north-northwest of Coolgardie.	Kalgoorlie-Boulder, Coolgardie	South-western Interzone (Coolgardie)	550 ha	~420 m	B6, B10, B13	Average annual rainfall at Coolgardie is 259 mm. Rainfall is not strongly seasonal in occurrence. Annual evaporation at the site is ~2,700 mm.	Situated in the Yilgarn Craton, in a basin complex bounded to the west, northeast and south by low ranges. Lake beds are sandy clay.	Six mesoscale-macroscale irregular sumplands and five microscale round sumplands
Lake Marmion	36 km east of Menzies.	Menzies	Austin (Murchison)	~35,300 ha	353 m	B8	Average annual rainfall at nearby Menzies is 244 mm, mostly falling in May-July. Average annual evaporation is ~3,200 mm.	Situated in the Yilgarn Craton, on lacustrine (lake bed) and mixed aeolian and alluvial (lake margins) valley-fill deposits. Lake Marmion is part of a palaeodrainage system that formerly drained southeast from Lake Ballard through Lake Marmion to Lake Rebecca and Ponton Creek.	A megascale irregular elongate sumpland with numerous micro to macroscale islands.
Lake Ballard	33 km northeast of Menzies, 80 km southwest of Leonora.	Menzies	Austin (Murchison)	60,000 ha	~380 m	B8	As for Lake Marmion.	Situated in the Yilgarn Craton, on lacustrine and alluvial valley-fill deposits. Lake Ballard is part of a palaeodrainage system that formerly drained to the southeast connecting through Lake Marmion to Lake Rebecca and Ponton Creek.	A megascale irregular elongate sumpland with numerous micro to macroscale islands.
Lake Barlee	148 km west-northwest of Menzies.	Menzies, Sandstone	Austin (Murchison)	194,380 ha (including small satellite lakes)	400 m	B8	Average annual rainfall at nearby Diemals Homestead is 262 mm, mostly falling in May-July. Average annual evaporation is 3,000 - 3,200 mm.	Situated in the Yilgarn Craton, on lacustrine and alluvial valley-fill deposits. Lake Barlee is part of a palaeodrainage system connecting east to Lake Raeside and Ponton Creek. Islands vary from low (<1m) and sandy, to high (>10m), steep-sided and rocky. There are four types: • banded ironstone exposures; • red sand dunes; • gypsum dunes; and • calcrete ridges. Some greenstone rocks are exposed on the lake bed.	Megascale irregular sumpland. It has five major "arms", three oriented north-south, two oriented east-west. Includes many hundreds of microscale to macroscale islands.

Notes:
1. Natural Regions as delineated by Beard (1990).
2. Wetland classification system of ANCA (1996):
   - B6 – seasonal freshwater lake.
   - B8 – Intermittent saline lake.
   - B10 – intermittent freshwater marsh.
   - B12 – seasonal saline marsh.
   - B13 – shrub-dominated freshwater marsh.

Table 3.15 (*cont'd*)

Lake	Hydrological Features				Ecological Features		
	Water Supply	**Inundation**	**Water Depth**	**Water Quality**	**Flora and Vegetation**	**Fauna**	**Ecological Role and Significance**
Lake Lefroy	Direct precipitation and episodic inflow from catchment. Catchment covers 395,000 ha (3,950km^2).	Partially inundated each year. The lake is probably completely dry for about 25% of the year.	Typical depth following winter rainfall is 20 mm. In 1975, 760 mm of rainfall resulted in 800 mm of water over the lake. Heavy rains in 1992 flooded the lake to depths approaching 2 m.	Saline to hypersaline. Slightly acidic to neutral (ie. 6.8 – 7.0).	No vegetation occurs on the lake bed. Lake and island margins support halophytic communities. Tree, mallee and shrubland communities occur on sand dunes.	No vertebrate fauna species inhabit the lake bed. Invertebrate productivity is limited by the hypersaline conditions of the lake.	Not a significant waterfowl breeding site.
Rowles Lagoon System	Surface inflow from numerous creeks originating up to 25km away. Catchment is moderately disturbed.	Seasonal (ie. some water in stream-fed lakes in most years). Rowles Lagoon may be near-permanent. Inundation may persist through at least one summer following episodic flooding brought by summer-autumn rain events of tropical origin.	Rowles Lagoon is usually <1 m deep but has been reported to be 7 m deep at times (was 5.8 m deep in the centre of open water area in November 1992). Clear, Carnage and Muddy lakes were 4.8 m, 4.6 m and 3.3 m respectively in November 1992. Brown Lagoon was at least 2 m deep in August 1992.	Fresh, probably stasohaline. Light brown colour in some lakes (eg. Rowles Lagoon), apparently no colour in others.	Open scrub and heathland dominated by tea-tree (Melaleuca xerophila). Low shrubland of lignum Muehlenbeckia cunninghamii and Lycium australe (in Brown Lagoon). Canegrass (Eragrostis australasica) also occurs. Surrounding areas support low open-forest or open woodland with low shrubland or low open woodland beyond.	41 waterbird species have been recorded at this site, eight of which are listed under treaties. No other wetland in temperate parts of the arid interior is known to support a comparable number of species. Three migratory shorebird species atypical of inland Australia (Grey Plover, Black-tailed Godwit and Ruddy Turnstone) have been recorded at the site as has the threatened species the Freckled Duck. Other migrant shorebirds use the area briefly.	A large and good example of the tea-tree/lignum swamp community (probably the largest in the southwest of the arid interior). A drought refuge area and a significant breeding area for waterbirds in the southwest of the arid interior after major flooding.
Lake Marmion	Mainly direct precipitation; also episodic surface input from sheet flow and creeks. Catchment covers ~294,000 ha and is moderately disturbed.	Episodic. The whole basin is probably inundated once every five or so years on average, usually by single major summer-autumn rain events of tropical origin. Water may persist six to nine months.	0.4 m in May 1975, 0.5 m in June 1995.	Fresh initially, then saline and hypersaline. Class: hypersaline; poikilohaline. Red-brown colour when windy, none when calm.	No vegetation occurs on the lake bed. The islands and lake margins support low shrublands. The samphire communities include *Halosarcia* sp., *Frankenia* sp. and *Lawrencia helmsii*. Low woodlands of Eucalyptus striaticalyx occur on islands >2m in height. Surrounding areas support open scrub dominated by *Acacia aneura*, *Casuarina pauper* and *Eucalyptus* spp.	Waterbirds recorded at the lake include Australian Shelduck, Grey Teal, Avocet and Silver Gull. The lake may also be an important breeding site for the Banded Stilt. Other species include the Whistling Kite, Wedge-tailed Eagle and Peregrine Falcon.	A good example of an intermittent saline lake of the bioregion. May be a major breeding area for the Banded Stilt.
Lake Ballard	Mainly direct precipitation; also episodic surface inflow from creeks. Catchment covers ~13,900 km^2 and is moderately disturbed.	As for Lake Marmion.	Maximum recorded is 0.3 m (1975), 0.5 m (1995).	Fresh initially, then saline. Class: hypersaline; poikilohaline. Red-brown colour when windy, none when calm.	No vegetation occurs on the lake bed. *Eucalyptus striaticalyx* woodlands grow on the gypsum dunes and islands, sometimes with the unusual Dunna Dunna (*Lawrencia helmsii*). The northern perimeter of the lake is dominated by low shrubland of succulents, saltbush (*Atriplex* sp.) or bluebush (*Maireana* spp.) with scattered low trees and shrubs of mulga (*Acacia aneura*) and wattles (*Atriplex* sp.).	Seven waterbird species have been recorded including the Great Egret, Australian Shelduck, Grey Teal and Red-necked Avocet. The lake is used for breeding by large numbers of Banded Stilt. Brine shrimp are abundant when the lake fills and are the main food of Banded Stilt adults and chicks. Other species observed at the lake include the Peregrine Falcon.	A good example of an intermittent saline lake of the bioregion. Lake Ballard is one of the most important breeding sites in Australia for the endemic Banded Stilt.
Lake Barlee	Mainly direct precipitation; also episodic surface inflow from many creeks (mostly 3-5 km long). Catchment covers ~1.79M ha and is moderately disturbed.	Episodic. The whole basin is probably inundated once every ten years, usually from one or more major (summer-autumn) rain events of tropical origin. Water may persist for six to nine months.	Maximum recorded is 0.5 m (2 July 1992). Usually less variation over vast areas.	Probable class: hypersaline, poikilohaline. Initially a light brown colour, later none.	No vegetation occurs on the lake bed. Islands and lake margins support samphire (which includes *Halosarcia* spp.). *Eucalyptus striaticalyx* woodlands grow on gypsum dunes, sometimes with the unusual Dunna Dunna (*Lawrencia helmsii*).	Eight waterbird species have been recorded (including the Back Swan, Australian Shelduck, Pink-eared Duck, Red-capped Plover Black-winged Stilt and the Silver Gull). The lake is also used for breeding by large numbers of Banded Stilt.	A good example of an intermittent saline lake. One of the larger (discrete) inland lakes in WA. A major breeding area for the Banded Stilt.

Table 3.15 *(cont'd)*

Lake	Social and Cultural Values	Land Tenure		Land Use		Disturbance or Threats
		On Site	Surrounding Area	On Site	Surrounding Area	
Lake Lefroy	Education and Research: Numerous studies have been conducted under the Lake Lefroy Strategy. Aesthetics: Large saline wetland with contrasts between topographically flat lake bed and the dunes and rocky cliffs. Historical and current mining activities are viewed from the Red Hill Lookout.	Extensive areas covered by mining tenements.	Mining tenements and pastoral leases.	Gold and nickel exploration and mining	Primarily pastoral purposes.	Historical: Salt mining was conducted on the lake adjacent to Widgiemooltha. Current: Mining operations on lake beds and surrounds. Feral predators including foxes and cats may potentially pose a threat to nesting birds (this needs to be determined).
Rowles Lagoon System	Education: This site has potential for education of visitors and students of wetland ecology. Recreation: Rowles Lagoon is a popular picnic and boating site in spring-summer.	Formerly the Rowles Lagoon Nature Reserve (4274). Regazetted as the Rowles Lagoon Conservation Park (4274, Class C) in 1994. Southernmost wetland and Canegrass Lagoon are in pastoral leases.	Leasehold (Jeedamya, Riverina, Kookynie, Melita and Adelong pastoral stations).	Nature conservation, recreation, pastoral purposes and water supply.	Pastoral purposes and mining.	Current: Disturbance from water-skiing and other recreational use, excessive inundation (dead trees evident in inner parts of lakes) and accidental grazing within the reserves (damaging wetland vegetation). Potential: Siltation (due to over-grazing in the site's catchment), pollution of inflow water (leachate from mine sites).
Lake Marmion	Cultural: Not known, but Jenkins (1975) reported that Aborigines regarded Banded Stilt chicks as a delicacy and were attracted to the Lake Ballard area (only 15 km from Lake Marmion) when nesting took place in 1973.	Mostly within the Mendleyarri pastoral lease. Part of the southern end is in the Goongarrie National Park.	Pastoral lease and national park.	None (part) and national park (part).	Pastoral purposes (sheep).	Current: None. Potential: Mining.
Lake Ballard	Cultural: Jenkins (1975) reported that Aborigines regarded Banded Stilt chicks as a delicacy and were attracted to the Lake Ballard area when nesting took place in 1973. Research: Detailed study of the Banded Stilt breeding event in 1995 and ongoing monitoring by CALM and C.D.T. Milton.	The lake is Vacant Crown Land.	Leasehold (Jeedamya, Riverina, Kookynie, Melita and Adelong pastoral stations).	None	Pastoral purposes (sheep), mineral exploration and gold mining.	Current: Mineral exploration. Introduced predators (foxes *Vulpes vulpes* and cats *Felis catus*) may prey on breeding adult Banded Stilts, chicks and eggs when the lake becomes shallow (Jenkins, 1976). Potential: Impacts associated with mining.
Lake Barlee	Education: Use of the Mt Elvire station buildings as a base for nature study and/or education has been proposed. Research: Ongoing research and monitoring by CALM of breeding by Banded Stilts. Aesthetics: A vast, undisturbed and rarely visited saline wetland, with high contrast between flat lake-bed and steep-edged islands/bluffs in places. Periodically supports spectacular concentrations of waterbirds.	The lake is Vacant Crown Land.	Mostly pastoral lease (Lake Barlee, Cashmere Downs, Perrinvale and Diemals) or Vacant Crown Land. Some is in proposed State Forest for sandalwood conservation (relinquished Mt Elvire pastoral lease).	None	Mostly pastoral grazing (sheep). Part to be used for forestry.	Current: No information available Potential: Impacts associated with mining of lakebed and surrounds. Breeding stilts may be threatened by foxes and cats when the lake becomes very shallow.

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4. COMMUNITY AND GOVERNMENT CONSULTATION PROGRAMME

The Proponent consults with a range of stakeholder groups about its operations at Lake Lefroy as part of its day-to-day operations. This consultation includes regular contact with:

- the DME, DEP and CALM through telephone discussions, site visits and the Goldfields Land Rehabilitation Group;
- the Goldfields Environmental Forum;
- the Shire of Coolgardie, on an as-needs basis;
- the local pastoralist on day-to-day management issues; and
- native title claimants through the Proponent's community relations department.

The government departments consulted during the preparation of the PER and the issues raised by these agencies are listed in Table 4.1. The Project has also been discussed with the Shire of Coolgardie, the local pastoralist, the native title claimant groups and the Conservation Council of Western Australia. In addition, a presentation on the project was made at the Salt Lake Ecology Seminar held at the Perth Zoo on 7 July 1999. A copy of this paper is available in the proceedings of the seminar (Morris, 1999).

Further briefings will be conducted during the public review period for the PER.

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Table 4.1

Summary of Environmental Issues Raised by Stakeholders

Agency	Type of Consultation	Issues Raised	Proponent's Response
Environmental Protection Authority and Department of Environmental Protection (Perth and Kalgoorlie branches)	Briefing in Perth on 18 February and 8 July 1999. Site briefing on 17 August 1999.	The main issues to be addressed in the PER are as listed in the EPA Guidelines. Other issues include those listed below.	See Table 5.1.
		What is the likelihood of settlement/subsidence in backfilled pits?	In any backfill situation, there is likely to be some subsidence. This is allowed for during the backfilling process and is not considered to be a significant issue for the Project.
		What options are being considered for dewatering discharge?	There are four options for the discharge of mine water, as follows: • discharge to an unconfined area on the lake bed; • discharge to a bunded area on the lake bed; • discharge to a bunded area on the lake bed that will be used for mining develoment in the future; and • discharge to an inactive pit on or adjacent to Lake Lefroy Further information on these options is provided in Section 2.5.
		What options are being considered for the rehabilitation of mining disturbances?	The procedures used for the rehabilitation of project disturbances will be modified to suit the site-specific conditions of the area being rehabilitated (see Section 5.13). These procedures will also be modified in response to the results of monitoring and research programmes.
		Any environmental management commitments made in the PER should be auditable.	Noted. A summary of the commitments made in this PER is presented in Section 6.
		What is the concentration of heavy metals in dewatering discharge? What impact is this likely to have on the invertebrates inhabiting the lake?	Heavy metal concentration in current mine water discharge is generally below detection limit for most metals. In certain cases (e.g. Redoubtable), orebody geology has resulted in slightly elevated levels of copper, nickel and lead. Testwork has shown that lake-bed sediments will absorb and immobilise any metals which may occur in the dewatering discharge. There will be no impact on invertebrates in the lake.
		What factors of the Project Description are likely to change in implementing the proposed Project?	It is likely that changes will be made to the layout and timing of the individual pit developments. The description of the proposed mining developments provided in Section 2 is indicative. Proposed changes to the Project will be addressed in the AEMP.
Department of Minerals & Energy	Briefing in Perth on 18 February 1999. Site briefing on 21 June 1999.	Emphasis should be placed on minimising overburden dump footprints.	Overburden dumps will be designed and managed in accordance with SIG-EP 007: Waste Dump Design, Construction and Water Management (Appendix J) and the techniques described in Section 2.3.
		What success has been achieved in minesite rehabilitation on the lake to date?	To date, two islands have been constructed on the lake from overburden. These are Epsilon Island and Omega Island. Omega Island has been partially rehabilitated and eucalypts, saltbushes and spinifex have become established on the island. Rehabilitation of Epsilon Island will commence when the landforming process is complete. Data from rehabilitation monitoring at these sites will be used in the planning of future overburden dump rehabilitation.
		What research is the Proponent conducting in rehabilitation?	The Proponent proposed to investigate the use of lake muds as growth media in rehabilitation. The feasibility of using overburden in the reconstruction of foreshore dunes will also be considered. See Section 5.13.2 for further information.
		What impact will the Project have on surface water movement?	Construction of mine infrastructure such as causeways, haul roads and safety bunds may locally disrupt the pattern of surface water movement. This impact will be reduced by: • utilising existing causeways where possible; • removing those causeways no longer required for the Project; • constructing causeways and haul roads with culverts; and • designing overburden dumps and abandonment bunds to minimise disruption of surface water flow.
		What will be the cumulative impacts of the Project?	Cumulative impacts associated with project development are: • potential impacts on the quality and quantity of surface water and groundwater due to mine dewatering and discharge of mine water, accidental release of pollutants and other chemicals, and run-off from any acid-generating materials (see Sections 5.4 and 5.7); • creation of new landforms which modify the lakescape and may affect the movement of water across the lake (see Section 5.5); and • the behaviour of final pit voids (see Section 5.5).

Table 4.1 (*cont'd*)

Agency	Type of Consultation	Issues Raised	Proponent's Response
Department of Minerals & Energy (cont.'d)		Closure conditions: • Which pits will be left open and which will be backfilled? • Would it be possible to remove the safety bund and allow the pit to fill with hypersaline water?	Where practical, pits will be backfilled with overburden on completion of mining according to the decision process outlined in Figure 2.9. Groundwater inflow will naturally infill pit voids with hypersaline water to a level close to the lake surface. Removal of safety bunds will be given consideration but will only be undertaken where this does not compromise public safety.
		What contingencies have been allowed for in the event of a worst case or radical alternative outcome from the current hydrological studies by CSIRO?	Most of the hydrological studies are nearing completion, and the final outcomes are not expected to be significantly different to those presented in CSIRO (1999b). However, it is always possible that an unexpected outcome may result from any research project. Should this eventuate, the Proponent will conduct further investigations in order to determine the significance of the outcome and whether planning for, and the management of, the Project requires modification.
		What is the acid generation potential of the lake sediments and how does the environment assimilate it if it occurs. In particular, if a pit that has acid-generating rock in the pit walls fills with water, can St Ives Gold demonstrate that the water will not go acid? If it does, how will the lake cope with it?	The acid generating potential of the ore zones and overburden in the proposed mine pits is low. Though sulphide-bearing bedrock does occur in some areas, the pits will generally not be deep enough to expose this material. Acid generation testwork will be conducted as part of the Proponent's routine metallurgical testwork. See Section 3.4.3 and 5.7 for further information.
		What will be the final water levels in any pits that remain open post-closure?	Final pit void water bodies will recover to a level slightly below the regional water table (which is located just below the lake bed).
Department of Conservation & Land Management	Site briefing on 30 June 1999.	Avoid disturbance of natural islands if possible as they are potential breeding sites for birds.	Alpha, Beta, Delta and Gamma islands have been disturbed by previous and current mining operations. Oyster, Coral and Landmark islands are relatively undisturbed. No new facilities or infrastructure will be constructed on these islands as a result of this Project (see Section 5.6).
		Need to provide a comparison between discharge water and lake surface water quality with respect to ionic composition.	Discharge water will be hypersaline and will have similar physical and chemical characteristics to the lake's surface water. However, the concentration of metals in dewatering discharge can vary due to differences in aquifer geology (see Section 5.4.3).
		What are the outcomes of the studies by Curtin University?	The results of the ecological studies are described in Sections 3.9, 3.11 and 3.12.
		What is the quality of the water in pit lakes likely to be?	Water in final void lakes will be hypersaline. Water quality will initially be similar to water quality in the surrounding aquifer and will slowly increase in TDS due to evaporation and wall rock interaction. See Section 5.5.
Water & Rivers Commission	Briefing in Perth on 4 June 1999.	What is the interaction between groundwater and surface water?	The surface and shallow groundwater systems are in dynamic equilibrium with water being transferred between the systems via groundwater seepage and leakage through the lake bed.
		What impact will the presence of overburden and infrastructure on the lake bed have on surface water flow?	The movement of water across the surface of Lake Lefroy is wind-driven, so water will continue to flow around permanent features such as overburden dumps and abandonment bunds. The Proponent will design these features such that the flow of surface water around them is not impeded. Culverts will be incorporated into causeways constructed for the Project. All causeways will be removed when no longer required for Project activities. See Section 5.4.1.
		What is the longterm behaviour of the mine voids likely to be?	Water in final void lakes will be hypersaline. Water quality will initially be similar to water quality in the surrounding aquifer and will slowly increase in TDS due to evaporation and wall rock interaction. See Section 5.5.
		What is the impact of adding more salt to a salt lake environment through dewatering discharge?	Mine water discharge will not significantly impact on the total salt balance of the Lake Lefroy system. The amount of salt added to the lake surface through dewatering discharge will be small compared to salt stored in the halite crust and the near surface aquifer. Lake Lefroy is evolving from an ephemeral lake to a salt pan, so increased salt buildup with time will occur due to natural processes. Any salt buildup around discharge points will be dissolved and redistributed across the lake surface during flood conditions.
		Will the quality of the water in the lake be altered as a result of dewatering activities or dewatering discharge?	No significant impact is anticipated as dewatering discharge generally has similar physical and chemical characteristics as the lake water. See Section 5.4.2 and 5.4.3 for further information.
Department of Resources Development	Briefing in Perth on 27 August 1999.	No significant environmental issues were raised.	-

5. ENVIRONMENTAL IMPACTS AND MANAGEMENT

This section identifies the environmental impacts likely to arise from the construction, operation and closure of the proposed Project, assesses the significance of these impacts and describes how they will be managed. The environmental impacts associated with the development of individual pits and the cumulative impacts from successive mining developments on the lake are addressed.

5.1 IDENTIFICATION AND RELEVANCE OF ENVIRONMENTAL FACTORS

The environmental factors that the EPA considers should be addressed in assessment of the proposed Project are listed in Table 5.1.

The significance of the impacts associated with the proposed Project was assessed by using the Proponent's Qualitative Environmental Risk Assessment procedure (see SIG-EP 021 in Appendix J). This procedure is based on AS/NZS 4360:1995 (Risk Management) and is used by the Proponent to:

- identify the environmental risks likely to be associated with a project (or activity);
- establish environmental objectives relevant to the project; and
- develop appropriate control mechanisms to ensure that the environmental objectives are achieved.

The results of this assessment are presented in Table 5.1.

As there is considerable overlap in the types of impacts that may occur during the construction and operation of the Project, these are discussed in the following sections according to the nature of the issue, rather than the project phase. The issues associated with the closure of the Project primarily relate to the behaviour of final mine voids, which is discussed in Section 5.5.

The cumulative impacts associated with the Project are discussed where relevant in the following sections.

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Table 5.1

Identification of Environmental Factors

Element	Environmental Factor	Work Required for the Environmental Review of the Project (as identified by the EPA Guidelines)	Environmental Conditions/Impacts	Proposed Mitigation and Management Measures	Predicted Outcome
BIOPHYSICAL					
Biodiversity	Lake Lefroy and its surrounds	The EPA Guidelines require that the Proponent demonstrate that biodiversity will not be compromised by this proposal.	Surveys have been conducted of the terrestrial flora and vegetation, aquatic flora, vertebrate fauna, terrestrial invertebrates and aquatic invertebrates of the Project Area. The results of these surveys are presented in Sections 3.8 to 3.12. The Project will not adversely affect the biodiversity of the Project Area.	No specific measures are required.	Biodiversity of Lake Lefroy and its surrounds will not be compromised.
Nature Conservation Values	Lake Lefroy and its surrounds	The EPA Guidelines require that the Proponent: • identify areas represented in local, regional, national and international reserves or agreements; and • assess the nature conservation values of the Project Area.	National parks, nature reserves, timber reserves and other areas included in the conservation estate in the Kalgoorlie area are shown on Figure 3.16. The Project Area is not included in conservation reserves or agreements and has no significant conservation values.	No specific measures are required.	No impacts on the conservation estate of the Goldfields region.
Terrestrial Flora	Vegetation	The EPA Guidelines require that the Proponent: • conduct baseline studies to identify existing plant communities; • assess potential impacts (direct and indirect) on vegetation (local and regional) as a result of mining and associated activities; • propose measures to manage impacts.	A flora and vegetation survey of the Project Area was completed in 1993 (see Section 3.8). Vegetation is only present in the Project Area on the islands and along the shorelines of Lake Lefroy. Flora and vegetation will be affected by clearing operations. Less than 3 ha of vegetation will be cleared during the development of the Phoebe and Thunderer pits. This comprises shrublands and woodlands on deep dunal sands and a halophytic complex dominated by chenopods and samphires. These communities have been disturbed previously by sand mining. Approximately 0.3 ha of woodland vegetation may be cleared during the development of the Delta Cutback. Most of the area to be developed for this pit has already been disturbed by previous mining operations. Vegetation may also be affected by the use of saline water for dust suppression and if inundated by hypersaline mine water discharge.	• SIG-EP 014: Vegetation and Topsoil Management. • Rehabilitate disturbed areas on a progressive basis. • Bund roads to prevent the egress of saline water to adjacent vegetation. • Use fresh water for dust suppression on topsoil stockpiles. • Position mine water discharge points away from, and will not draining to, fringing vegetation.	No significant impacts.
	Declared Rare and Priority Flora	The EPA Guidelines require that the Proponent: • conduct baseline studies to identify any Declared Rare and/or Priority Flora; • assess potential impacts (direct and indirect) on species as a result of mining activities and construction of infrastructure; • analyse the likelihood of occurrence of taxa not flowering at the time of survey; and • propose measures to manage impacts.	A flora and vegetation survey of the Project Area was completed in 1993 (see Section 3.8). *Acacia kalgoorliensis* (a Priority 3 species) has been recorded in the Project Area but will not be affected by the Project. A DRF species, *Pityrodia scabra*, is known to occur in the Lake Lefroy area but has not been recorded in the Project Area and will not be affected by the Project.	No specific measures are required.	No loss of DRF or Priority Flora species or individuals.
Terrestrial Fauna	Fauna Species	The EPA Guidelines require that the Proponent: • conduct baseline studies to identify existing fauna in the Project Area; • assess potential impacts (direct and indirect) on terrestrial and avian fauna (local and regional) as a result of mining and associated activities; and • propose measures to manage impacts.	Three vertebrate fauna surveys have been undertaken. The results of these surveys indicate that the long history of mining around Lake Lefroy has had little impact on the vertebrate fauna of the area. The fauna species known or likely to occur in the Project Area have also been recorded elsewhere in the Goldfields region. The Project will not result in the loss of any vertebrate fauna species or populations inhabiting the area. The main impact on fauna will be loss of habitat through vegetation clearing. However, the amount of clearing will be minimal (<4 ha) and this is not considered to be a significant impact.	• Minimise vegetation disturbance. • Cover open foundation holes, drill holes and trenches. • Inspect open holes and trenches regularly for trapped fauna and release trapped individuals. • Prohibit firearms and domestic pets in the Project Area. • Rehabilitate disturbed areas on a progressive basis to minimise loss of habitat. • Raise workforce awareness about fauna. • Avoid direct contact with fauna wherever possible. • Park vehicles and machinery only in designated locations to minimise habitat damage. • Discourage off-road recreational activities. • Continue the Proponent's current fauna monitoring programme and feral animal trapping programme.	No significant impacts on fauna habitats or species.

Table 5.1 *(cont'd)*

Element	Environmental Factor	Work Required for the Environmental Review of the Project (as identified by the EPA Guidelines)	Environmental Conditions/Impacts	Proposed Mitigation and Management Measures	Predicted Outcome
Salt Lakes	Lake Lefroy	The EPA Guidelines require that the Proponent: • assess the potential impacts on Lake Lefroy due to mining and exploration operations occurring on the lake and from construction of associated facilities. Specifically: – the potential impacts on the lake's hydrology and ecology arising from mining in the lake bed and abandonment of the pits; – potential impacts on the lake's ecology arising from construction of the overburden dumps, causeways and bunds; – assess the impacts on lake hydrology and ecology arising from discharges to the lake from dewatering during normal annual lake fluctuations and periodic flooding events known to be important triggers of biological activity; • evaluate the effects of the potential impacts on the functions and environmental values of Lake Lefroy; and • propose measures to manage impacts.	Exploration on the lake may result in: • drill hole collapse; • spillage of hydrocarbons from equipment; • visual impact of tracks and drill castings on the lake; • localised changes in micro-topography due to drill castings left on the lake's surface; • provision of additional fauna habitat and access for feral animals (causeways); • noise; and • dust generation from vehicle movement on unsealed tracks and causeways. Mining and the presence of new infrastructure on the lake will result in changes to the movement of water across the lake due to the creation of new landforms on the lake bed and along part of its shoreline (see Section 5.4.1). Movement of water across the lake surface is wind-driven, and water will flow around permanent features such as overburden dumps and abandonment bunds (where these are maintained). Temporary structures such as causeways will be removed when no longer required, so will not have any longterm effect on surface water flow. Therefore, the impact of the Project on surface water flow is not considered to be significant. There is little or no biological activity on the lake itself as this is limited by the hypersaline conditions of the lake. The habitats adjacent to the lake (i.e. the plant communities and playas that occur adjacent to the lake) are more productive (see Section 3.8-3.12 for further details). Less than 4 ha of vegetation and 2.4 ha of playas will be disturbed by the development of the Project. This is an insignificant portion of the total area of habitat available. Therefore, the impact is not considered to be of local or regional significance. The discharge of mine water to the lake bed may result in localised changes to the quality and quantity of water at the discharge sites. The discharge will be hypersaline and will have similar physical and chemical characteristics to the lake's surface water. The concentration of metals may vary as this is a function of aquifer geology. Localised hardening and discolouration of the salt crust may occur where the lake's surface water and the discharge water have different hydrochemical signatures. There will be a short term build-up of salt on the surface of the lake at the discharge point but this will be redistributed within the lake system during flood conditions. See Section 5.4.2 for further details. Lake Lefroy does not to experience the freshwater phase that occurs at the other lakes following significant rainfall events and that triggers biological activity. Therefore, the impact of dewatering discharge on this factor will not be significant.	• Complete the hydrological investigations by CSIRO. Report the results in the AEMP. • Monitor surface water flows, levels and quality using the existing monitoring network. • Backfill pits. Consider removing abandonment bunds from around final voids. • Remove causeways and other infrastructure when no longer required. • SIG-EP 007: Waste Dump Design, Construction and Water Management. • SIG-EP 008: Hydrocarbon Management Plans. • SIG-EP 013: Development and Review of Site Closure Plans. • SIG-EP 019: Planning, Construction and Maintenance of Access Tracks. • SIG-EP 015: Rehabilitation Objectives and Progress Criteria.	The impact of the Project on the surface water and groundwater of Lake Lefroy is an important issue. Surface water flow will be modified by the changes to the lakescape, but this is not considered to be a significant impact. The Project will not result in significant impacts on the ecology of the lake and its surrounds. Dewatering discharge will cause localised and short term changes to the quality and quantity of water at some discharge points. The salt crust may harden and become discoloured at some discharge points, but this will be highly localised. The impact of this on the hydrology and ecology of the lake is not considered to be significant.

Table 5.1 (*cont'd*)

Element	Environmental Factor	Work Required for the Environmental Review of the Project (as identified by the EPA Guidelines)	Environmental Conditions/Impacts	Proposed Mitigation and Management Measures	Predicted Outcome
Land	Landform	The EPA Guidelines require that the Proponent: • assess potential impacts of the proposal on the existing landforms; • describe the management of the waste dumps, causeways, bunds and final voids, with regard to their long term stability and potential for erosion; • investigate the stability of excavations and discuss options for their long term management; and • propose measures to manage impacts.	It is estimated that approximately 420 ha (0.7%) of the surface of Lake Lefroy will be converted to islands and that mine voids will cover approximately 155 ha (0.3%). The stability of these features depends primarily on the stability of the lake sediments. A number of studies have been conducted into the stability of lake sediments, and it has been demonstrated that, in sediments 5-15m thick, the potential failure surfaces for open voids would not extend to more than 30m behind the pit crest. The risk of slumping is reduced in those voids that fill with water. Though minor slumps may occur in the early stages of re-saturation, the stability of the sediments is unlikely to be compromised as the salt build-up at on the sediment surfaces would prevent further erosion. See Section 5.6 for further information. The risk of erosion from features such as overburden dumps will be minimised by rehabilitating disturbed areas on a progressive basis. Causeways and other infrastructure will be removed and rehabilitated when no longer required for the Project.	• Rehabilitate disturbances on a progressive basis. • SIG-EP 007: Waste Dump Design, Construction and Water Management. • Conduct further studies into the stability of pit slopes. • Complete the studies by CSIRO into the behaviour of final voids.	Surface water flow will be modified by the changes to the lakescape, but this is not considered to be a significant impact. The management of final voids may be modified depending on the findings of the studies into the behaviour of final voids and the stability of pit slopes.
	Rehabilitation	The EPA Guidelines require that the Proponent describe: • the measures proposed to rehabilitate the impacted areas to an acceptable standard that will integrate the post-mining landform with the surrounding environment; • revegetation programmes; • completion criteria; • rehabilitation programmes to include mining pits, overburden dumps, causeways, bunds and borrow pits; • the removal of infrastructure and clean-up of any contaminated areas.	Impacted areas will be rehabilitated on a progressive basis using the environmental procedures listed in the next column, and as described in Section 2. These procedures will be modified as appropriate to suit the site-specific conditions of each of the sites to be rehabilitated. Planning for rehabilitation and the progress made in rehabilitating Project disturbances will be reported in the AEMP.	• SIG-EP 007:Waste Dump Design, Construction and Water Management • SIG-EP 013: Development and Review of Site Closure Plans • SIG-EP 014: Vegetation and Topsoil Management • SIG-EP 015: Rehabilitation Objectives and Progress Criteria • SIG-EP 023: Rehabilitation Monitoring	Progressive rehabilitation of Project disturbances to meet the standards specified in the AEMP.
POLLUTION MANAGEMENT					
Air	Particulates/Dust	The EPA Guidelines require that the Proponent: • identify existing sources of dust; • assess potential increases in dust resulting from the construction and operation of the mine and associated activities; and • assess potential impacts of increased dust on surrounding vegetation from the construction and operation of the mine and associated activities.	Dust is generated by the existing mining operations through the movement of vehicles on unsealed haul roads and access tracks, and from exposed surfaces such as ore stockpiles. High levels of fugitive dust occur naturally in the region, particularly when high winds occur following dry periods. Dust will be generated during the construction and operation of the Project as a result of earthworks and the movement of vehicles.	• Use hypersaline water for dust suppression on haul roads and access tracks (water trucks). • Use hypersaline water sprays on ore pads and other exposed surfaces if required. • Use freshwater for dust suppression on topsoil stockpiles.	No significant impacts. The Proponent's existing DEP pollution control licence will apply to the proposal. This licence specifies management and limits to control dust generation.
	Greenhouse Gases	The EPA Guidelines require that the Proponent: • detail source(s) and amounts of greenhouse gases released as a result of mining activities; and • propose measures to minimise greenhouse gas emissions.	Total CO_2 emissions at St Ives in 1998 were 135,730 t. The main sources of greenhouse gas emissions for the Project will be the use of diesel fuel during: • mining and exploration activities; • the transport of ore to the St Ives Gold Mill; • the transport of overburden to an overburden management area; • pumping for mine dewatering; and • the use of explosives. The release of carbon through vegetation clearing is not considered significant. Approximately 44 kg of CO_2 is generated per tonne of ore milled. Therefore, it is estimated that 906,000 t of CO_2 will be generated over the 10 year life of the Project.	• Minimise the haulage distances to either the Mill or overburden management areas. • Reduce the haulage gradient (within the overall pit design criteria) so as to reduce engine loads and therefore fuel consumption. • Utilise the competitive tendering process to ensure the use of efficient machinery.	No significant increase in greenhouse gas emissions by St Ives Gold's overall operations as a result of the proposed mining developments.

Table 5.1 (*cont'd*)

Element	Environmental Factor	Work Required for the Environmental Review of the Project (as identified by the EPA Guidelines)	Environmental Conditions/Impacts	Proposed Mitigation and Management Measures	Predicted Outcome
Water	Groundwater quality	The EPA Guidelines require that the Proponent: • describe the groundwater abstraction for the mining development; • describe the fate of water abstracted in any on-site mine operations; and • propose measures to manage impacts.	The proposed mining developments will be dewatered using in-pit sumps and/or bores, as per current practice. Further investigations are required to determine the dewatering requirements of the proposed pits but it is anticipated that these will be similar to the requirements of the existing in-lake pits. Mine water will be discharged to Lake Lefroy. Four options exist for dewatering discharge, as discussed in Section 2.5.	• Conduct further studies to determine the dewatering requirement for the individual pits. • Direct mine water to settlement ponds prior to discharge. • Monitor discharge quality and quantity.	Localised impacts may occur where the hydrochemical signature of the discharge water is different to that of the receiving water. The conditions of the Proponent's DEP licence include a requirement to conduct water quality monitoring on a three or six monthly basis (depending on the parameter being measured).
	Surface water quality	The EPA Guidelines require that the Proponent: • describe the water requirements for the mining development and other associated operations; • describe the fate of water used in any on-site and mine operations; • discuss options for disposal of runoff to ensure the surface water quality is maintained; • identify contaminants (such as hydrocarbons) discharged to Lake Lefroy; and • propose measures to manage impacts.	Water is required for dust suppression and for drilling. This requirement will be met using hypersaline water from dewatering operations. Potable water for domestic consumption and dust suppression on topsoil stockpiles will be obtained from the Proponent's existing water supply. Hydrocarbons will not be discharged to the lake.	• Bund roads to prevent the egress of saline water to adjacent vegetation. • Use fresh water for dust suppression on topsoil stockpiles. • Contain and collect run-off from workshop areas and washdown bays, and direct it through an oil-water separator. Recycle water through the washbay with no discharge to the lake. Recycle waste oil or disposal by other suitable means. • SIG-EP 008: Hydrocarbon Management Plans. • SIG-EP 003: Spill Response Preparedness. • SIG-EP 005: Emergency Spill Response.	No significant impacts.
SOCIAL SURROUNDINGS					
Public health and safety	Risk and hazard	The EPA Guidelines require that the Proponent describe the methods proposed to manage the final voids, overburden dumps and access causeways.	Addressed under the factors of Landform and Rehabilitation.	Addressed under the factors of Landform and Rehabilitation.	Addressed under the factors of Landform and Rehabilitation.
Social	Road transportation	The EPA Guidelines require that the Proponent describe the transport requirements for the proposal, including anticipated impact on local authority roads.	Ore and overburden will be transported within the Project Area via haul trucks. Ore is transported to the St Ives Mill via road trains. Light vehicle use will also occur. Vehicle movements will be restricted to haul roads and access tracks within the Project Area, and to the St Ives Causeway.	• Restrict vehicle use to haul roads and access tracks. • Discourage off-road vehicle usage.	No significant impacts.
	Recreation	The EPA Guidelines require that the Proponent: • establish the recreational values of Lake Lefroy; and • propose measures to manage impacts.	Recreational users of Lake Lefroy include motorbike riders, walkers and photographers. These users will not be affected by the Project. The Project Area is of limited recreational value due to access limitations. See Section 3.13.2 for further information.	No specific measures required.	No significant impacts.
Culture and heritage	Aboriginal culture and heritage	The EPA Guidelines require that the Proponent: • identify Aboriginal cultural and heritage sites of significance through archaeological and ethnographic surveys of the Project Area and through consultation with local Aboriginal groups and the Department of Aboriginal Affairs; • consult with the Aboriginal people of the area to determine potential impacts of the proposal on cultural associations with the Project Area; and • propose measures to manage impacts.	A number of Aboriginal heritage studies have been conducted in the Lake Lefroy area on behalf of the Proponent (as described in Section 3.13.4). In addition, contact is made with local Aboriginal groups and individuals (including the Native Title claimants) on a regular basis. No sites of significance or importance to Aboriginal people have been identified in the Project Area as a result of these investigations and consultation. The proposed mining developments will not directly or indirectly impact any Aboriginal heritage sites in the Lake Lefroy area.	The Proponent will continue to liaise with Aboriginal groups and individuals on a regular basis.	Aboriginal heritage sites will not be affected by the proposal.

5.2 ENVIRONMENTAL MANAGEMENT SYSTEM

Each of WMC's operations develops and implements an EMS within a framework consistent with the EMS standard ISO 14001. St Ives Gold's EMS provides a framework for the company to achieve and systematically manage continual improvement in environmental performance (Figure 5.1). A description of the Proponent's EMS is provided as Appendix G and a copy of the Proponent's Environmental Policy is provided as Appendix H.

The EMS is reviewed and evaluated periodically in order to identify opportunities for improvement and subsequent implementation, and to ensure that it remains relevant to the Proponent's activities. Environmental issues relevant to the operations are identified through biennial technical audits, biennial system audits and an annual management review. Environmental objectives and targets are set on an on-going basis, and are reviewed as part of the business planning process each year.

WMC is committed to public reporting of its environmental performance and, since 1995, has released an Environment Progress Report on an annual basis. WMC's environment progress reports are available on its web page (www.wmc.com.au). The site report for St Ives Gold from the 1998 Environment Progress Report is provided as Appendix I.

The Proponent's progress in the environmental management of the proposed gold mining developments will also be reported in the AEMP (as described in Section 1.11).

Commitment 1

Prior to the commencement of mining, the Proponent will prepare an Annual Environmental Management Plan (AEMP) that will provide further details on the design and layout of the individual mining developments planned for the first 12 months of the Project's life and the environmental management measures that will apply to these developments. The AEMP will be updated on an annual basis to provide a review of the mining developments undertaken during the previous 12 months and to provide additional detail on the mining developments (and relevant environmental management measures) planned for the next 12 months.

Commitment 2

Two years prior to the completion of the Project, the Proponent will review its planning for the closure, decommissioning and rehabilitation of the Project. This review will address, but will not necessarily be limited to, the following:

- the removal or, if appropriate, retention of plant and infrastructure developed as a result of the Project;
- the rehabilitation of any remaining disturbances in the Project Area;
- the development of a "walk-away" solution for pits, overburden dumps, causeways, borrow pits, haul roads and other associated infrastructure; and
- the identification and remediation of any contaminated areas (including provision of evidence of notification to relevant statutory authorities).

The findings of this review will be reported through the AEMP process.

5.3 EXPLORATION

The Proponent will continue to explore Lake Lefroy within its approved exploration and mining leases (Figure 1.4). The techniques used for exploration are continually evolving as part of the Proponent's commitment to continuous improvement and to reducing its impact on Lake Lefroy.

Exploration is currently conducted through the use of geophysical and geochemical data, in conjunction with drilling programmes of varied spacing, to target concealed gold mineralisation. Targeting criteria (which include the nature of the host rocks, structural orientation, magnetic structure and tectonic lineaments) are used to define and rank the lake exploration targets. As a result, the Bahama and North Revenge prospects have been identified as the highest ranking targets on Lake Lefroy and will be among the first to be developed by the Proponent as part of this Project.

Historically, the main constraint to drill testing lake targets was the mobility of drill rigs across the surface of the lake. Rock causeways were previously used to access the lake targets but construction and rehabilitation costs were significant so alternative exploration methods have been developed. Exploration on the lake is now mainly conducted using a wide-track aircore rig and percussion rig mounted on a hovercraft (an example of which is shown on the front cover of the PER). The hover platform supports the weight of the drill and uses wheels to move across the lake surface. Crawler-mounted diamond drill rigs are also utilised. Rock causeways are only constructed and used in the final stages of resource definition.

The environmental issues associated with exploration on Lake Lefroy are:

- the risk of drill holes collapsing in soft lake sediments, resulting in a small area of depression;
- potential for spills of hydrocarbons and other drilling fluids;
- generation of noise due to the use of equipment; and
- visual impacts associated with hovercraft tracks and drill castings (drill samples) on the lake.

These impacts are of low significance and are easily managed using standard management practices. All drill holes will be capped as per standard practice at St Ives Gold. Equipment used on the lake will be serviced on a regular basis to minimise the risk of hydrocarbon and other leaks, and spill response plans will be implemented as required (as described in SIG-EP 005 in Appendix J).

Hovercraft tracks will be left on the lake as a result of exploration. The use of hovercrafts for exploration has reduced the need for causeways and therefore the visual impact of this phase of the Project. These tracks are covered when the salt crust dissolves and reforms following significant rainfall events. Any drilling samples left on the lake are flattened at the completion of drilling and become covered with a salt crust as the lake goes through its wettting and drying cycle. These impacts are therefore not considered to be significant.

5.4 SURFACE WATER AND GROUNDWATER

The effect of the proposed Project on the surface water and groundwater of Lake Lefroy has been identified as one of the most important issues to be addressed in this PER. The key aspects are considered to be:

- changes to the movement of water across the lake due to the creation of new landforms on the lake bed and along a small portion of its shoreline (see Section 5.4.1);
- potential impacts on the quality and quantity of surface water and groundwater due to:
  - mine dewatering operations and the subsequent discharge of mine water (see Section 5.4.2 and 5.4.3);
  - the accidental release of pollutants and other chemicals (see Section 5.14);
  - run-off from any acid-generating materials (see Section 5.8); and
- the behaviour of final pit voids (see Section 5.5).

5.4.1 Movement of Surface Water

Existing Environment

As discussed in Section 3.7.2, the lake bed in the Project Area is dry for much of the year. Water is only present following rainfall events and around dewatering discharge points (though this disperses within a short distance of the discharge point and is lost via evaporation and infiltration into the lake bed). The lake bed is flat, so the regional lake bed gradient does not have a significant influence on flow patterns. Surface water movement over the lake's surface is influenced primarily by wind direction.

Environmental Impacts and Management

As the movement of water across the surface of Lake Lefroy is wind-driven, water will continue to flow around permanent features such as overburden dumps and abandonment bunds around final voids (where these are to be maintained). The Proponent will design these features such that the flow of surface water around them is not impeded. Therefore, their presence will not significantly influence surface water flows.

Flow to some areas (such as within the flood protection bunds) will be restricted or prevented. Experience on-site has shown that, with time, those areas that have been cut off from surface water flow often develop a ground cover of samphires and other salt-tolerant species (Plate 5.1). Water flow may also be restricted in some areas due to the presence of causeways and haul roads. The Proponent will minimise this impact by:

- utilising the existing network of causeways for access around the site, where possible;
- removing all causeways not required for Project operations; and
- incorporating appropriate culvert design in the causeways and haul roads, as required.

This impact is not considered to be significant as surface water flow will be reinstated once this infrastructure is removed.

5.4.2 Mine Dewatering

Existing Dewatering Regime and Impacts

As described in Section 2.5, dewatering operations are currently being conducted at the Junction, Santa Ana, Intrepide and Argo pits as well as the Leviathan complex, and were conducted previously at Revenge and Redoubtable. Dewatering of nickel mines at Lake Lefroy (e.g. the Hunt/Beta, Long and Victor mines) was also conducted until recently. In 1997/98, a total of 5,868 ML of water was abstracted by St Ives Gold and KNO (Tables 2.3 and 2.4), which is insignificant compared to the large volumes of groundwater in storage within the shallow aquifer and the underlying fractured aquifer.

Dewatering creates a cone of depression in the immediate vicinity of the pit. This increases the hydraulic gradient and the potential for surface water to infiltrate the lake sediments. However, the impact of groundwater drawdown as a result of dewatering activity is mitigated by:

- discharge of dewatering water close to the cone of depression (and subsequent recirculation to the groundwater system via seepage through the lake bed);
- groundwater recharge as a result of rainfall infiltration; and
- groundwater inflow from surrounding parts of the aquifer.

Consequently, the current dewatering operations are not considered to have a significant impact on the Lake Lefroy environment.

Environmental Impacts of the Proposed Dewatering Operations

The proposed mining developments will be dewatered using in-pit sumps and/or bores, as per current practice. Further investigations will be required to determine the dewatering requirements of the proposed pits but it is anticipated that these will be similar to the requirements of the existing in-lake pits (as described above and in Section 2.5). The results of these investigations will be reported in the AEMP.

The impact of dewatering the individual pits is not considered to be significant. A cone of depression will develop around each of the pits being dewatered, but will be restricted to the vicinity of the pit. The total volume of water being abstracted will vary as dewatering operations commence and cease at the different pits, but the total volume of water being abstracted will be insignificant compared to the large volumes of groundwater present in the lake system, ongoing groundwater recharge through infiltration of mine water discharge and rainfall, and groundwater inflow. Therefore, the cumulative impact of the proposed dewatering operations is also not considered to be significant.

Commitment 3

The Proponent will conduct further hydrogeological investigations to determine the dewatering requirements of the proposed mine pits. The results of these investigations will be reported in the AEMP.

5.4.3 Mine Water Discharge

Environmental Impacts and Management

The volume of mine water which will be discharged to the lake as a result of the proposed mining developments is expected to be similar to that discharged from current operations and will be small in comparison to the volume of water introduced to the lake as a result of major storm events. This is illustrated by Table 5.2 which indicates that the volume of dewatering discharge during 1997/98 was equivalent to approximately 2.5% of the water introduced to Lake Lefroy during cyclones Elaine and Vance.

Table 5.2

Mine Water Discharge and Stormwater Volumes

Source of Water	Volume of Water
Mine water discharge by St Ives Gold in 1997/98	5,004 ML
Mine water discharge by KNO in 1997/98	864 ML
Total mine water discharge in 1997/98 (St Ives Gold + KNO)	5,868 ML
Water introduced to Lake Lefroy as a result of cyclones Elaine and Vance	222,000 ML

The discharge of mine water to the lake bed may result in localised changes to the quality and quantity of water at the discharge sites. The extent of this change will depend on the amount of water being discharged and any differences between the quality of the lake's surface water and that of the mine water.

It is expected that the quality of the mine water discharged to the lake will be similar to that currently being discharged by existing operations. All dewatering discharge from these mines is hypersaline and generally has similar physical and chemical characteristics to the lake's surface water (Table 5.3). However, the concentration of metals in dewatering discharge can vary, primarily due to differences in aquifer geology. For example, although the concentration of metals in discharges from Argo, Intrepide, Junction, Revenge and the Leviathan complex are consistently low, slightly higher levels of nickel, copper and lead have been occasionally recorded from the Redoubtable discharge (Table 5.4).

Where the lake's surface water and dewatering discharge water have different hydrochemical signatures, there is potential for the precipitation of low-solubility compounds such as iron silicates. Precipitation of such compounds may cause localised hardening and discolouration of the salt crust. This has occurred at two of the Proponent's discharge sites, with 3.1 ha of salt crust staining at the Argo outfall and a discoloured area of 7.2 ha around the Junction outfall (WMC Resources Ltd, 1997b). However, stained areas are mantled by precipitated salt when the halite crust re-establishes following flood conditions. Therefore, staining of the salt crust is not considered to be a significant environmental impact.

Table 5.3

Water Quality Monitoring Results (Averages) for Dewatering Discharge by St Ives Gold

Parameter	Argo	Junction (Lake Finn Discharge)	Leviathan Complex (Victory Outlet)	Santa Ana	Revenge	Redoubtable	Intrepide	Control
pH	6.3	7.5	6.8	6.5	6.8	7.2	6.3	6.5
TDS (mg/L)	285,975	174,529	316,257	320,000	311,720	196,500	338,333	324,632
EC (mS/cm)	498	297	515	573	560	330	573	586
HCO_3 (mg/L)	78	143	78	58	79	133	58	58
CO_3 (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1
Cl (mg/L)	149,992	91,773	177,329	173,333	177,281	103,000	185,000	184,918
SO_4 (mg/L)	25,046	14,333	21,421	22,667	21,411	15,160	24,833	12,679
NO_3 (mg/L)	<0.2	62	11.5	<0.2	68	55	0.7	2
Na (mg/L)	79,192	53,167	96,443	96,000	97,924	59,560	103,000	117,097
K (mg/L)	1,277	553	1,201	1,487	1,221	730	1,417	747
Ca (mg/L)	365	237	707	370	424	550	285	1,200
Mg (mg/L)	15,625	9,000	14,709	17,400	13,561	8,350	17,662	7,461
Soluble Fe (mg/L)	1.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Si (mg/L)	31	43	49	43	43	6	127	24
TSS (mg/L)	60	25	18	20	62	Not determined	33	20

Source: WMC Resources Limited (1997b)

Table 5.4

Concentration of Metals in Water Samples from Discharge Points

Parameter	Argo	Junction (Lake Finn Discharge)	Leviathan Complex (Victory Outlet)	Santa Ana	Revenge	Redoubtable	Intrepide	Control
Al (mg/L)	2	1	2	2	2	Not determined	2	2.4
As (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cd (mg/L)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Co (mg/L)	<0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cu (mg/L)	0.3	<0.5	<0.5	0.8	1.2	<0.5	0.7	0.5
Fe (total) (mg/L)	2.7	<0.5	0.7	<0.5	2.1	<0.5	0.7	0.4
Mn (mg/L)	2.0	0.9	2.4	2.1	1.8	1.0	2.1	<0.5
Ni (mg/L)	<0.5	<0.5	0.5	<0.5	<0.5	1.0	<0.5	<0.5
Pb (mg/L)	<0.5	<0.5	0.7	<0.5	<0.5	1.4	0.8	<0.5
Se (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn (mg/L)	<0.5	<0.5	<0.5	<0.5	1.4	0.5	<0.5	<0.5

Source: WMC Resources Limited (1997b)

The lake bed sediments play a significant role in absorbing and immobilising any metals which may occur in the dewatering discharge. Test work has confirmed that the concentration of copper and nickel in sediment samples from the Junction discharge site is higher than in the naturally-occurring lake sediment collected some distance from the discharge point (Figure 5.2). This suggests that copper and nickel have accumulated in the surface lake sediments at the discharge point as a result of mine water discharge (WMC Resources Limited, 1997b). The elevated copper and nickel concentrations in Junction dewatering discharge is related to the mineralogy of the Junction orebody and is not anticipated to be an issue for the lake pit ore bodies.

Settlement ponds are used to limit the amount of sediment entrained in mine water discharge and the amount (and resultant impact) of sediment released to the lake due to dewatering is therefore negligible. In contrast, photographic records and anecdotal data confirm that the sediment load of runoff following major storm events is very high, and is estimated to be of the order of 250 mg/L to 500 mg/L (CSIRO, 1999b). For example, it is estimated that cyclones Elaine and Vance introduced in the order of 33,000 t of sediment to Lake Lefroy. The volume of sediment which enters Lake Lefroy as a result of mine water discharge is small in comparison.

The high salinity of the receiving water body promotes rapid coagulation and settlement of suspended sediments from the lake which discolour the halite crust. Over time, the evaporation of surface water leads to the re-deposition of salts on the lake floor which mantle the clastic sediment and re-establish the halite crust.

It is considered that the discharge of hypersaline mine water will not have a significant impact on the total salt balance of the Lake Lefroy system. The surface water and shallow groundwater systems are in dynamic equilibrium and thus, the transfer of water (and dissolved salt) between these systems due to mine water discharge and subsequent infiltration of surface water through the lake bed will merely accelerate a natural process that is already active within the Project Area. The volume of salt which will be discharged onto the lake surface as a result of the proposed development is anticipated to be similar to that discharged by current operations (1.2-2.3 Mt/a) and is small in comparison to the volume of salt in storage in the top 1 m of the halite crust (calculated to be 94 Mt) and salt dissolved within hypersaline water in the near surface aquifer (estimated to be approximately 79 Mt). It should also be recognised that as Lake Lefroy is a system in transition between an ephemeral lake and a salt pan, increased salt buildup in the lake bed with time is anticipated as a result of natural processes (Clarke, 1994a).

Though there will be a short term build-up of salt on the surface at the discharge point, this will be redistributed within the lake system when the surface salt layers dissolve during flood conditions after major storm events. It is also likely that the shallow aquifer (from which most of the dewatering discharge is originally sourced) will be recharged by seepage of the discharge into the lake sediments.

Water Monitoring

The discharge of mine water to Lake Lefroy is licenced by the DEP. The conditions attached to the Proponent's Licence that are relevant to dewatering discharge include a requirement to conduct water quality monitoring on a three or six monthly basis (depending on the parameter being measured). Water quality monitoring is conducted by the Proponent in accordance with the monitoring procedures presented in Appendix J.

An extensive surface water monitoring network has been established in and around Lake Lefroy to monitor surface water flows, levels and quality on a regular basis. This system has already provided valuable information on the impact of cyclones Elaine and Vance on the Lake Lefroy system. The Proponent will continue this surface water monitoring programme and will review the scope, timing and duration of this programme in consultation with the regulatory authorities.

Commitment 4

The Proponent will continue to use the existing surface water monitoring network at Lake Lefroy to monitor surface water flows, levels and quality on a regular basis. The results of the monitoring programme will be reported in the AEMP.

5.5 FINAL VOIDS

5.5.1 Existing Voids

Data on the water quality at two voids at St Ives were reviewed by the Proponent to predict the likely behaviour of mine voids that remain following the development of the proposed Project. These are:

- the North Orchin pit, which was left to recover for several years prior to cut back during 1999; and
- the Revenge Pit, which closed in 1998 (see Table 2.2 for further details).

Reconnaissance profile sampling conducted at North Orchin during November 1998 indicated that the pit void water body had the following characterisitics:

- no apparent thermal stratification;
- uniform pH and dissolved oxygen profiles throughout the water body; and
- TDS concentrations were between 327,000 mg/L and 333,000 mg/L, with a slight increase towards surface (which may have reflected evaporative concentrations and/or wall rock interactions).

This information indicated that no acid generation was taking place in the North Orchin pit.

The rate of inflow to the Revenge pit indicates that the water level will reach a steady state condition at a level about 290 mRL, which is 5 m below lake level (Berry, 1999). Groundwater modelling indicates that the water level in the Revenge pit void will recover to steady state in between five and ten years (CSIRO, 1999b; Berry, 1999). Prior to cut back, the water level in the North Orchin pit void had stabilised at 272 mRL, which is significantly lower than the water level in the Revenge void. This depressed water level is believed to have been partly due to ongoing dewatering of underground mining at the Leviathan complex which has since ceased (Berry, 1999).

5.5.2 Environmental Issues and Management

Where possible, pits will be backfilled with overburden on completion of mining. In cases where it is not feasible to backfill mined-out pits, voids will remain which will infill with water once dewatering ceases. The decision on whether or not to backfill pits will be made according to the process outlined in the decision tree presented in Figure 2.9.

Water levels in the final voids on Lake Lefroy are expected to recover relatively rapidly to a level slightly below the regional water table (which is located just below the lake bed). The rate of recovery and long term water level in final voids will be influenced by:

- the rate of groundwater inflow from the surrounding aquifer, which is primarily a function of aquifer permeability (and will decline as the void water level approaches steady state);
- possible reduction in recharge from the surrounding aquifer due to dewatering of adjacent underground operations (as was the case with recovery of the North Orchin pit void water body, which was affected by dewatering from the underground Victory complex); and
- variations in evaporative losses due to factors such as:
  - higher total evaporation due to an increase in surface area of the void water body; and
  - a gradual reduction in evaporation rate as void water salinity increases.

Water quality within the final void water bodies will evolve slowly at a rate that will depend on:

- the balance between evaporative losses and recharge as a result of direct rainfall recharge, stormwater inflow and recharge from the surrounding aquifers;
- the quality and relative quantities of recharge from these sources; and
- possible leaching of salts as a result of wall rock chemical reactions (Berry, 1999).

The mechanisms that influence final void water quality are illustrated by comparing water quality within the North Orchin pit to that within the surrounding aquifer. Dewatering bores around the pit indicate salinities of 220,000 mg/L to 250,000 mg/L, whereas water within the void ranges from 320,000 mg/L to 330,000 mg/L. This indicates a 40% increase in salinity in the void, which is attributed to the combined concentration effects of evaporative losses and wall rock chemical reactions (CSIRO, 1999b; Berry, 1999).

Groundwater in the shallow aquifer systems below Lake Lefroy is already hypersaline and has no beneficial use, so any salinity increase in final voids will not have an adverse impact on the suitability of groundwater for use.

Extensive coatings of evaporite minerals (mainly gypsum and some halite at evaporation fringes) have formed on the walls of the North Orchin pit. As Lake Lefroy is in transition between an ephemeral lake and a salt pan (Clarke, 1994a) it is probable that evaporation-driven precipitation will eventually cause final pit voids to infill with evaporite minerals, but such infill is likely to take hundreds or even thousands of years (CSIRO, 1999b).

It is anticipated that other pit void water bodies will develop similar physico-chemical characteristics to those observed in the North Orchin water body. This will result in the development of oxygenated water bodies which have no significant thermal stratification and are neutral in pH throughout the profile. Under such conditions, acid generation and resultant metal mobilisation is unlikely to be a significant issue (Berry, 1999).

5.6 LANDFORMS

5.6.1 Existing Environment

The landforms and land systems in the Project Area are described in Sections 3.5 and 3.6. Most of the proposed mining developments will be located on the lake bed of Lake Lefroy, which is relatively flat and has a well-developed halite crust. Two of the pits (Thunderer and Phoebe) will be developed in the dune system on the eastern shoreline of Lake Lefroy whilst the Delta Cutback will be developed on Delta Island (a small island comprising gypsum and siliclastic dunes on a basement outcrop).

Mining activity in the St Ives area over the past 90 years has resulted in considerable surface disturbance and the creation of new landform types. For example, gold mining has been conducted on Delta Island since 1989 and two new islands (Omega Island and Epsilon Island) have been developed in adjacent areas using overburden from these mines. Alpha, Beta, and Gamma islands have also been disturbed by previous and current mining operations. Oyster, Coral and Landmark Island are relatively undisturbed.

Commitment 5
The Proponent will not construct any new facilities or infrastructure on Gamma Island, Oyster Island or Coral Island.

5.6.2 Environmental Impacts and Management

The development of the proposed Project will result in additional changes to the lakescape. Approximately eight new islands will be constructed on the lake and the Alpha, Beta and Delta islands will be extended using overburden from adjacent mines. Mine pits will be backfilled where possible, but some voids will remain.

The extensive network of causeways that currently exist in the Project Area, and those causeways developed as a result of this Project, will be removed progressively when no longer required. The St Ives causeway will be given to the local authority for future use by the public.

The area covered by new landforms at the end of the Project's ten year life will depend on a range of factors including:

- the final size and shape of the pits, which in turn will depend on the results of further exploration and resource delineation tasks and those factors listed in Section 2.2.2;
- the timing and sequencing of the mining development (which will be determined by the criteria listed in Section 2.2.3);
- whether the pits are mined using open cut or underground methods; and
- the final design of the waste dump islands.

Based on indicative layouts provided as Figures 2.2 to 2.4 and 2.6 to 2.8, it is estimated that approximately 420 ha (0.7%) of the surface of Lake Lefroy will be converted to islands and that mine voids will cover approximately 155 ha (0.3%). The main issues associated with these changes to the lakescape are:

- potential impacts on the direction of the surface water patterns;
- the longterm behaviour and management of open voids;
- the visual impact of the new landforms (see Section 5.16); and
- the stability of the new landforms.

The stability of the new landforms (i.e. the open pits, abandonment bunds and overburden islands) will depend primarily on the stability of the lake sediments on which these features are located and the erosion potential of the landforms. The risk of erosion of features such as overburden dumps and abandonment bunds will be minimised by rehabilitating disturbed areas on a progressive basis. Temporary stabilisation measures will be adopted where necessary.

A number of studies have been conducted into the stability of lake sediments as part of the geotechnical investigations for pit wall design (e.g. Golder Associates, 1995, 1996, 1997; Daniel, 1998a, b; and Daggers and Li, 1999). The results of these studies have been used to design the batter angles for the lake sediments and no significant stability problems have been experienced during mining. Where minor slumps have occurred, the catchment berms at the base of the lake sediments have been effective in preventing the slumped material spilling to lower levels in the pits (Li, 1999).

Three voids are currently present on the lake (Delta, South Delta and Redoutable). No instability of pit walls has been experienced in these voids. Studies by Golder Associates (1995, 1996) and Daggers and Li (1999) have demonstrated that, in sediments 5-15 m thick, the potential failure surfaces for open voids would not extend to more than 30 m behind the pit crest. Safety bunds are generally placed 50 m to 100 m from the crest of the pits to ensure that their integrity is not undermined by any slumping or failures that may occur (Li, 1999).

The risk of slumping is reduced in those voids that fill with water. Minor slumps could occur during the early stages of re-saturation as the sediments would have been partially drained near the batter surfaces during mining. However, the stability of lake sediments is unlikely to be compromised as the salt build-up in the sediment surfaces prevents erosion and hence improve stability. Observations made at existing voids indicate that this build-up of salt occurs reasonably quickly.

There might be periods where the water level in the pit remains several metres below the lake surface. Though this may not impose stability problems in terms of static loading and saturation, wind induced erosion could affect the stability of the sediments. The risk of this occurring can be minimised by breaching the bunds after mining to allow the pit to fill more quickly but at this stage it is difficult to assess the long term stability of the lake sediments when partially submerged in lake water. Therefore, the Proponent will conduct further investigations into the stability of the pit slopes to facilitate the management of final voids.

Commitment 6

The Proponent will minimise the risk of erosion and sedimentation by minimising the extent of disturbance of the lakescape and progressively rehabilitating disturbed areas.

Commitment 7

Further geotechnical investigations will be conducted to assess the stability of the pit walls post-mining. The findings of these studies will be used in the development of management procedures and closure plans for final mine voids.

5.7 ACID MINE DRAINAGE

The acid generating potential of the ore zones and overburden in the proposed mine pits is low (Campbell and Associates, 1994). Though sulphide-bearing bedrock does occur in some areas, the pits will generally not be deep enough to expose this material.

Acid generation testwork will be conducted as part of the Proponent's routine metallurgical testwork. The results of this testwork will be used to identify any overburden with acid-generating potential. This material will be encapsulated within overburden dumps to prevent acid generation. Ore stockpiles on the lake and its shoreline will be bunded to contain any acidic runoff.

Pits will be backfilled where possible. Any voids that remain after mining are expected to flood to above the natural, *in situ* base of oxidation relatively quickly, thus reducing the potential for acid generation from the pit walls.

5.8 TERRESTRIAL FLORA AND VEGETATION

5.8.1 Existing Environment

Vegetation is only present in the Project Area on the islands and along the shorelines of Lake Lefroy (Figure 3.13). Those plant communities that will be affected by the proposed mining development are described below.

The plant communities that will be affected by the development of the Phoebe pit are:

- Community S3 – low open scrub of regenerating shrubs (including *Melaleuca* species over chenopod species, mixed shrubs and succulents) on disturbed areas;
- Community S7 - open woodland of *Eucalyptus platycorys* over very sparse mixed shrubs and *Triodia scariosa* on deep dunal red sands; and
- Community S12 – very open woodland of *Eucalyptus gracilis* and *Eucalyptus trichopoda* with occasional *Casuarina pauper* over sparse mixed shrubs and a relatively dense cover of spinifex on deep aeolian silica sands and gypsum dunes (Plate 3.8).

Community S3 and S12 are also presented in the Thunderer pit area. In addition, a narrow strip of Community H2 (a halophytic complex dominated by chenopod species and *Frankenia pauciflora)* occurs on the seasonally inundated fringe of Lake Lefroy (Plate 3.11).

Most of the area proposed for the development of the Delta Cutback has been disturbed by previous mining operations. However, small areas of Community S1 (very open woodland of *Callitris glaucophylla, Acacia ligulata* and *Jacksonia arida* with occasional *Eucalyptus griffithsii* on deep aeolian silica sands, Plate 3.7) and Community S6 (an open woodland of *Eucalyptus platycorys, Eucalyptus salicola* and *Eucalyptus trichopoda* over *Triodia* species on deep dunal sands, Plate 3.9) will be affected by this development.

5.8.2 Environmental Issues and Management

Clearing of Vegetation

Less than 4 ha of vegetation will be cleared during the development of the Project. This comprises some 2.9 ha of vegetation in the Phoebe and Thunderer pit areas and 0.3 ha in the Delta Cutback pit area.

The vegetation impacted by the development of the Phoebe and Thunderer pits primarily comprises shrublands and woodlands on deep dunal sands (Table 5.5). The vegetation in these areas has been disturbed previously through sand mining and is not known or likely to support DRF or Priority Flora species.

Table 5.5

Vegetation Clearing – Phoebe and Thunderer

Plant Community	Area of Community shown on Figure 3.13b (ha)	Indicative Area of Disturbance			
		Phoebe		Thunderer	
		Area (ha)	%	Area (ha)	%
H2: halophytic complex dominated by chenopod species and *Frankenia pauciflora*.	9.6	-	-	0.2	2.1
S3: low open scrub of regenerating shrubs (including *Melaleuca* species over chenopod species, mixed shrubs and succulents) on disturbed areas.	56.0	1.1	2.0	0.8	1.4
S7: open woodland of *Eucalyptus platycorys* over very sparse mixed shrubs and *Triodia scariosa* on deep dunal red sands.	124.0	0.2	0.2	-	-
S12: very open woodland of *Eucalyptus gracilis* and *Eucalyptus trichopoda* with occasional *Casuarina pauper* over sparse mixed shrubs and a relatively dense cover of spinifex on deep aeolian silica sands and gypsum dunes.	74.8	0.3	0.4	0.3	0.4
Total	**264.4 ha**	**1.6 ha**	-	**1.3 ha**	-

A small area of vegetation (~ 0.3 ha) may also be cleared during the development of the Delta Cutback on Delta Island (Table 5.6). However, most of the area to be developed for this pit has already been disturbed by previous mining operations.

Table 5.6

Vegetation Clearing – Delta Cutback

Plant Community	Area of Community on Delta Island (as shown on Figure 3.13b) (ha)	Indicative Area of Disturbance	
		Area (ha)	%
S1: very open woodland of *Callitris glaucophylla*, *Acacia ligulata* and *Jacksonia arida* with occasional *Eucalyptus griffithsii* on deep aeolian silica sands.	2.0	0.1	5.0
S6: an open woodland of *Eucalyptus platycorys*, *Eucalyptus salicola* and *Eucalyptus trichopoda* over *Triodia* species on deep dunal sands.	3.0	0.2	6.6
Total	**5.0 ha**	**0.3 ha**	-

The Proponent is committed to minimising surface disturbance and to retaining stands of vegetation within the Project Area where possible. The Project has been designed to minimise clearing of vegetation and disturbance to the playa lakes that occur in the Phoebe-Thunderer area. The overburden dumps associated with these pits will be located on the lake bed, rather than on land adjacent to the pits, to further reduce the extent of disturbance of the playas and vegetation types in these areas.

Clearing of vegetation is controlled through compliance with the Proponent's surface disturbance reporting procedures (see SIG-EP 014 in Appendix J). These will ensure that land clearing is kept to a minimum and that environmental issues are taken into account in the planning and implementation of site preparation activities. Topsoil and vegetation cleared during the construction of the Project will be retained and respread during rehabilitation.

Commitment 8

The Proponent will ensure that disturbed areas are rehabilitated on a progressive basis to minimise disturbance of flora, vegetation and fauna habitats on the islands and along the shorelines of the Project Area.

Use of Saline Water for Dust Suppression

Saline water is used for dust suppression throughout the Proponent's operations at St Ives. This practice may result in a decline in the condition or death of adjacent vegetation if plants are exposed to the salt water through overspraying or saline run-off. To address this, measures will be implemented to prevent overspraying by water trucks, and roads will be bunded to prevent the egress of saline water to the surrounds with run-off from these areas directed to catch pits. Therefore, the use of saline water for dust suppression at Phoebe and Thunderer and along the alternative haulage route is unlikely to result in significant impacts on vegetation health.

Commitment 9

The degree of dust generation will be minimised through the watering of haulage roads (and other roads as necessary) with saline water. Roads on the shoreline and in near-shore areas will be bunded to prevent the egress of saline water to adjacent vegetation.

Mine Dewatering Discharge

Most of the water abstracted from open mine pits and underground workings is discharged to Lake Lefroy. This water is pumped to settling ponds before being discharged onto the lake. The discharge points are located offshore, and at an elevation lower than the adjacent shoreline. Consequently, there is no risk that the water being discharged will not flood or otherwise impact on the fringing vegetation.

Commitment 10

The Proponent will protect plant communities inhabiting the shoreline of Lake Lefroy from the impacts of mine water discharge onto the lake by ensuring that the discharge points are located away from, and do not drain to, these communities.

5.9 AQUATIC FLORA

5.9.1 Existing Environment

As described in Section 3.9, the studies by John (1999) indicate that the salt-encrusted region of Lake Lefroy is generally devoid of aquatic flora. These species are more likely to occur in the ephemeral pools and playas adjacent to Lake Lefroy. The filamentous cyanobactrium *Schizothrix* sp. is considered to be the most common and dominant alga in these areas. This species has an important functional role in the ecosystem as it forms algal mats that bind sand particles together and helps to prevent sand erosion. It also provides the basis for the invertebrate food chain within the samphire regions and ephemeral pools adjacent to Lake Lefroy.

The algal mats formed by *Schizothrix* sp. are common throughout the samphire regions and playas that occur along the shoreline of Lake Lefroy, but do not occur on the halite crust of the lake itself. Consequently, the only impacts on these mats that are likely to occur will be associated with the development the Phoebe and Thunderer pits on the shoreline of Lake Lefroy.

5.9.2 Environmental Impacts and Management

Approximately 51 ha of playas and claypans that could support the *Schizothrix* mats are present in the area shown on Figure 13.3b. The development of the Phoebe and Thunderer pits will result in the disturbance of approximately 2.4 ha of this habitat type. This represents <5% of this type of habitat shown on Figure 13.3b and an insignificant portion of the total area of suitable habitat in the Lake Lefroy area. Consequently, this disturbance is not considered to be of local or regional significance.

Table 5.7

***Schizothrix* Mats – Phoebe and Thunderer**

Extent of Suitable Habitat[1]	Area (ha)	
Total Area of habitat shown on Figure 13.3b	51.0	
Within Phoebe pit	0.4	(0.8%)
Within Thunderer pit	2.0	(3.9%)
Total area of disturbance (Phoebe + Thunderer)	2.4	(4.7%)

Note: 1. As shown on Figure 13.3b

As indicated previously, the Project has been designed to minimise disturbance to the playa lakes in the Phoebe-Thunderer area. The overburden dumps associated with these pits will be located on the lake bed, rather than on land adjacent to the pits, to further reduce the extent of disturbance of the playas in these areas.

Growth of the *Schizothrix* mats is triggered by the availability of water following prolonged periods of desiccation. The mucilaginous sheaths swell up by absorbing water and the dormant cells in the trichome inside the sheaths rejuvenate and undergo cell division. Though little is known about the salt tolerances of *Schizothrix*, it is unlikely to be able to tolerate hypersaline conditions (J. John, pers. comm.). Therefore, the playas and ephemeral pools adjacent to Lake Lefroy will not be used for any new discharge of mine water.

Commitment 11

The Proponent will minimise physical disturbance to the playas and claypans adjacent to Lake Lefroy and ensure that any new discharge points for mine dewatering operations are located away from, and do not drain to, these areas.

5.10 VERTEBRATE FAUNA

5.10.1 Existing Environment

Despite the presence of the existing mining operations and associated infrastructure and activities, the fauna assemblage of the Kambalda area is considered by Ninox (1995) to be relatively intact where disturbance is low to moderate. Ninox found that the low rocky hills adjacent the northern shoreline of Lake Lefroy were significantly richer in species than other habitats within the study area. These hills will not be affected by the proposed Project. Those habitats with the lowest species richness were the previously-mined foredunes adjacent to Lake Lefroy (in which Phoebe and Thunderer will be developed), Delta Island and the lake bed itself.

As discussed in Section 3.10, the fauna habitats in the Project Area are well represented throughout the region and none are considered to be regionally significant. CALM has advised that the natural islands on Lake Lefroy may be locally significant as they may provide breeding sites for bird species, particularly waterbirds. The lake is not known to be an important breeding site for waterbirds but the

Proponent will nonetheless minimise disturbance of the natural islands in accordance with Commitment 5.

5.10.2 Environmental Impacts and Management

The significance of disturbing the fauna habitats represented at the fauna monitoring sites has also been assessed by Ninox (1995) using the criteria listed in Appendix K. These criteria were developed by Ninox using a range of sources including the Australian Heritage Commission (1990), O'Brien (1988) and the Western Australian Water Authority (1993). As such, they represent a consolidation of similar attempts to create habitat impact, or habitat significance, indices. However, these criteria should be regarded as preliminary only.

Each criterion was scored on a scale of 1-5, after which the scores were aggregated. The aggregate achieved for each monitoring site was then compared against the ranking given in Table 5.8. The results for those monitoring sites located within the Project Area (i.e. KFS1, KFS2 and KFS5) are provided in Table 5.9. Site KFS3 was not included in this assessment as many of the criteria do not apply to this highly disturbed section of foredune. At this high level of disturbance, the application of impact criteria is not warranted as the original foredune system and associated vegetation have been removed and future development within its confines will have minimal impact. KFS5 is also a disturbed site but was included due to the amount of regeneration that has occurred.

Table 5.8

Level of Significance based on Aggregate Score for Individual Criteria

Aggregated Score	Level of Significance
11 – 25	Site is of low to very low conservation significance. There is little hindrance to development for a site that scores at the lower end of the scale. Proceed with caution for a site that scores at the upper end of the scale.
26 – 40	Site is of moderate conservation significance. Further assessment may be required to clarify the issues associated with a site that scores at the higher end of the scale and potentially manage specific impacts.
41 - 55	Site is of high conservation significance. Development is inappropriate or inadvisable.

Table 5.9

Scores for the Fauna Monitoring Sites in the Project Area

Criteria[1]	Score for each Criterion		
	KFS1 (Delta Island)	KFS2 (Lake Foredunes)	KFS5 (Low Granite/Basalt Hill)
1. Regional Representation	5	3	4
2. Regional Conservation Status	5	4	4
3. Local Conservation Status	1	1	1
4. Special Regional Attributes	3	2	3
5. Special Local Attributes	1	1	2
6. Ecological Processes	5	3	4
7. Cumulative Impact	3	3	3
8. Rare Resident Fauna	1	1	2
9. Rare or Protected Migratory and Nomadic Fauna	1	3	1
10. Endemic or Localised Fauna	3	2	4
11. Impact Management and Mitigation	3	3	4
Aggregate Score	**31**	**26**	**32**

Source: Ninox (1995)

Note: 1. See Appendix K for a description of these criteria.

In comparing the aggregate scores listed in Table 5.6 with the ranking given in Table 5.5, it is evident that the habitats at these monitoring sites could be considered to have moderate conservation value. However, all three sites scored towards the lower end of the scale for this ranking, indicating that the disturbance of these habitat types can be managed using the Proponent's current management practices.

Other risks to fauna may include:

- indirect disturbance to off-site fauna populations;
- predation by feral cats and foxes;
- loss of fauna habitats due to wildfires;
- the uncontrolled use of off-road vehicles; and
- accidental death and injury to fauna.

Risks to fauna will be minimised by:

- minimising the extent of disturbance of vegetation on the island and shoreline in the Project Area (see Section 5.8);
- covering open foundation holes, drill holes and trenches as soon as possible to prevent injury to fauna. Trenches that are to remain open for long periods will include sections with gentle slopes to facilitate the escape of fauna;
- all exploration holes in areas adjacent to the lake will be capped and inspected regularly to ensure that the integrity of the capping is maintained;

- inspecting open holes and trenches regularly for trapped fauna and releasing trapped individuals;
- prohibiting firearms and domestic pets in the Project Area;
- rehabilitating disturbed areas on a progressive basis to minimise loss of habitat (as per Commitment 8);
- raising awareness of the workforce about the conservation of fauna and their habitats through the Proponent's environmental induction programme;
- avoiding direct contact with fauna wherever possible;
- parking vehicles and machinery only in designated locations to minimise habitat damage; and
- discouraging off-road recreational activities.

The Proponent's current fauna monitoring programme and feral animal trapping programme will continue during the life of the Project.

Commitment 12
The Proponent will continue to implement its fauna monitoring programme and feral animal trapping programme during the life of the Project.

5.11 TERRESTRIAL INVERTEBRATE FAUNA

5.11.1 Existing Environment

As discussed in Section 3.12, more than 160 species of terrestrial invertebrates were collected during this survey (Appendix F). The most abundant were the ants (49 species), spiders (41 species) and beetles (20 species).

Most of the terrestrial invertebrates recorded at Lake Lefroy by Hudson (1995) and Brennan (1999) have been recorded at other salt lakes in the Goldfields region (Appendix F). Some species (such as a species of comb spider and two species of tiger beetles) are currently considered to be endemic to Lake Lefroy because few other surveys have been conducted in the region.

5.11.2 Environmental Impacts and Management

The proposed Project may impact on the terrestrial invertebrate fauna of the Project Area through:

- direct disturbance of their habitats through clearing activities or the discharge of mine water;
- changes in primary productivity within the lake which may affect invertebrates at higher levels of the food chain; and
- changes to the structure of vegetation fringing the lake.

These issues are discussed below.

Habitat Disturbance

The impact of discharging mine water to the lake on terrestrial invertebrates was assessed by Brennan (1999) by comparing the assemblage of ants, beetles and spiders at the Redoubtable discharge site with the assemblages present at the two Reference Sites. These groups were selected as bio-indicators as they are:

- speciose and abundant;
- readily sampled;
- sensitive to biotic and abiotic changes in the environment;
- functionally important (as indicated by Friend and Williams, 1996; Andersen, 1990; and Churchill, 1997).

Brennan (1999) found that the assemblage of species at sites affected by dewatering discharge was different to the assemblage of species at sites not affected by this activity. For example, burrowing species such the wolf spider *Lycosa salifodina* were recorded at the Southwest and Northeast Reference Sites and at Redoubtable in areas unaffected by dewatering discharge, but were absent from Redoubtable's discharge site. This may be due to the presence of surface water at the site and/or the formation of a thicker salt crust (>15 cm) as a result of the discharge of mine water which may inhibit the burrowing behaviour of these species (Brennan, 1999).

It is concluded that the discharge of mine water to the lake surface may change the species composition of invertebrate communities in the immediate area of the discharge. However, the area affected by the discharge of mine water is likely to be small (approximately 5 ha per discharge point) in comparison to the area of available habitat for these species (>55,000 ha). Therefore, this impact is not considered to be significant.

Changes in Primary Productivity

Changes in primary productivity in a lake system may affect terrestrial invertebrates at higher levels in the food chain. For example, some species of staphilinid beetles (Staphylinidae) are known to feed on algae and diatoms (Herman, 1986 as cited in Lawrence and Britton, 1994). Staphilinid beetles were recorded at Lake Lefroy by Brennan (1999) and may be grazing on the aquatic flora that occurs on the playas and ephemeral pools located adjacent to Lake Lefroy. It is possible that changes to the abundance of these primary producers will affect the terrestrial invertebrates inhabiting those areas (Brennan, 1999). However, this impact is predicted to be highly localised (as discussed in Section 5.9) and not significant.

The Proponent's commitment to protecting the aquatic flora of the playas and ephemeral pools adjacent to Lake Lefroy (Commitment 11) will assist in minimising impacts on terrestrial invertebrate populations in these areas.

Changes in the Structure of Fringing Vegetation

Changes to the structure of the vegetation in the vicinity of the Phoebe and Thunderer pits (e.g. through clearing and subsequent revegetation) may trigger changes to the terrestrial invertebrate communities inhabiting these areas. Previous studies have found that terrestrial invertebrates are particularly responsive to changes in vegetation structure and cover (for reviews see Uetz, 1979; Holldobler and Wilson, 1990; and Wise, 1993). More recently, Brennan (1996) found that experimental manipulation of vegetation structure alters the composition of ant communities. For example, greater structural complexity may increase the types of foraging and nest sites, thereby allowing higher ant species richness. Individual movement may also be affected by changes in vegetation structure (Brennan, 1999).

These findings are supported by the results of sampling at the Revenge mine by Brennan (1999) who found that the establishment of samphire species on an area of the lake where water flow ceased has altered the assemblage of invertebrate species at this site. The samphires have become established in an area where aeolian sediments have been deposited and have been colonised by a species-rich ant community. However, species that characterise the lake floor at the reference sites (such as the tiger beetles *Megacephala* spp.) and which might have been expected to occur at Revenge are absent from this area (Brennan, 1999).

It is therefore concluded that the composition of invertebrate species may change as the structure of vegetation in the Phoebe-Thunderer area alters due to mining activities. The extent to which this will occur is not significant as less than 3 ha of vegetation will be cleared in these areas (see Section 5.8.2 for further details) and similar habitat exists in adjacent areas unaffected by the proposed mining developments.

5.12 AQUATIC INVERTEBRATE FAUNA

5.12.1 Existing Environment

Two aquatic invertebrate fauna surveys have been conducted at Lake Lefroy. The first survey was conducted in February 1999 during dry lake-bed conditions. The second survey was conducted during April and June 1999 and sampled the wet lake-bed conditions that occurred following Cyclone Vance.

The results of the "dry" sampling in February 1999 are presented in Section 3.11. In summary, the data collected during this survey indicate that the ephemeral pools and claypans that support the dense algal mats are the most productive habitats of those sampled. Invertebrate species recorded in these habitats include brine shrimps, ostracods and copepods. In the basin of Lake Lefroy proper, invertebrate productivity is very low as it is limited by the hypersaline conditions of the lake during flood conditions.

The data collected during the "wet" sampling is currently being analysed. The findings of this survey will be reported in the AEMP.

5.12.2 Environmental Impacts and Management

The main impact on aquatic invertebrates associated with the proposed mining developments is loss of habitat due to disturbance of the playas and ephemeral lakes. The development of the Phoebe and Thunderer pits will result in the disturbance of approximately 2.4 ha of this habitat type. This represents <5% of this type of habitat shown on Figure 13.3b and an insignificant portion of the total area of suitable habitat in the Lake Lefroy area. Consequently, this impact is not considered to be significant.

Aquatic invertebrates may not be able to tolerate the physio-chemical conditions that prevail around dewatering discharge sites. Therefore, discharging mine water to the playas and ephemeral pools may impact those invertebrate species inhabiting these areas. However, the Proponent is committed to ensuring that the discharge points for mine dewatering operations are located away from, and do not drain to, these areas (as per Commitment 11). Therefore, the potential impact on aquatic invertebrate communities in the Project Area due to dewatering discharge is not considered to be significant.

5.13 REHABILITATION

5.13.1 Strategies and Procedures

The procedures used by St Ives Gold to plan and manage the rehabilitation of disturbances within the Project Area are described in Section 2 of the PER and in the following environmental procedures:

- SIG-EP 007: Waste Dump Design, Construction and Water Management;
- SIG-EP 013: Development and Review of Site Closure Plans;
- SIG-EP 014: Vegetation and Topsoil Management;
- SIG-EP 015: Rehabilitation Objectives and Progress Criteria; and
- SIG-EP 023: Rehabilitation Monitoring.

These procedures will be modified as appropriate to suit the site-specific conditions of each of the sites to be rehabilitated. Planning for rehabilitation and the progress made in rehabilitating Project disturbances will be reported in the AEMP.

5.13.2 Research

Research projects will be established by the Proponent to investigate:

- the use of lake muds as a growth medium in rehabilitation; and
- the feasibility of using overburden in dune reconstruction.

These investigations are described below.

Lake Muds as Growth Media in Rehabilitation

One of the difficulties in rehabilitating overburden dumps as islands is the lack of suitable topsoil or other growth media for vegetation. However, it has been observed that samphires have become established in some areas of lake bed that have been cut off from surface water flow (Plate 5.1) which suggests that some lake muds may be able to be used as growth media for revegetation if the salt content is reduced through leaching. Therefore, an investigation will be conducted to determine the properties of a range of muds from Lake Lefroy and their suitability as plant growth media.

The principal properties which influence the usefulness of lake muds for revegetation are texture, salinity and sodicity. Secondary properties include mineralogy, water relations, specific surface area and chemical fertility. A prime consideration will be the risk of the development of severe sodicity during leaching with associated adverse soil structure problems. In this respect, the presence of gypsum in the muds will be an important factor.

The investigation will include laboratory research, greenhouse trials and field trials. In addition, monitoring will be carried out at those sites within the Project Area where lake muds have been used in rehabilitation. Optimum handling criteria will be developed for those mud types found to be suitable as growth media.

The findings of this research will be reported in the AEMP.

Commitment 13

An investigation will be conducted into the use of lake muds as growth media in rehabilitation. Optimum handling criteria will be developed for those mud types found to be suitable as growth media. The results of these investigations will be reported in the AEMP.

Feasibility of Using Overburden in Dune Reconstruction

It has been suggested that it may be possible to use some of the overburden from the Phoebe and Thunderer pits to reconstruct those dunes in the Project Area that were disturbed by early sand mining operations. This is only a recent suggestion and no work has been conducted in determining the feasibility of this concept. However, the Proponent is prepared to give this further consideration. The results of these deliberations will be reported in the AEMP.

Commitment 14

The Proponent will give further consideration to the feasibility of using overburden from the Phoebe and Thunderer pits to reconstruct those dunes in the Project Area disturbed previously by sand mining. The results of these investigations will be reported in the AEMP.

5.14 POLLUTION PREVENTION

5.14.1 Particulates/Dust

Dust and other particulates will be generated by the Project primarily through:

- drilling and blasting;
- loading, transporting and dumping ore and overburden; and
- the movement of light vehicles, haul trucks, road trains, drill rigs and other vehicles.

Dust will also be generated from exposed surfaces such as ore stockpiles. The degree of dust generation depends on many factors including the moisture content of the ground surface.

High levels of fugitive dust are a natural occurrence in the region, particularly during periods of high wind speeds. In comparison, the volume of dust likely to be generated by the Project is negligible and will be controlled through the use of saline water for dust suppression.

5.14.2 Hydrocarbon Management

On-site hydrocarbon storage facilities for the proposed mining developments will be designed in accordance with AS1940-1993. Waste oil collected from the workshop area will be transferred to a collection tank for off-site disposal.

Hydrocarbons will be managed in accordance with SIG-EP 008 (Appendix J). Detailed hydrocarbon management audits will be carried out annually in accordance with the guidelines presented in SIG-EP 008. A spill response plan and clean-up procedures will be implemented if required (see SIG-EP 003 and 005 in Appendix J).

No significant environmental impacts are expected to occur as a result of the storage and use of hydrocarbons in the Project Area.

5.14.3 Greenhouse Gas Emissions

The Australian Government's "Greenhouse Challenge Program" is a voluntary government/industry initiative to reduce greenhouse gas emissions. In 1997, WMC became a signatory to this program and the first Greenhouse Challenge report is currently under preparation. In addition, WMC has publicly reported on greenhouse gas emissions through its annual Environmental Progress Report.

Emissions of carbon dioxide (CO_2) from the Proponent's operations have decreased each year since 1995-96 (Table 5.10). Total emissions in 1998 were 14% lower than 1995-96 even though production increased by 11% over the same period. St Ives Gold achieved a reduction in CO_2 emissions per tonne of ore milled of 23% based on 1995-96 levels. The main savings were gained through the conversion from electricity generated by Western Power to that generated by WMC from natural gas.

Table 5.10

Carbon Dioxide Emissions

Year	CO_2 Emissions per Tonne of Ore Milled (kg)	Total CO_2 Emissions (t)
1994-95	82	343,701
1995-96	57	158,270
1996-97	46	144,128
1997-98	45	137,275
1998	44	135,730

Source: St Ives Gold Site Report July 1997 to December 1998, from the WMC Environment Progress Report 1998. See Appendix I.

The main source of greenhouse gas emissions for the proposed Project will be the use of diesel fuel during:

- mining and exploration activities;
- the transport of ore to the St Ives Gold Mill;
- the transport of overburden to an overburden management area; and
- pumping for mine dewatering.

The use of explosives will also result in some emissions. The release of carbon through vegetation clearance is not considered significant given the Project's location, and would be balanced by the implementation of a progressive rehabilitation programme.

Using the estimated resources (Mt of ore) for this Project outlined in Table 1.1 and the emission index for 1998 (44 kg CO_2/tonne of ore milled), the estimated generation of CO_2 over the ten year life of the Project is 906,000 t. The following measures will be implemented to minimise the potential emissions of greenhouse gases:

- minimising, in the light of other environmental objectives, the haulage distances to either the processing facility or overburden management area; and
- reducing the haulage gradient (within the overall pit design criteria) so as to reduce engine loads and therefore fuel consumption.

In addition, the competitive tendering process will be utilised to ensure that the contactors used on the Project aim toward the use of the most efficient machinery available.

The Proponent is committed to continuous improvement of performance in the efficiency of energy consumption, the prevention of energy wastage and abatement of greenhouse gas emissions and will continue to report energy efficiencies through its annual reporting process.

5.14.4 Noise

Localised noise will be generated during the construction of the Project due to the use of earthmoving machinery, trucks and other equipment. The Project is located in a relatively remote area and adjacent to existing gold mining operations. Therefore, the increase in noise levels at the site due to proposed mining operations will not be significant.

Noise will be managed through environmental procedure SIG-EP 020: Environmental Noise (see Appendix J).

5.14.5 Sewage and General Refuse

The solid wastes from the offices and other facilities required for this Project will be disposed of by sanitary landfill disposal. The landfill is located adjacent to the St Ives Mill and will accept all non-toxic wastes. Domestic sewage and sullage will be treated either by the existing on-site sewage treatment plant or in septic systems.

The Proponent's environmental procedures relevant to the management of non-process wastes are:

- SIG-EP 006: Development, Maintenance, Monitoring and Closure of Landfills;
- SIG-EP 011: Tyre Disposal on Site; and
- SIG-EP 018: Non-process Waste Management.

These procedures are provided in Appendix J.

No significant impacts are expected to occur as a result of waste management and disposal techniques.

5.15 VISUAL IMPACTS

The visibility of the proposed mining developments will depend on:

- the locations of the observer;
- the height of the observer;
- the height of the features or structures being viewed;
- the nature of the intervening terrain, vegetation or structure; and
- the radius within which the observer can see.

The main public viewing point of the Project Area is the Red Hill Lookout. The lookout is part of the local tourist scenic drive and is one of the sites on the Eastern Goldfields Heritage Trail. It is often used by tourists and visitors to observe the mining operations at Lake Lefroy. However, the view of the proposed mining developments from the lookout will be limited (Figure 5.3) due to the viewing angle and the degree of screening offered by the natural and constructed islands on the lake.

The proposed mining developments will alter the lakescape through the development of additional islands. However, the Proponent's commitment to progressively rehabilitate disturbed sites within the Project Area will reduce the visual impact of these changes to the lakescape. Therefore, the visual impact of the Project is not considered to be significant.

5.16 ABORIGINAL HERITAGE

As discussed in Section 3.13.4, a number of Aboriginal heritage studies have been conducted on and around Lake Lefroy on behalf of the Proponent. No archaeological or ethnographic sites have been identified in the Project Area.

Contact between WMC's Community Relations Department and local Aboriginal groups and individuals is made on a regular basis (including regular liaison with the Native Title claimants) has not identified any contemporary economic, recreational or cultural associations with Lake Lefroy.

It is concluded that the proposed mining developments will not directly or indirectly impact any Aboriginal heritage sites in the Lake Lefroy area.

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6. SUMMARY OF ENVIRONMENTAL MANAGEMENT COMMITMENTS

The Proponent's commitment to sound environmental management is reflected in its implementation of its Environmental Policy, EMS and the Australian Minerals Industry's Code for Environmental Management. In addition, the Proponent has developed a number of commitments specific to the environmental management of the proposed mining developments. These commitments are listed in Table 6.1.

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Table 6.1

Summary of the Proponent's Environmental Management Commitments

Commitment	Objective	Action	Timing (Phase)	Whose Advice	Measurement/Compliance Criteria
1. Prior to the commencement of mining, the Proponent will prepare an Annual Environmental Management Plan (AEMP) that will provide further details on the design and layout of the individual mining developments planned for the first 12 months of the Project's life and the environmental management measures that will apply to these developments. The AEMP will be updated on an annual basis to provide a review of the mining developments undertaken during the previous 12 months and to provide additional detail on the mining developments (and relevant environmental management measures) planned for the next 12 months.	To ensure sound environmental management of the construction, operation and closure of the Project.	The Proponent will prepare an AEMP that provides: • a review the development of the Project in the previous 12 months; • a detailed description of the mining developments proposed for the next 12 months (including the environmental management measures incorporated into the design of the mines and associated infrastructure located on Lake Lefroy); and • a summary of projected activities for the next three years.	The first AEMP will be provided to the regulatory authorities prior to the commencement of mining. The AEMP will be provided to these authorities on an annual basis thereafter.	DEP, DRD, DME, CALM and WRC	Comments and feedback received from the regulatory authorities.
2. Two years prior to the completion of the Project, the Proponent will review its planning for the closure, decommissioning and rehabilitation of the Project. This review will address, but will not necessarily be limited to, the following: • the removal or, if appropriate, retention of plant and infrastructure developed as a result of the Project; • the rehabilitation of any remaining disturbances in the Project Area; • the development of a "walk-away" solution for pits, overburden dumps, causeways, borrow pits, haul roads and other associated infrastructure; and • the identification and remediation of any contaminated areas (including provision of evidence of notification to relevant statutory authorities). The findings of this review will be reported through the AEMP process.	To ensure that the Project Area is left in a safe and stable condition such that the tenements can be relinquished without any future liability for the Proponent or the State.	Planning for the closure, decommissioning and rehabilitation of the Project will be reviewed by the Proponent in consultation with relevant government agencies and other stakeholders.	Two years prior to the cessation of mining.	DEP, DRD, DME, CALM. WRC and other relevant stakeholders.	The findings of the review will be reported through the AEMP process and in WMC's Public Environment Report.
3. The Proponent will conduct further hydrogeological investigations to determine the dewatering requirements of the proposed mine pits. The results of these investigations will be reported in the AEMP.	To identify the dewatering requirements of each of the mine pits to be developed as part of this Project and to select the appropriate discharge option.	Investigations will be conducted to determine the volume and quality of water to be abstracted during the dewatering of each pit. The results of these investigations will also be used to select the appropriate mine water discharge option for each pit.	Operations phase.	DEP and WRC	The results of these investigations will be reported in the AEMP (or separately if timing constraints exist). The Proponent's DEP pollution control licence will be modified as appropriate.
4. The Proponent will continue to use the existing surface water monitoring network at Lake Lefroy to monitor surface water flows, levels and quality on a regular basis. The results of the monitoring programme will be reported in the AEMP.	To develop a more detailed understanding of the hydrology of Lake Lefroy.	Surface water monitoring will continue using the existing surface water monitoring network at Lake Lefroy. The proponent will review the scope, timing and duration of this programme in consultation with the regulatory authorities.	Throughout Project life, until a decision to cease the programme is made.	DEP and WRC.	The findings of the review will be reported in the AEMP.
5. The Proponent will not construct any new facilities or infrastructure on Gamma Island, Oyster Island or Coral Island.	To minimise further disturbance of natural islands within the Project Area.	The Proponent has designed the Project to ensure that no additional disturbance of Gamma Island, Oyster Island or Coral Island occurs.	Throughout Project life.	DME, DEP and CALM	No disturbance of these islands as a result of exploration or mining by the Proponent.
6. The Proponent will minimise the risk of erosion and sedimentation by minimising the extent of disturbance of the lakescape and progressively rehabilitating disturbed areas.	To control erosion and ensure that sediment loads in the lake do not increase significantly as a result of this Project.	Disturbed areas will be rehabilitated on a progressive basis. Temporary stabilisation measures will be adopted where necessary.	Throughout Project life.	DME and DEP	Rehabilitation progress will be reported in the AEMP and WMC's Public Environment Report.
7. Further geotechnical investigations will be conducted to assess the stability of the pit walls post-mining. The findings of these studies will be used in the development of management procedures and closure plans for final mine voids.	To obtain a better understanding of the factors influencing post-mining pit slope stability (particularly in relation to the long term stability of the lake sediments when partially submerged in lake water) and facilitate the development of appropriate management and closure strategies as required.	Further investigations into the stability of pit slopes will be conducted to facilitate the management and closure of final voids.	Operations phase.	DME and DEP	The findings of these investigations will be reported in the AEMP.
8. The Proponent will ensure that disturbed areas are rehabilitated on a progressive basis to minimise disturbance of flora, vegetation and fauna habitats along the shorelines of the Project Area.	To minimise disturbance to the biota of the Project Area.	Disturbed areas will be rehabilitated on a progressive basis.	Throughout Project life.	DEP and DME	Rehabilitation progress will be reported in the AEMP and WMC's Public Environment Report.

Table 6.1 (*cont'd*)

Commitment	Objective	Action	Timing (Phase)	Whose Advice	Measurement/Compliance Criteria
9. The degree of dust generation will be minimised through the watering of haulage roads (and other roads as necessary) with saline water. Roads on the shoreline and in near-shore areas will be bunded to prevent the egress of saline water to adjacent vegetation.	To minimise the generation of dust during the construction and operation of the Project.	Saline water will be used for dust suppression on haul roads and other exposed surfaces. Measures will be implemented to control over-spraying by water trucks. Roads will be bunded to prevent the egress of saline water to the surrounds with run-off directed to catch pits.	Construction and operation phases.	DEP and DME	Effectiveness of measures will be reported in the AEMP.
10. The Proponent will protect plant communities inhabiting the shoreline of Lake Lefroy from the impacts of mine water discharge onto the lake by ensuring that the discharge points are located away from, and do not drain to, these communities.	To prevent flooding of fringing vegetation with hypersaline water.	The dewatering discharge points will be located off-shore and at an elevation lower than the adjacent shoreline.	Construction and operation phases.	DEP	Effectiveness of measures will be reported in the AEMP.
11. The Proponent will minimise physical disturbance to the playas and claypans adjacent to Lake Lefroy and ensure that any new discharge points for mine dewatering operations are located away from, and do not drain to, these areas.	To minimise disturbance to the *Schizothrix* mats, aquatic flora and invertebrate fauna inhabiting the playas.	As above.	Construction and operation phases.	DEP	Effectiveness of measures will be reported in the AEMP.
12. The Proponent will continue to implement its fauna monitoring programme and feral animal trapping programme during the life of the Project.	To develop a better understanding of the vertebrate fauna of the Project Area and facilitate the development of appropriate management programmes as required.	Fauna monitoring will be conducted at the established monitoring sites. Cat trapping will continue in the Project Area and surrounds.	Construction and operation phases.	DEP, DME and CALM	The results of these programmes will be reported in the AEMP.
13. An investigation will be conducted into the use of lake muds as growth media in rehabilitation. Optimum handling criteria will be developed for those mud types found to be suitable as growth media. The results of these investigations will be reported in the AEMP.	To identify those lake muds that are suitable for use as plant growth media in rehabilitation programmes.	Laboratory research, greenhouse trials and field trials will be conducted. Monitoring of those sites within the Project Area where lake muds have been used in rehabilitation will also be conducted. Optimum handling criteria will be developed for those mud types found to be suitable as growth media.	Operations phase.	DEP, DME and CALM	The results of these investigations will be reported in the AEMP.
14. The Proponent will give further consideration to the feasibility of using overburden from the Phoebe and Thunderer pits to reconstruct those dunes in the Project Area disturbed previously by sand mining. The results of these investigations will be reported in the AEMP.	To determine the feasibility of using overburden in dune reconstruction.	The feasibility of using overburden in dune reconstruction will be given consideration. In the event that these deliberations indicate that this could be feasible, further investigations will be conducted to determine if and how this could be undertaken.	Operations phase.	DEP and DME	The results of these deliberations will be reported in the AEMP.

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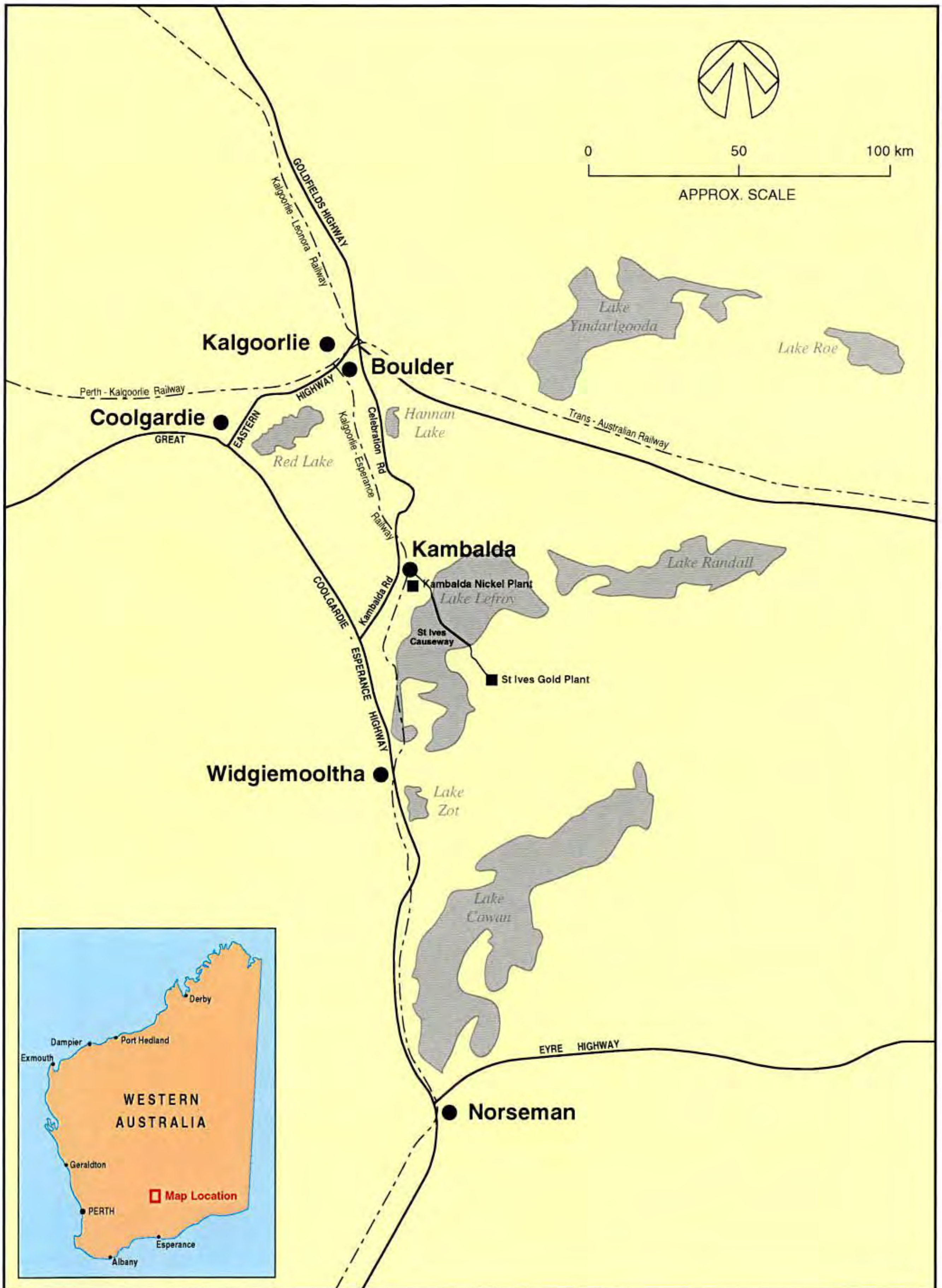
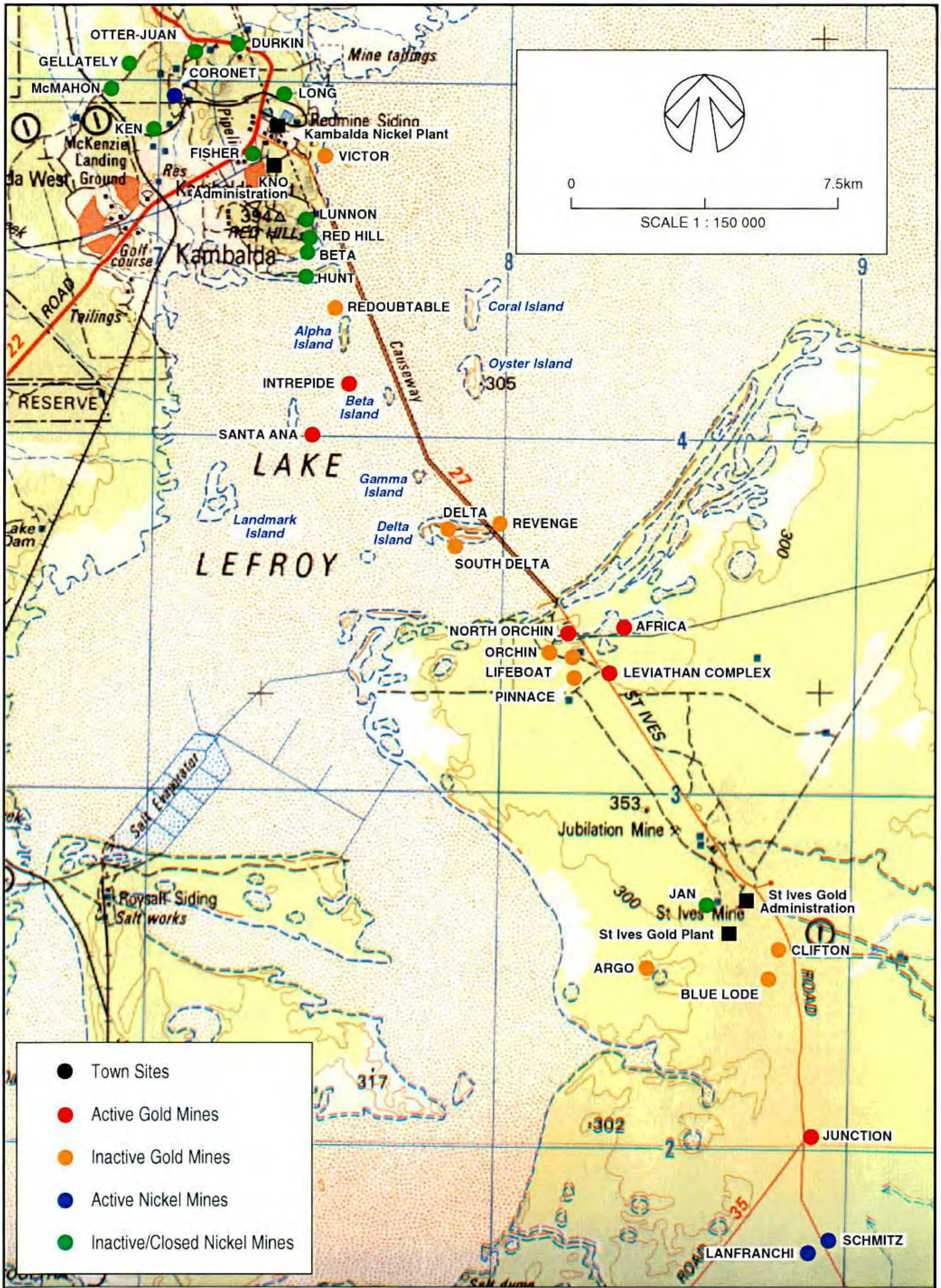


PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

REGIONAL LOCATION MAP

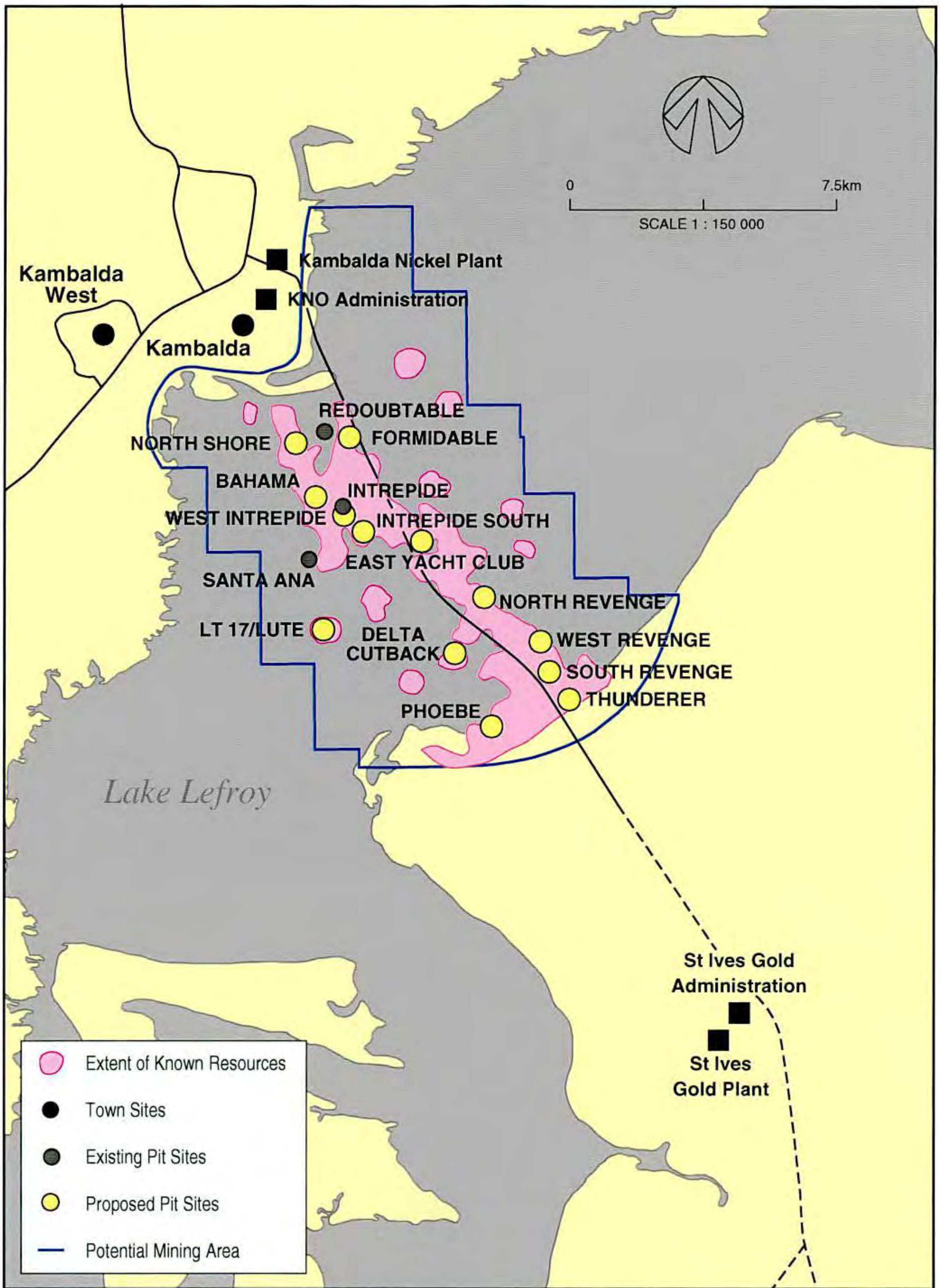
FIGURE 1.1



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

EXISTING OPERATIONS

FIGURE 1.2

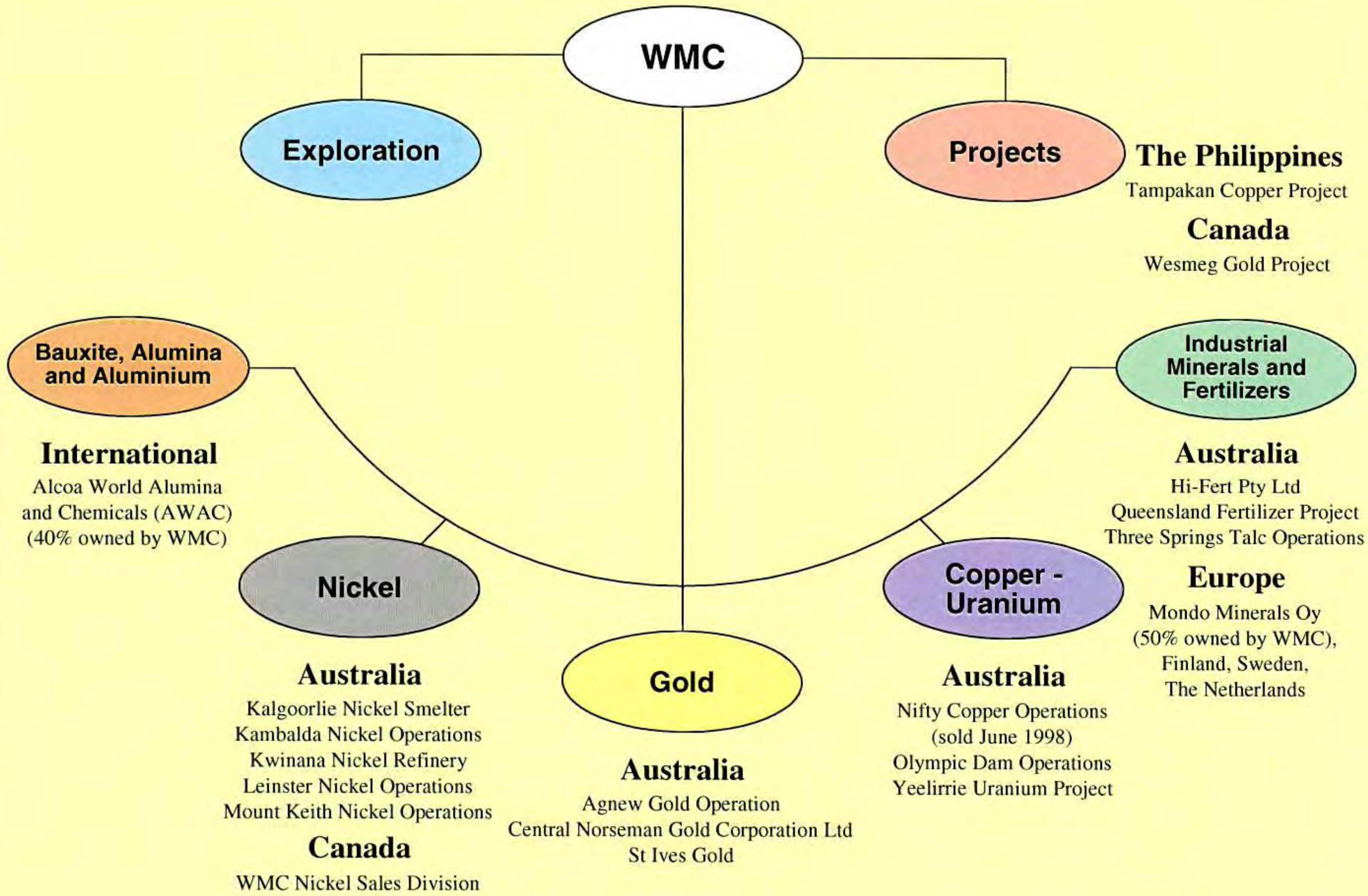


PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

PROPOSED MINING AREA

FIGURE 1.3

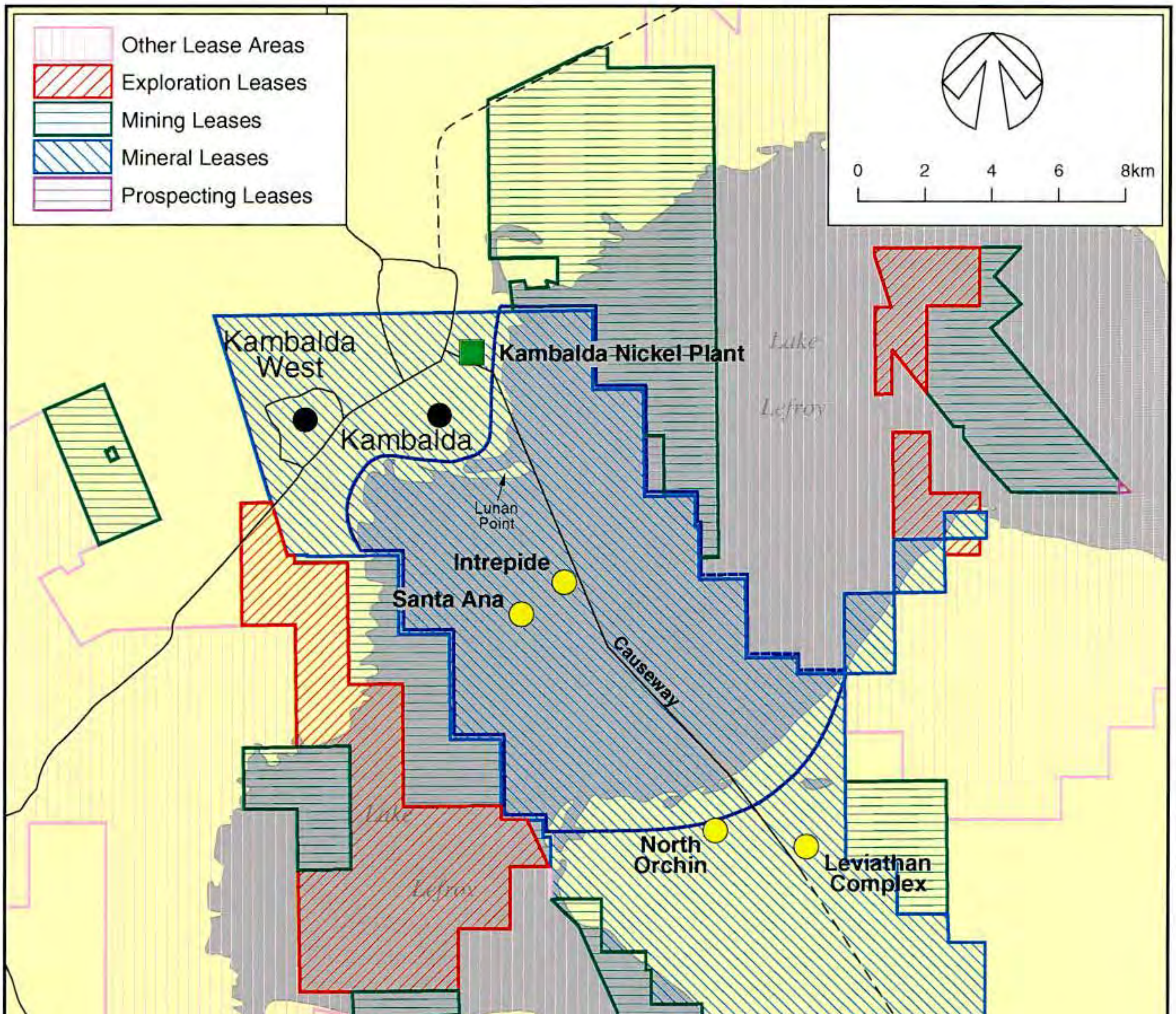
WMC SIMPLIFIED GROUP STRUCTURE



SOURCE: WMC Limited Environment Progress Report 1998

DCM GROUP

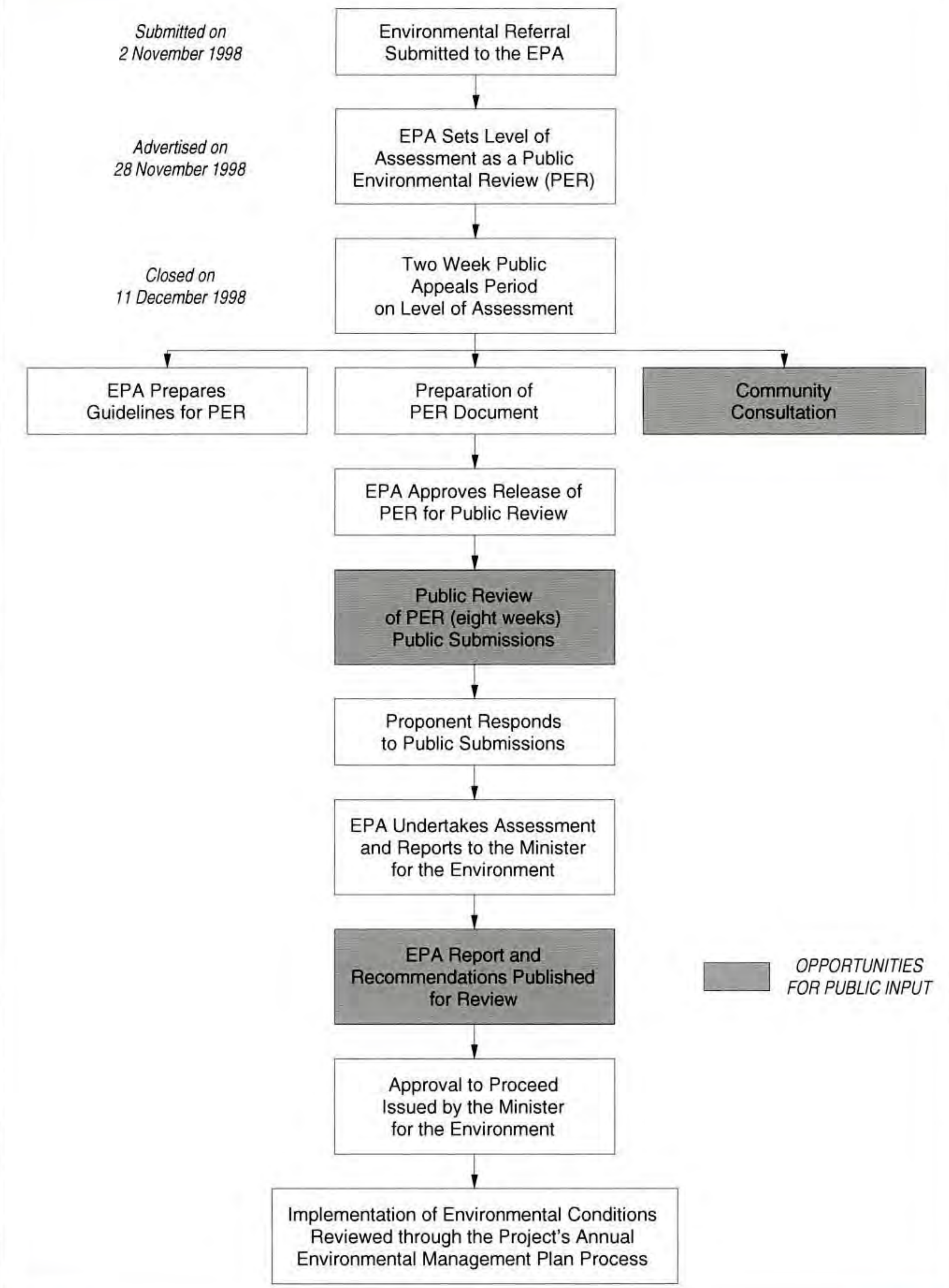
FIGURE 1.4



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

MINING TENEMENTS OVER LAKE LEFROY

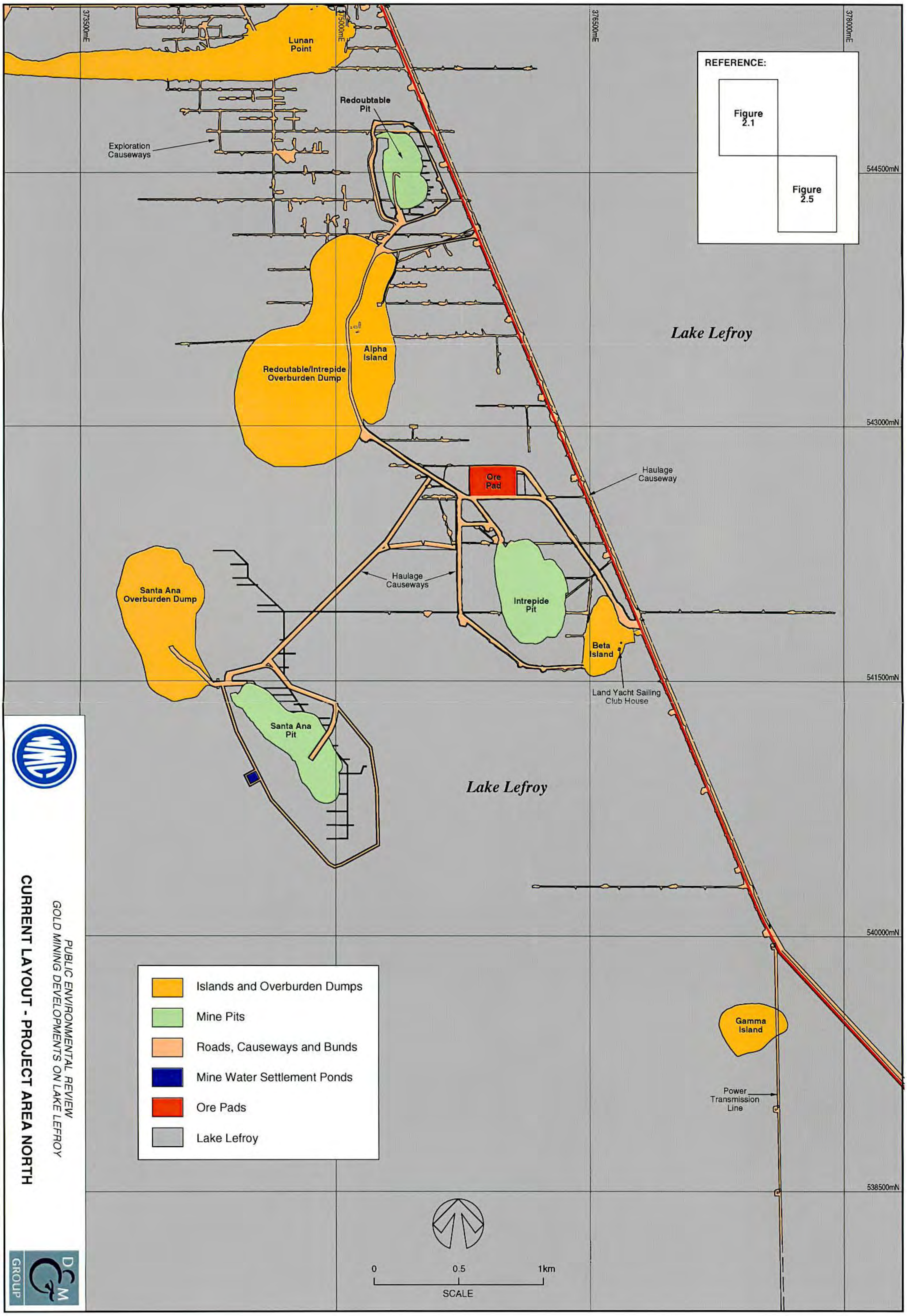
FIGURE 1.5



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

ENVIRONMENTAL ASSESSMENT AND MANAGEMENT PROCESS

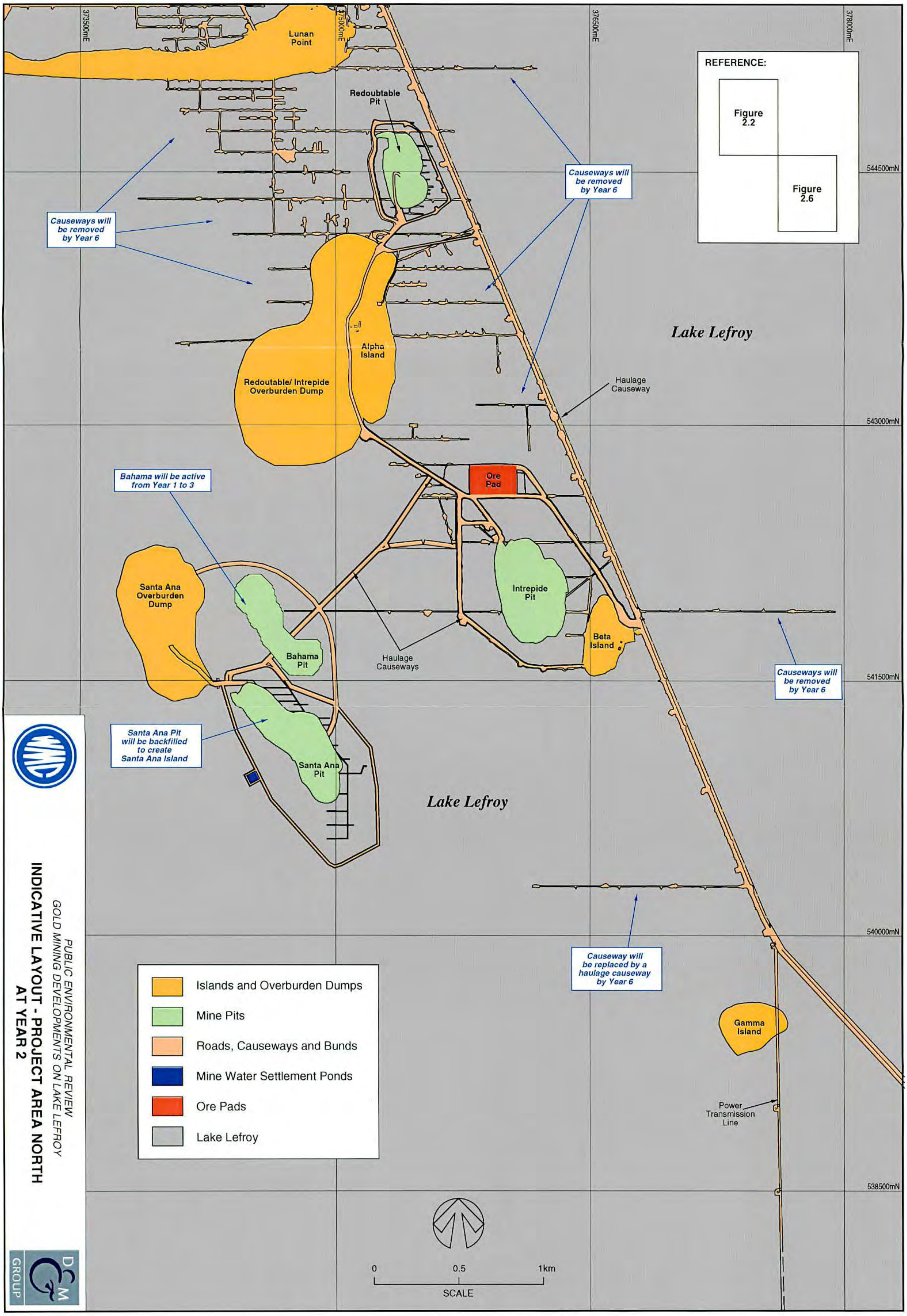
FIGURE 1.6



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

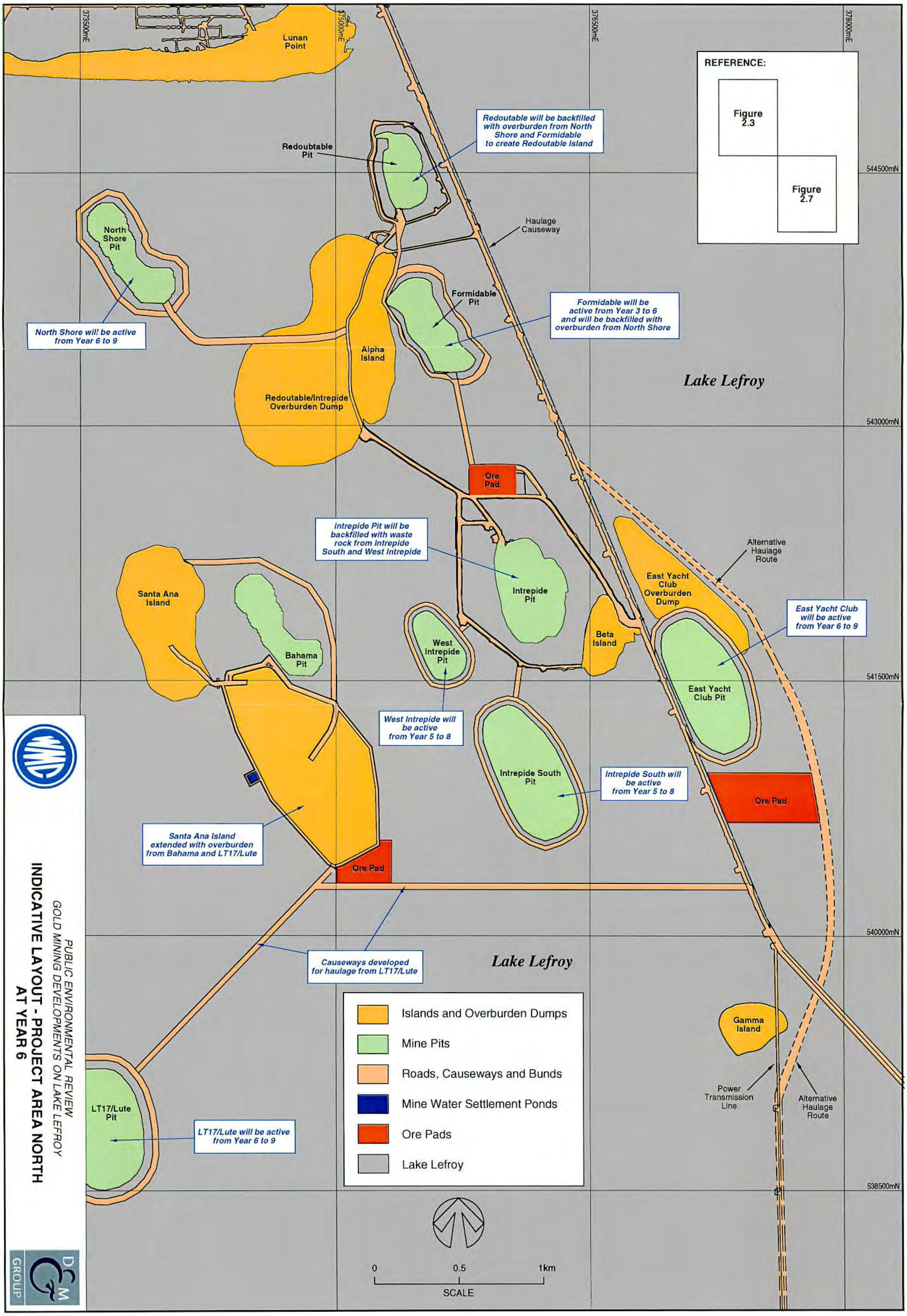
CURRENT LAYOUT - PROJECT AREA NORTH

FIGURE 2.1



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY
INDICATIVE LAYOUT - PROJECT AREA NORTH AT YEAR 2

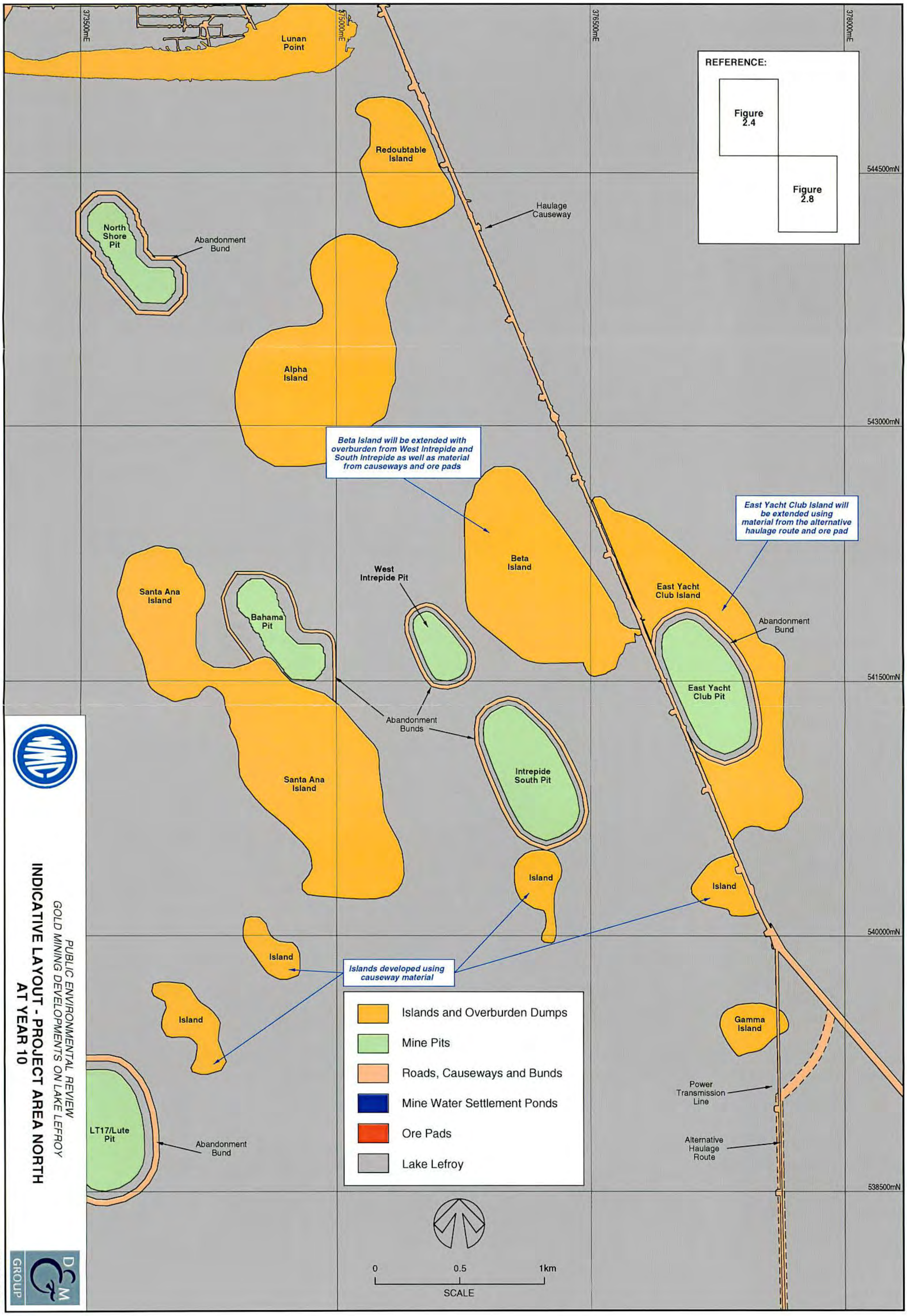
FIGURE 2.2



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

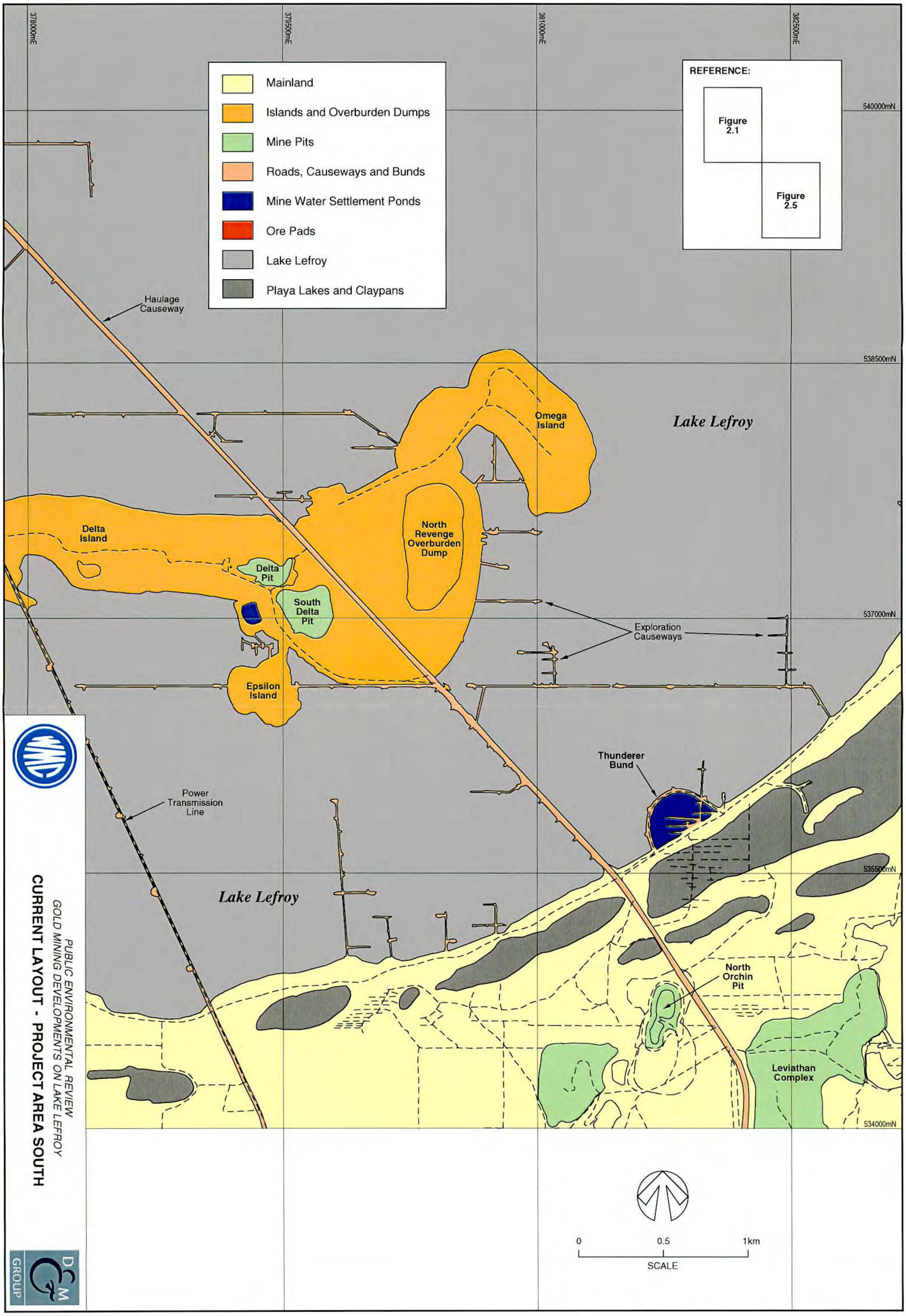
INDICATIVE LAYOUT - PROJECT AREA NORTH AT YEAR 6

FIGURE 2.3



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY
INDICATIVE LAYOUT - PROJECT AREA NORTH AT YEAR 10

FIGURE 2.4

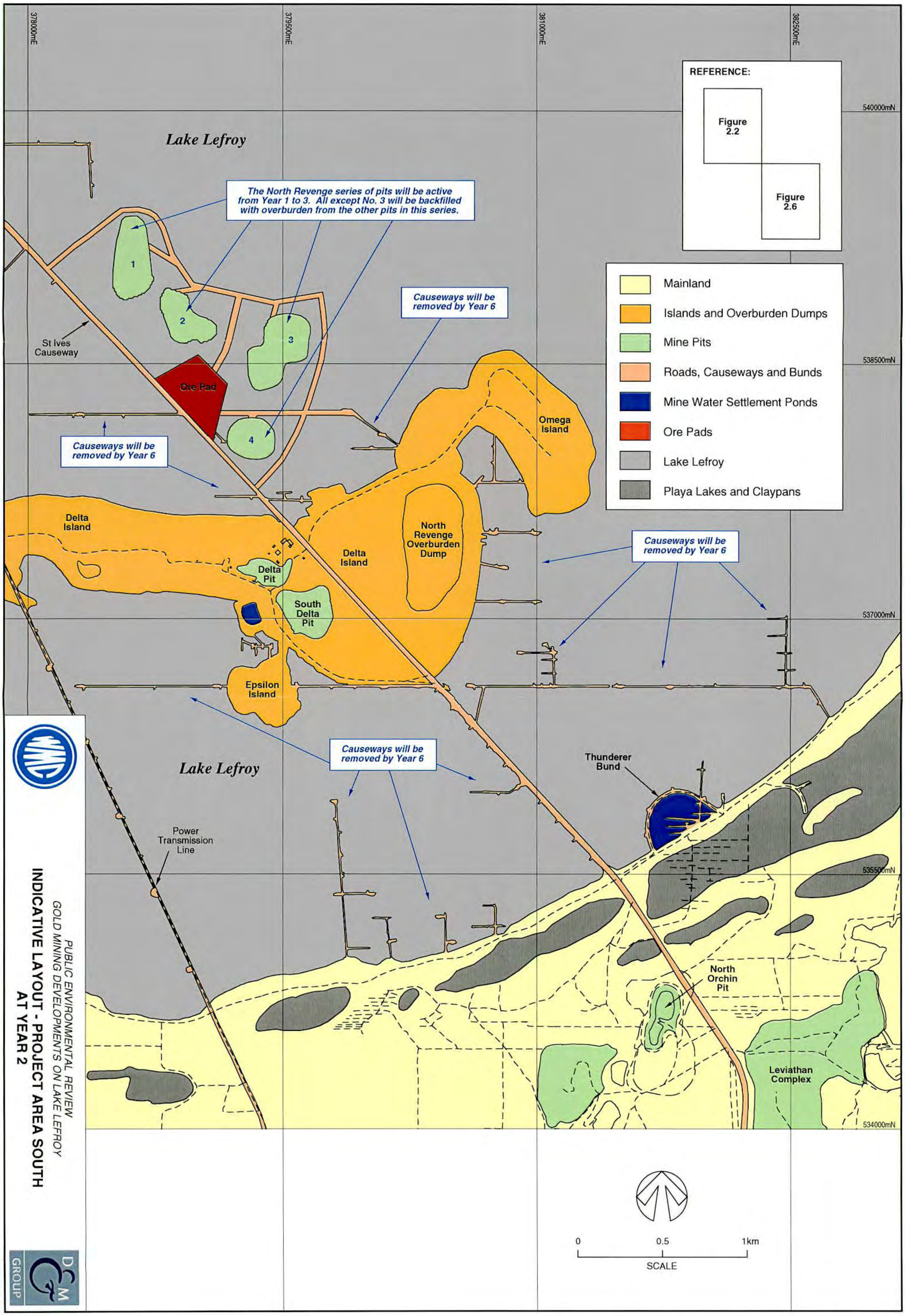


PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

CURRENT LAYOUT - PROJECT AREA SOUTH

DCM GROUP

FIGURE 2.5

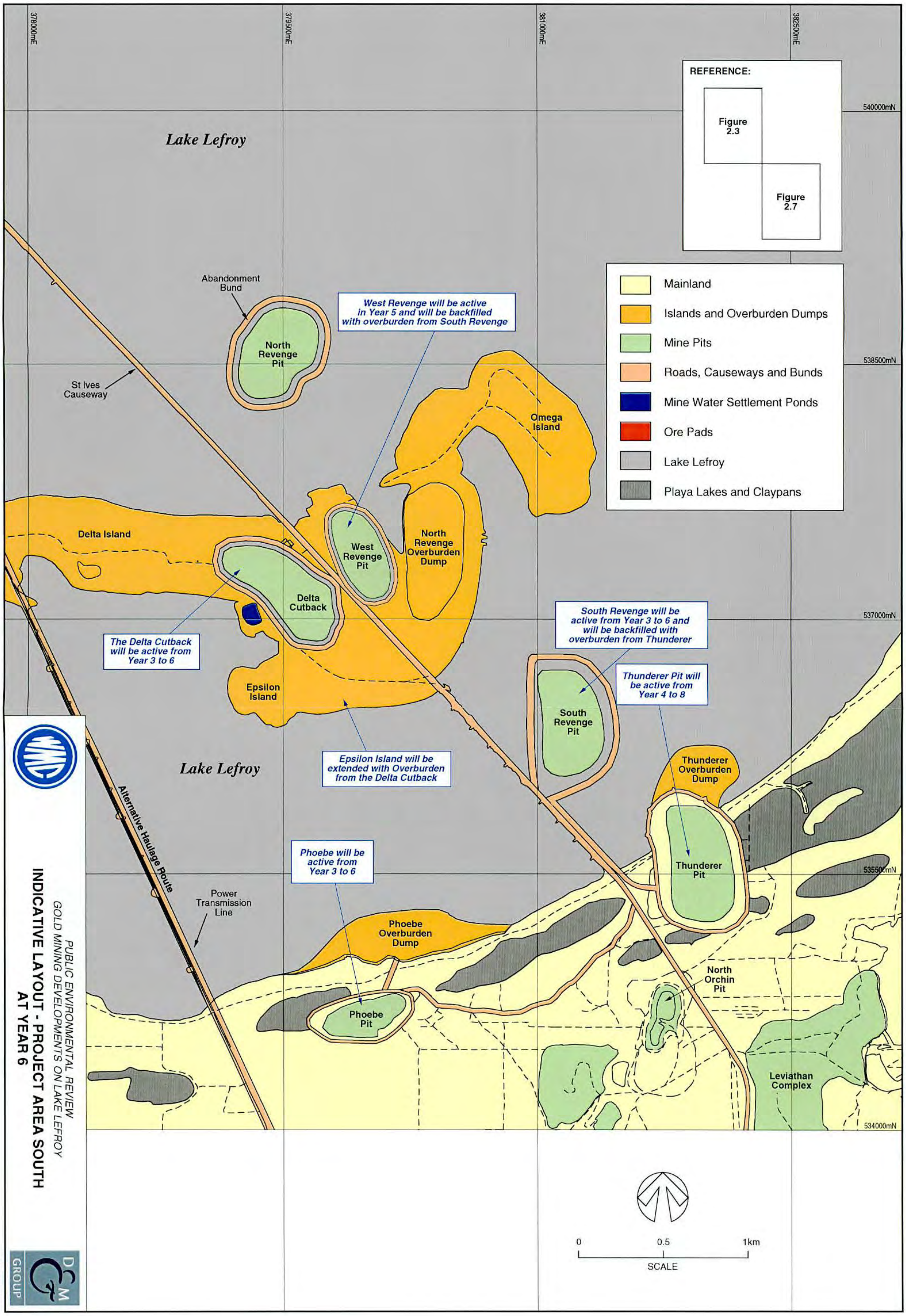


PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

INDICATIVE LAYOUT - PROJECT AREA SOUTH AT YEAR 2

DCM GROUP

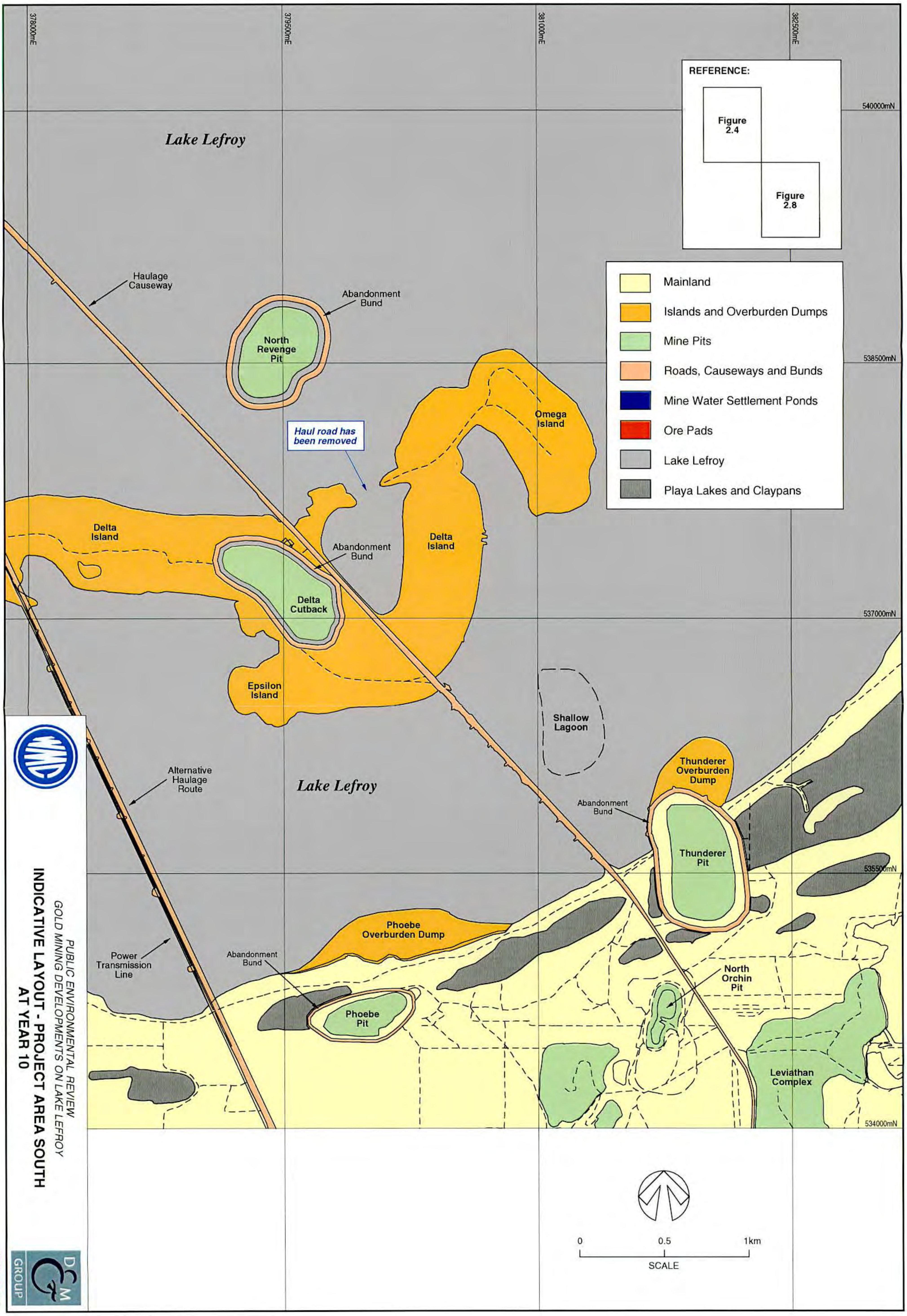
FIGURE 2.6



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

INDICATIVE LAYOUT - PROJECT AREA SOUTH AT YEAR 6

FIGURE 2.7

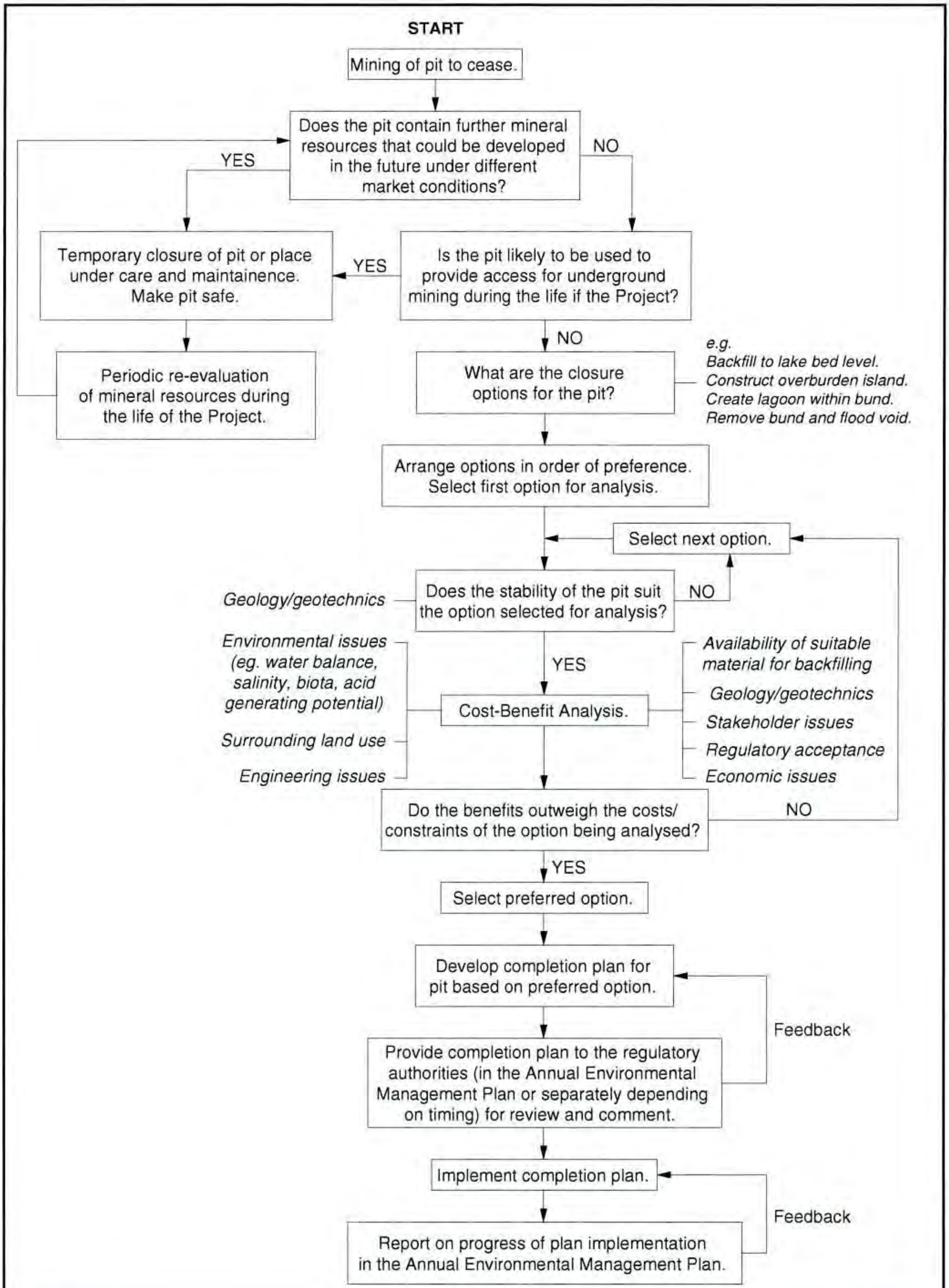


PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

INDICATIVE LAYOUT - PROJECT AREA SOUTH AT YEAR 10

DCM GROUP

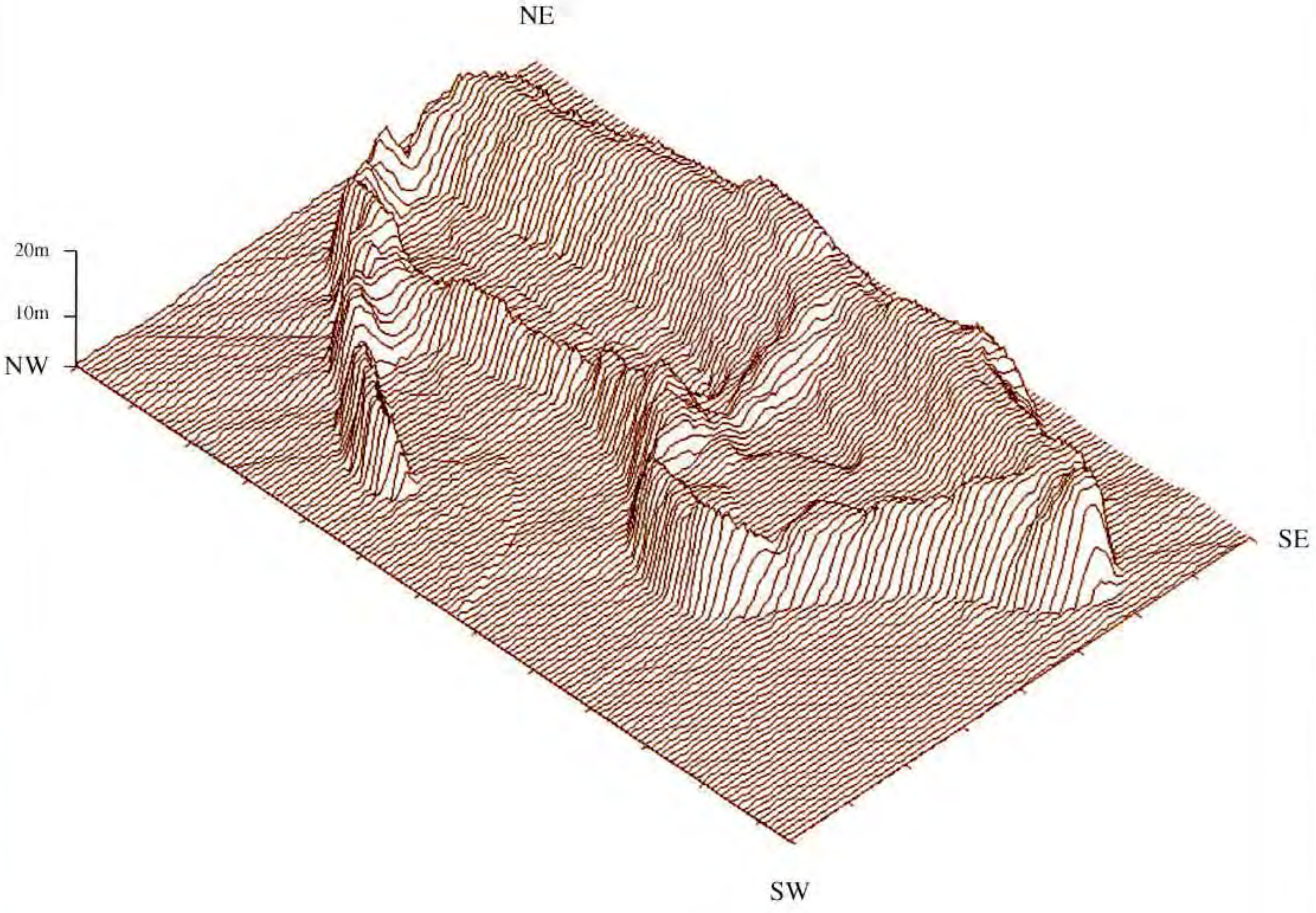
FIGURE 2.8



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

DECISION TREE FOR MINE VOIDS

FIGURE 2.9

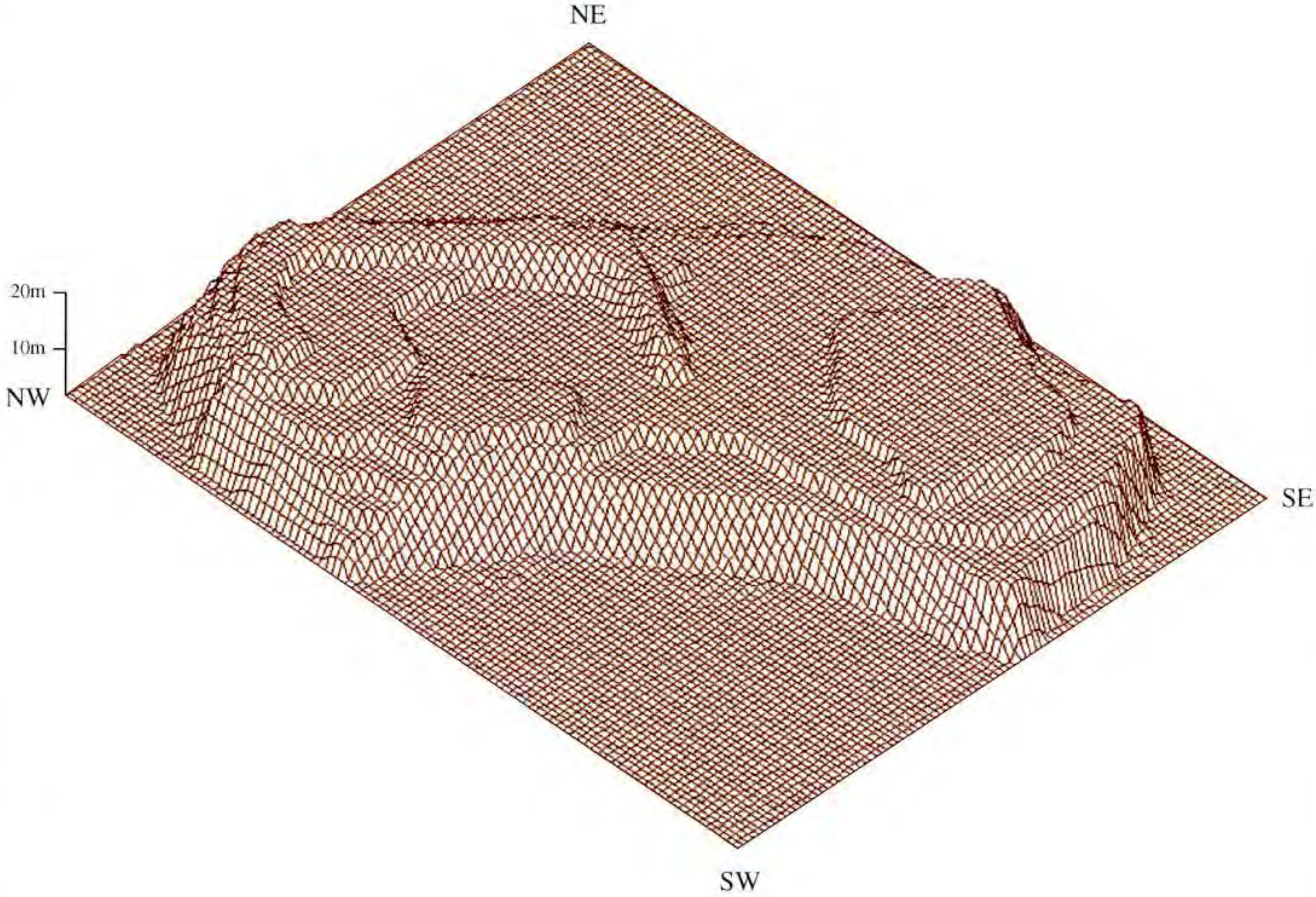


PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

GEOMORPHIC MODEL OF OYSTER ISLAND

DEM GROUP

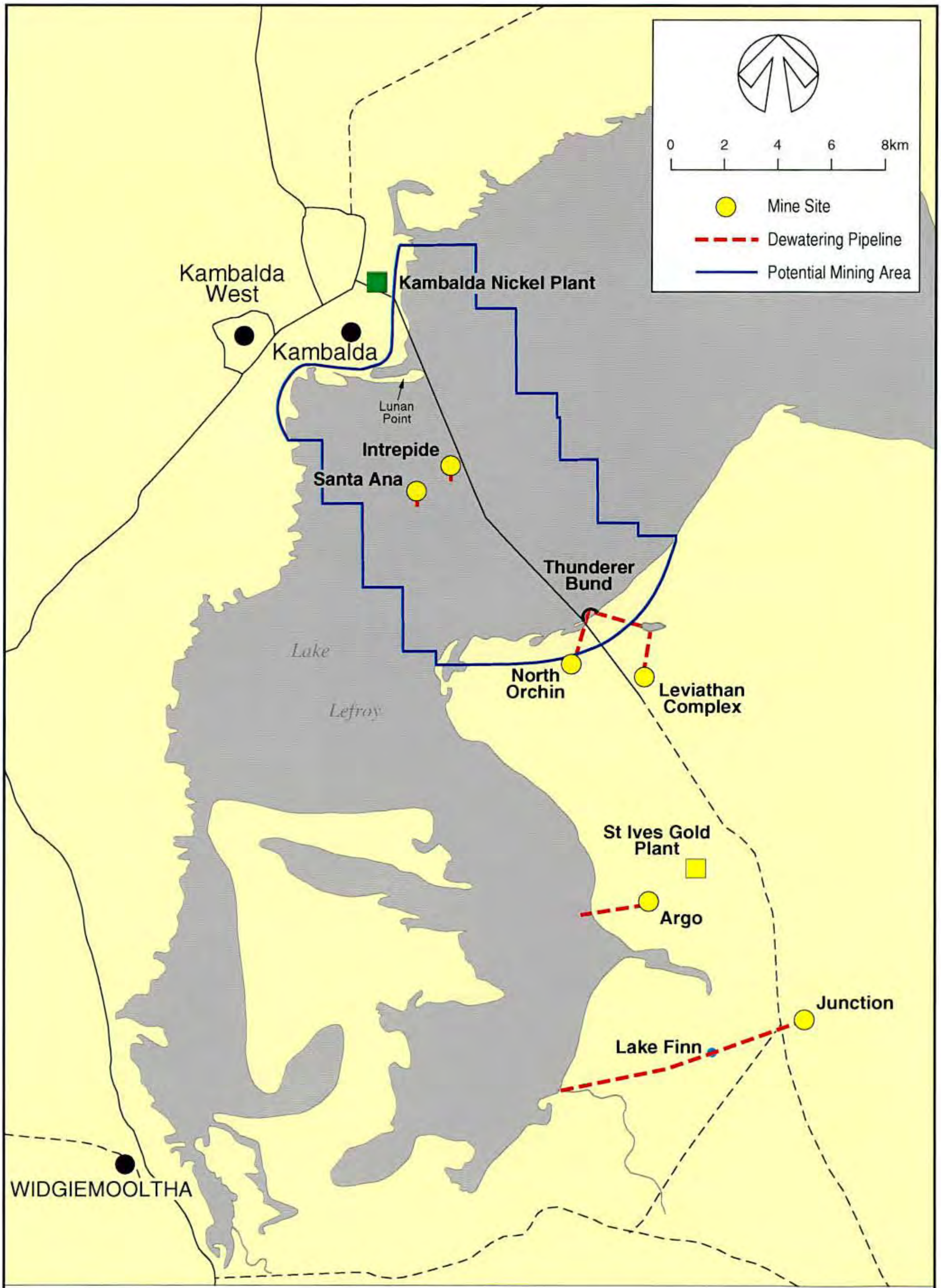
FIGURE 2.10



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

GEOMORPHIC MODEL OF OMEGA ISLAND'S POST-MINING LANDFORM

FIGURE 2.11



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

LOCATION OF CURRENT DEWATERING DISCHARGE POINTS

GROUP

FIGURE 2.12

PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

PALAEODRAINAGE NETWORK OF THE EASTERN GOLDFIELDS

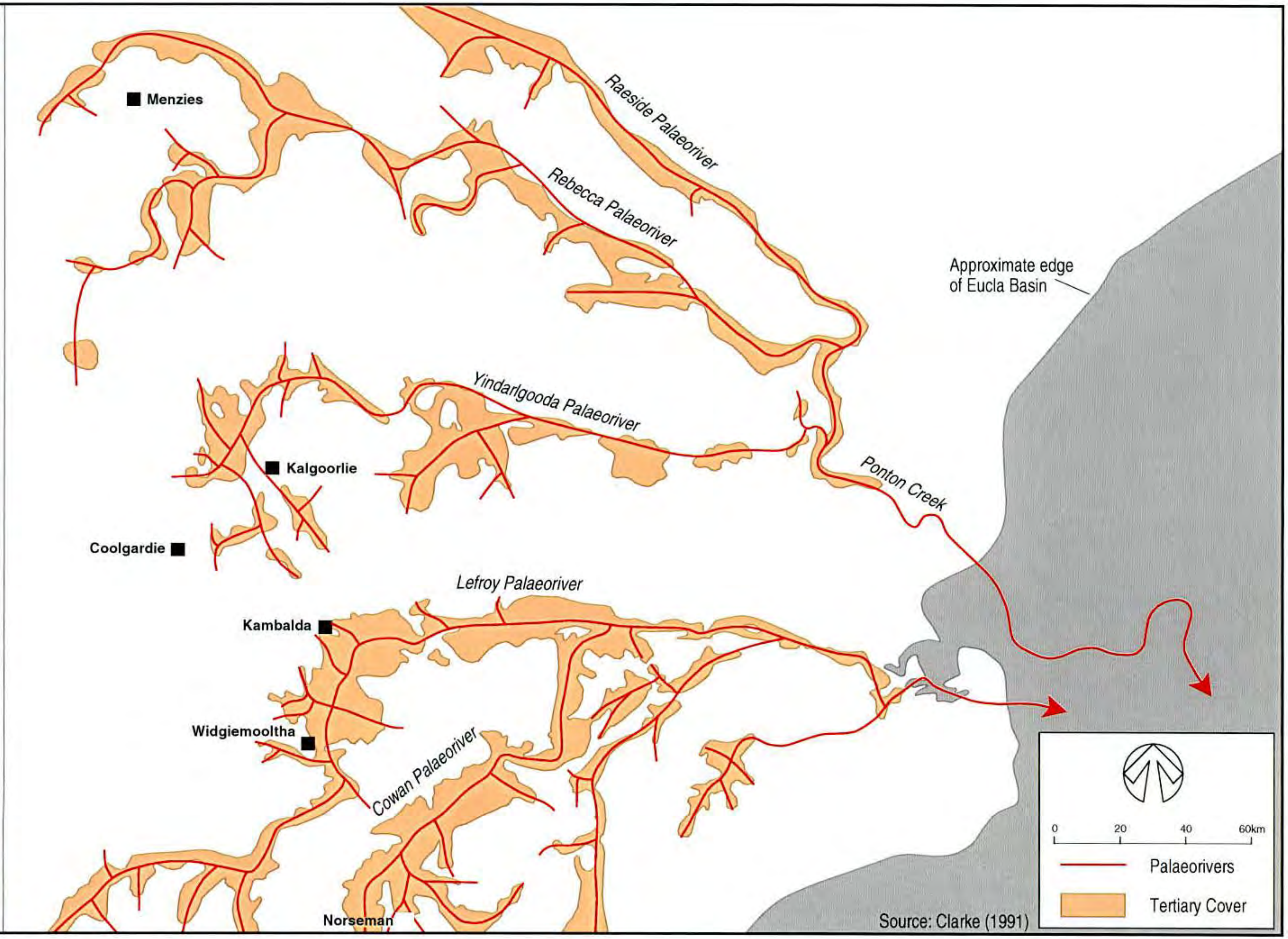
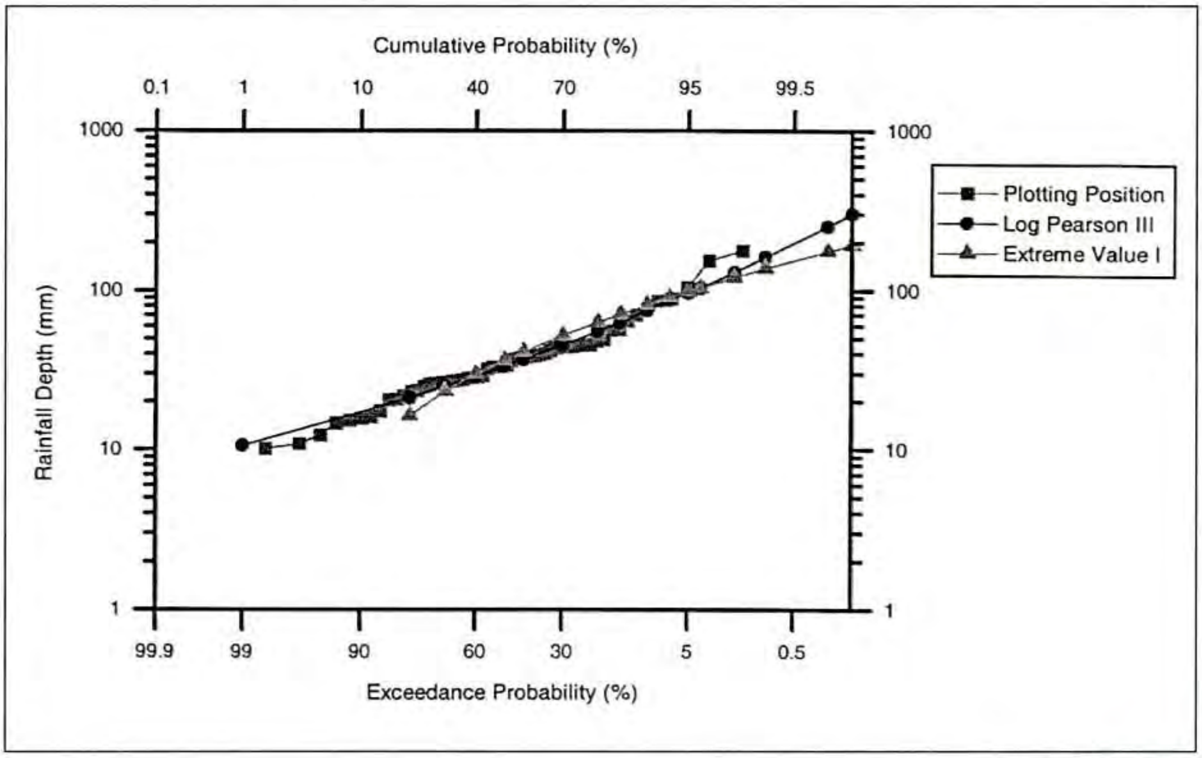


FIGURE 3.1



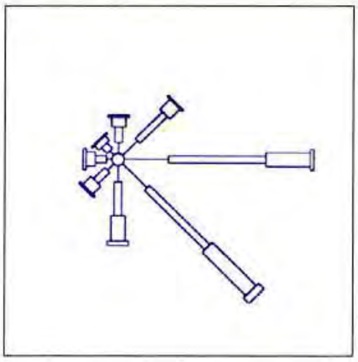
Source: CSIRO (1999b)

PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

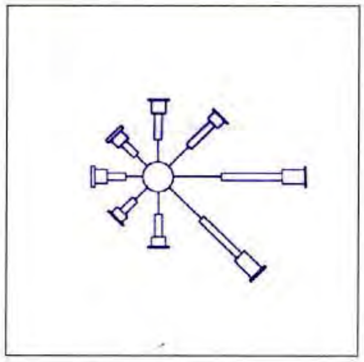
RAINFALL PROBABILITY DISTRIBUTION FOR KALGOORLIE

FIGURE 3.2

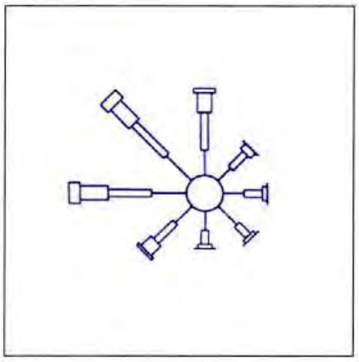
Summer



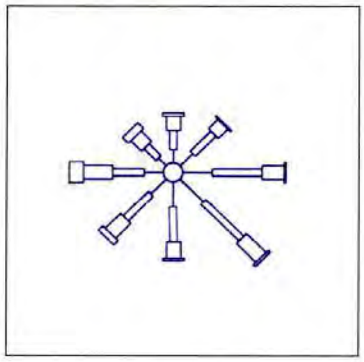
Autumn



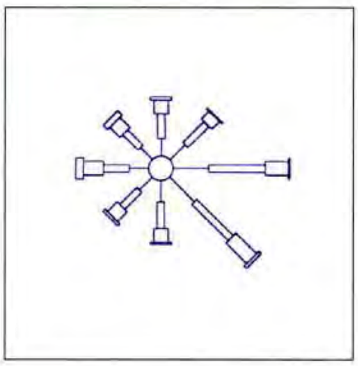
Winter



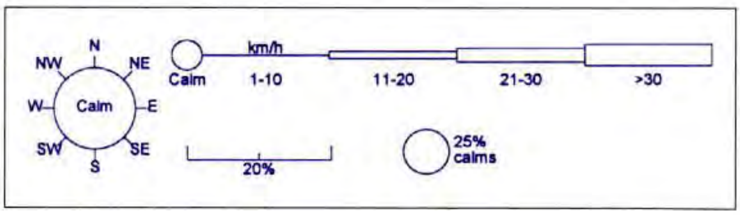
Spring



Annual



Legend

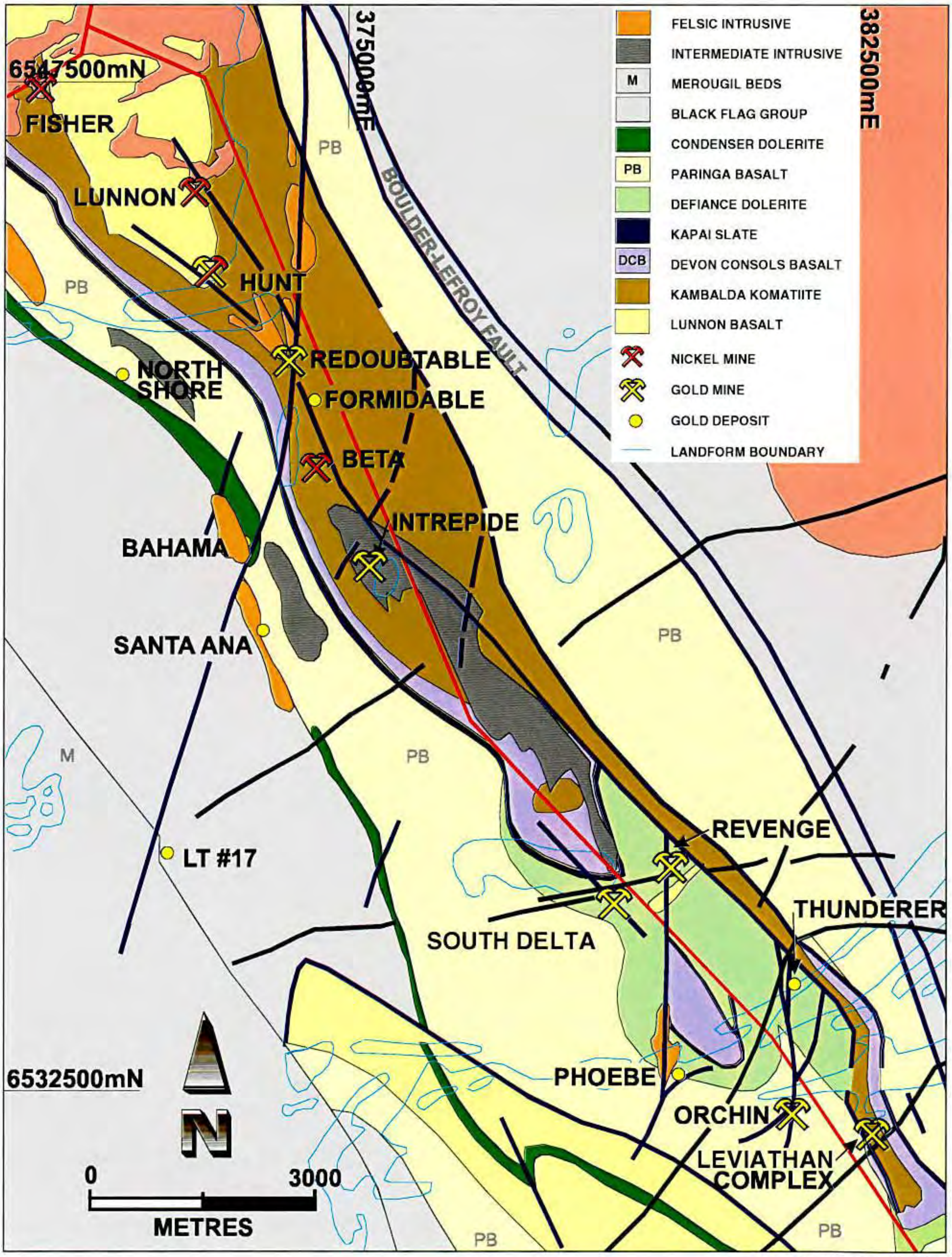


SOURCE: Bureau of Meteorology.

PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

WIND ROSES FOR KALGOORLIE AIRPORT

FIGURE 3.3



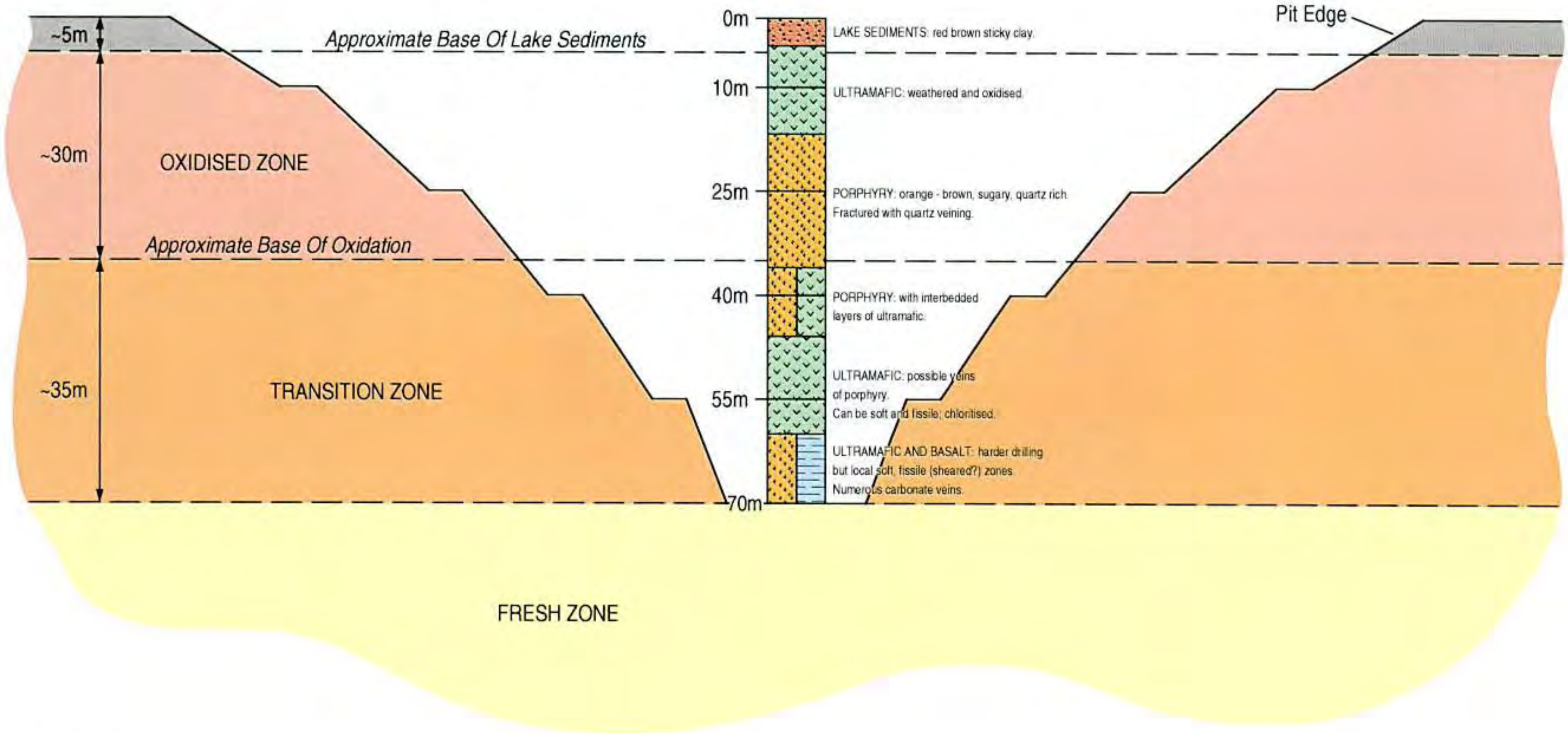
Source: Reddell and Dusci (1997)

PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENT ON LAKE LEFROY

SIMPLIFIED REGIONAL GEOLOGY

DCM GROUP

FIGURE 3.4



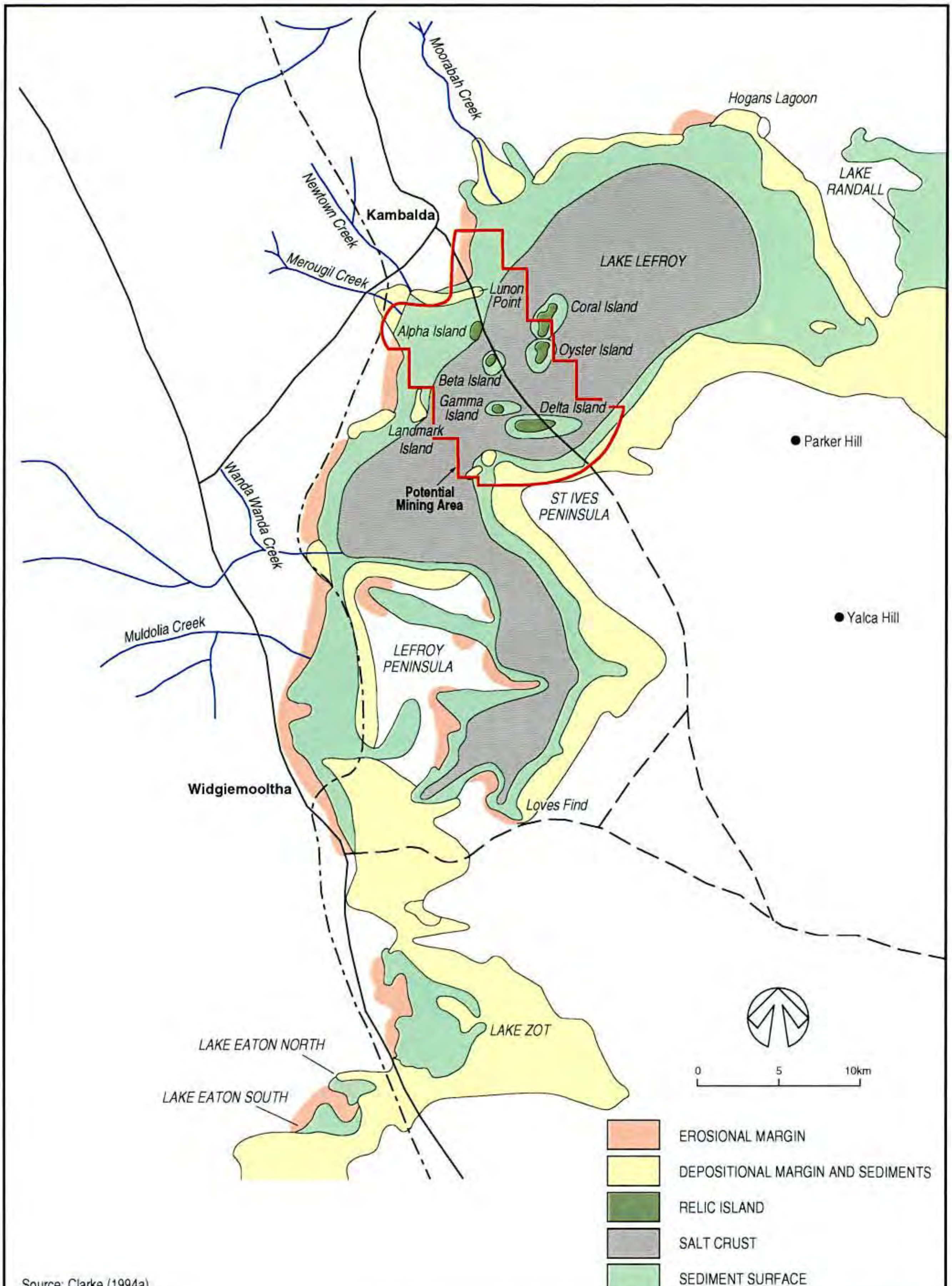
NOT TO SCALE
SCHEMATIC ONLY

PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

SIMPLIFIED STRATIGRAPHY

DCM GROUP

FIGURE 3.5



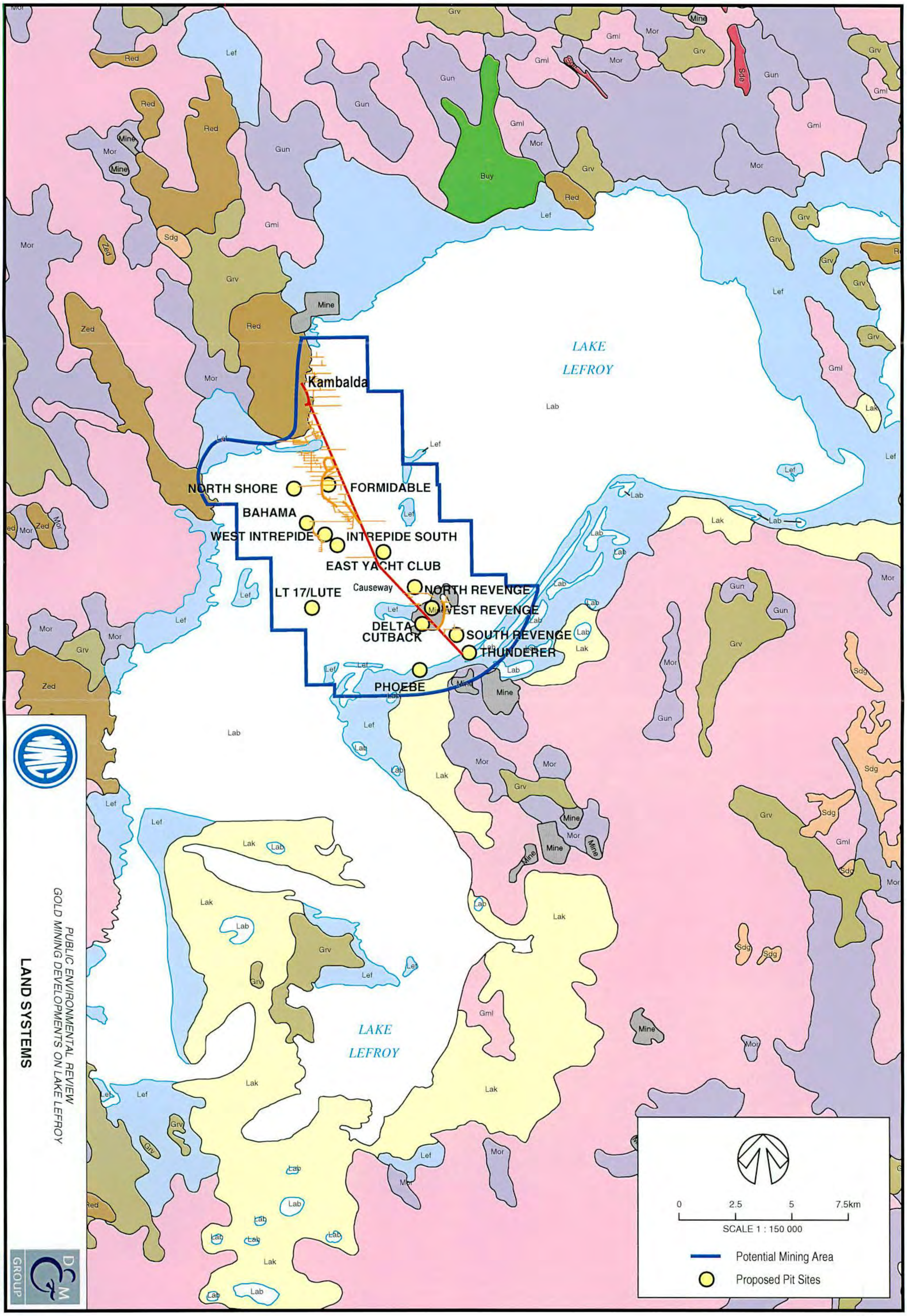
Source: Clarke (1994a)

PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

GEOMORPHIC MAP OF LAKE LEFROY

DCM GROUP

FIGURE 3.6



LAND SYSTEMS

PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

FIGURE 3.7a

LAND TYPE ONE:		HILLS WITH ACACIA SHRUBLANDS AND PATCHY EUCALYPT WOODLANDS
Bev	Bevon	Irregular low hills and rises with limonitic duricrust and stony plains.
Red	Red Hill	Basalt hills and ridges
Bin	Binneringie	Hills and plains based on gabbro.
Zed	Zed	Low hills and stony plains on sedimentary and meta-sedimentary rocks.
LAND TYPE TWO:		LOW HILLS WITH EUCALYPT-HALOPHYTE OR ACACIA-HALOPHYTE WOODLANDS OR SHRUBLANDS
Grv	Graves	Low hills and rises on basalt and greenstone and minor lower plains.
LAND TYPE FIVE:		IRREGULAR PLAINS AND LOW RISES SUPPORTING ACACIA SHRUBLAND AND MINOR HALOPHYTIC SHRUBLANDS
Ltm	Latimore	Gently undulating gravelly plains and low rises based on laterite.
LAND TYPE SIX:		STONY PLAINS AND LOWER ALLUVIAL PLAINS WITH PREDOMINANTLY SALINE SOILS AND HALOPHYTIC SHRUBLANDS/WOODLANDS
Gun	Gundockerta	Gently undulating plains on weathered greenstone with stony mantles and lower alluvial tracts.
Mor	Moriarty	Gently undulating plains with stony mantles, low rises with limonite and alluvial plains.
LAND TYPE SEVEN:		PLAINS WITH EUCALYPT WOODLANDS (SOMETIMES WEAKLY GROVED.) WITH HALOPHYTIC AND NON-HALOPHYTIC UNDERSTOREYS.
Gml	Gumland	Level to very gently inclined pediplains.
LAND TYPE NINE:		PLAINS WITH GRITTY SURFACES AND LOW HILLS AND DOMES ON GRANITE WITH ACACIA SHRUBLANDS
Sdg	Sedgman	Gritty surfaced plains and low granite hills and domes.
LAND TYPE THIRTEEN:		SANDPLAINS WITH SPINIFEX HUMMOCK GRASSLANDS, ACACIA SHRUBLANDS, HEATH AND EUCALYPTS
Bor	Boorabin	Level or gently undulating yellow sandplain.
Lak	Lakeside	Sandplains with occasional sand dunes and prominent claypans. (mallee eucalypts and spinifex.)
LAND TYPE FOURTEEN:		ALLUVIAL PLAINS WITH SALINE SOILS AND HALOPHYTIC SHRUBLANDS
Buy	Bunyip	Alluvial plains and drainage tracts with occasional gilgais.
LAND TYPE SEVENTEEN:		SALT LAKES AND FRINGING ALLUVIAL PLAINS WITH SALINE SOILS AND HALOPHYTIC SHRUBLANDS.
Lef	Lefroy	Salt lakes with fringing alluvial plains, minor sandy plains and dunes of kopi and sand.
Lab	Lakebed	Lakebed unit of the Lefroy land system
Sde		Area that is severely degraded and eroded.
Mine		Area of mining disturbance.

The land systems are grouped into broad land types in recognition of similarities in landform, soils and vegetation (after Pringle et al., 1994)

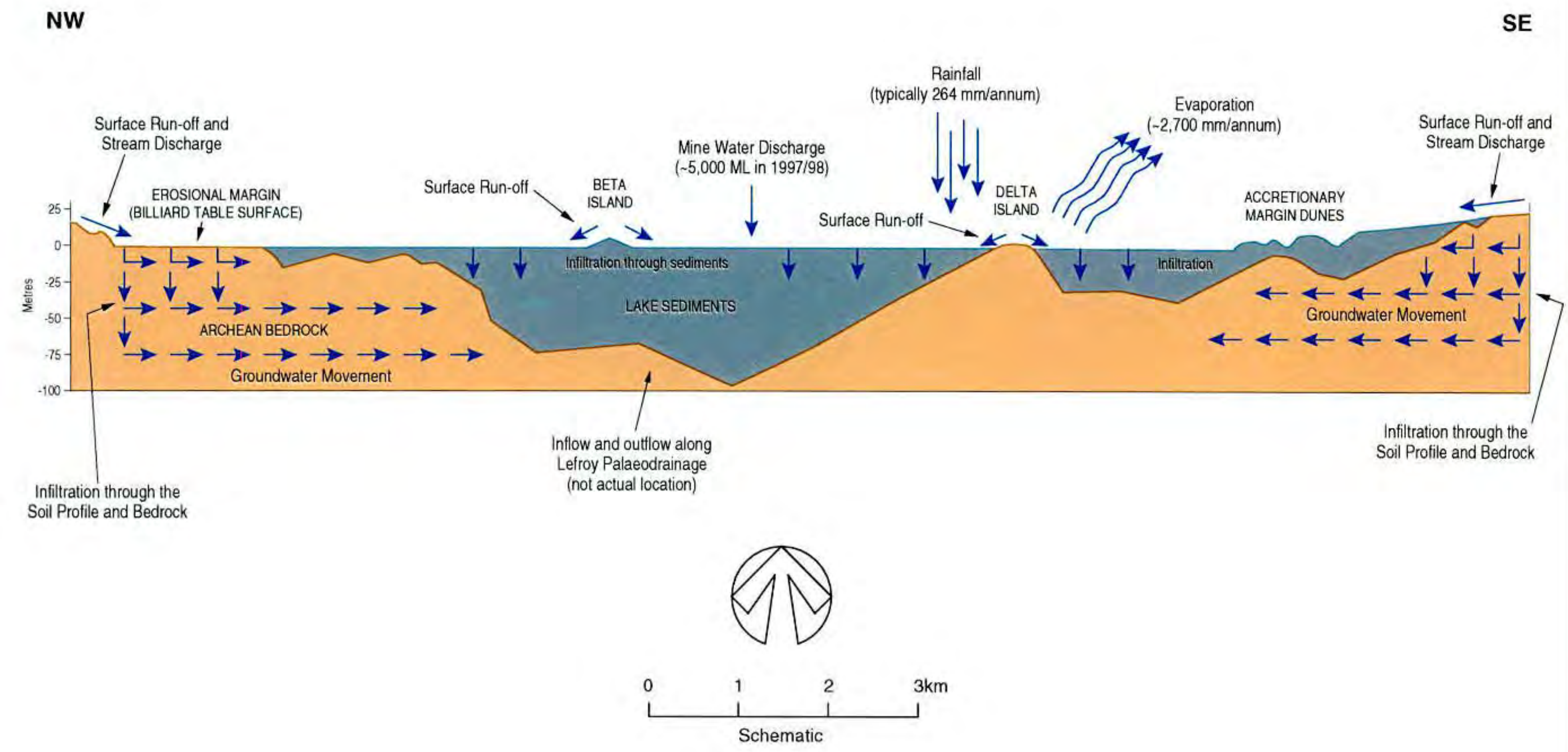
Source: Payne et al., (1998)

PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

LAND SYSTEMS LEGEND

DCM GROUP

FIGURE 3.7b



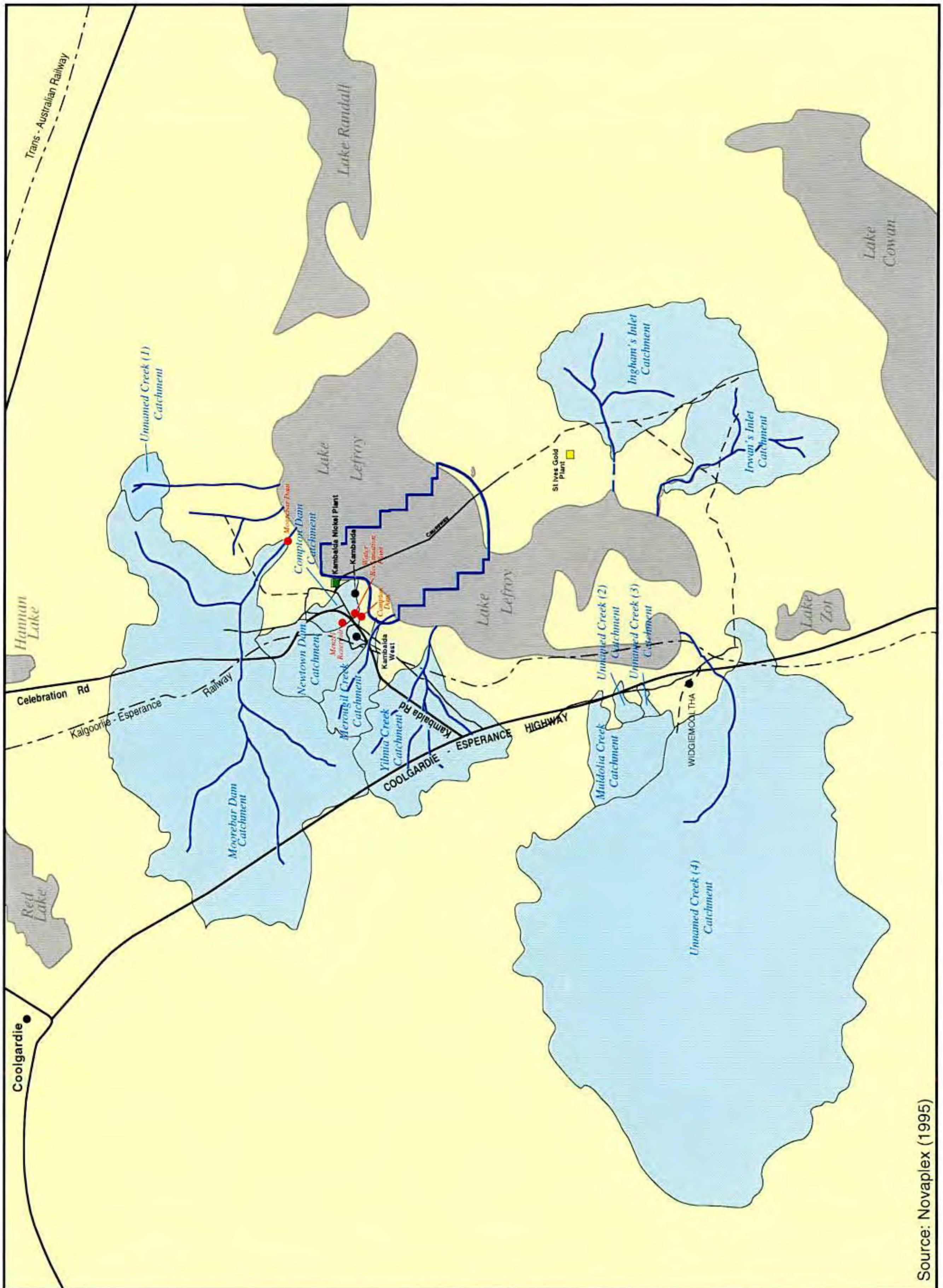
Source: Base map from Clarke (1993)

HYDROLOGICAL CYCLE

PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

DCM GROUP

FIGURE 3.8

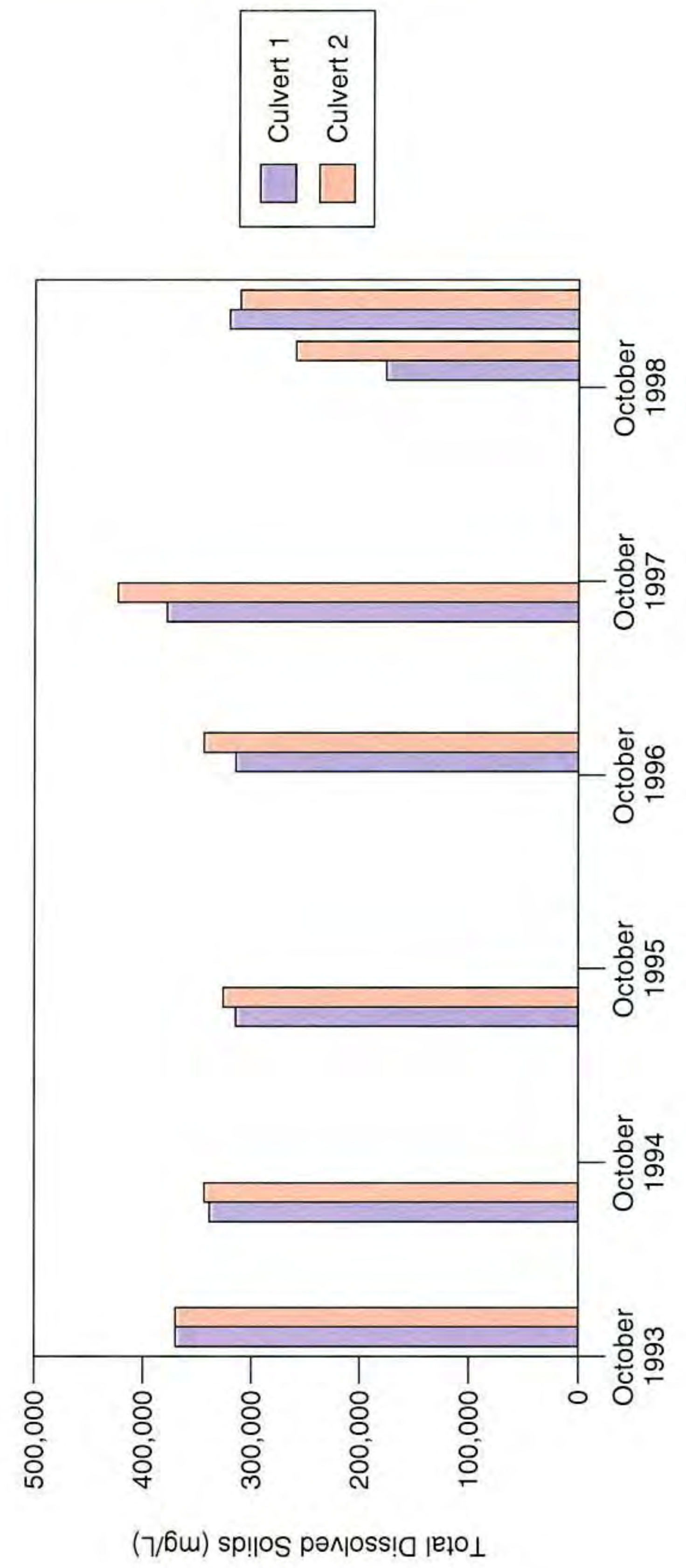


PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

PRELIMINARY MAPPING OF MAJOR SURFACE WATER CATCHMENTS

DCM GROUP

FIGURE 3.9



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

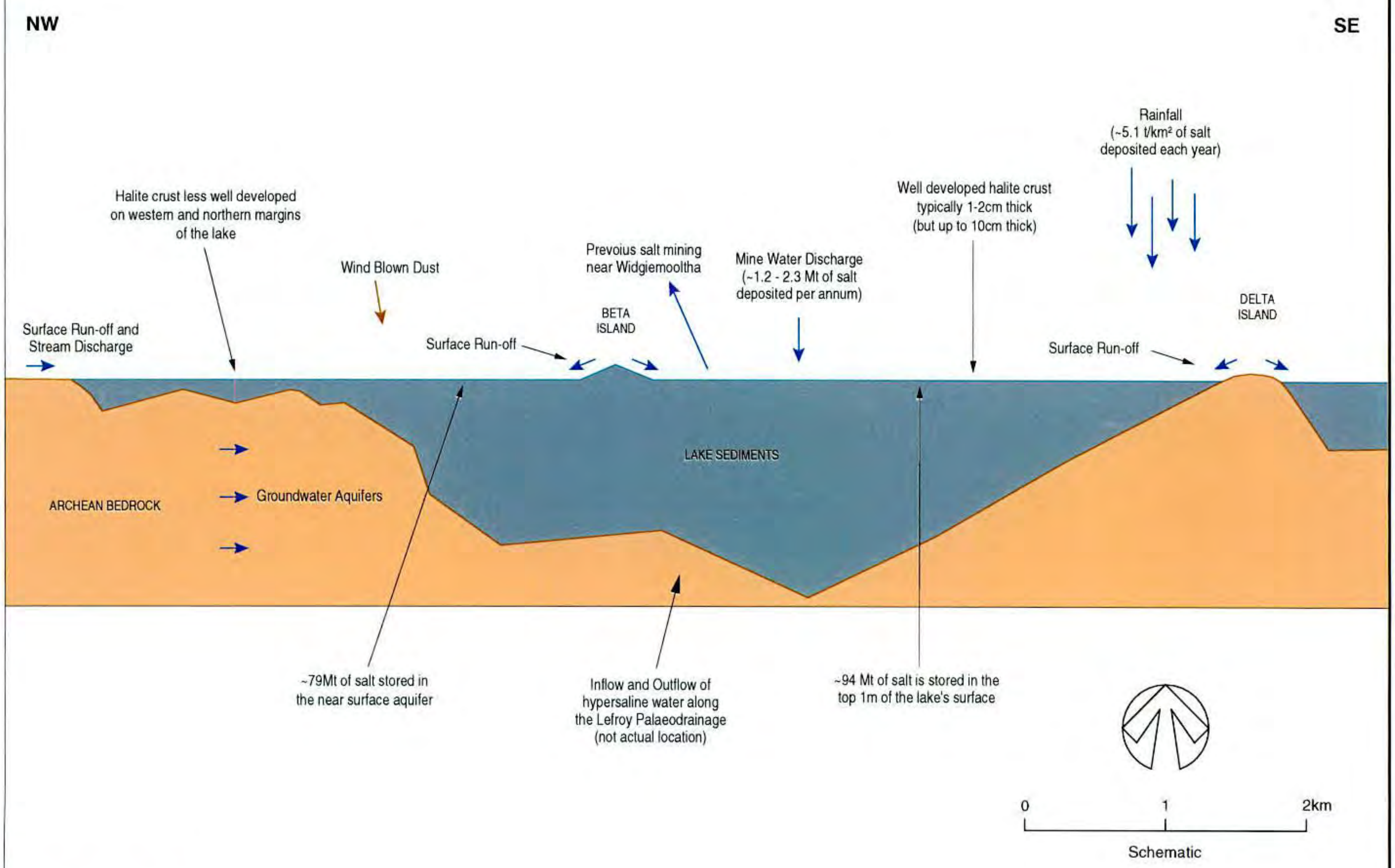
SALINITY OF SURFACE WATER AT THE CAUSEWAY CULVERTS

FIGURE 3.10

FIGURE 3.11

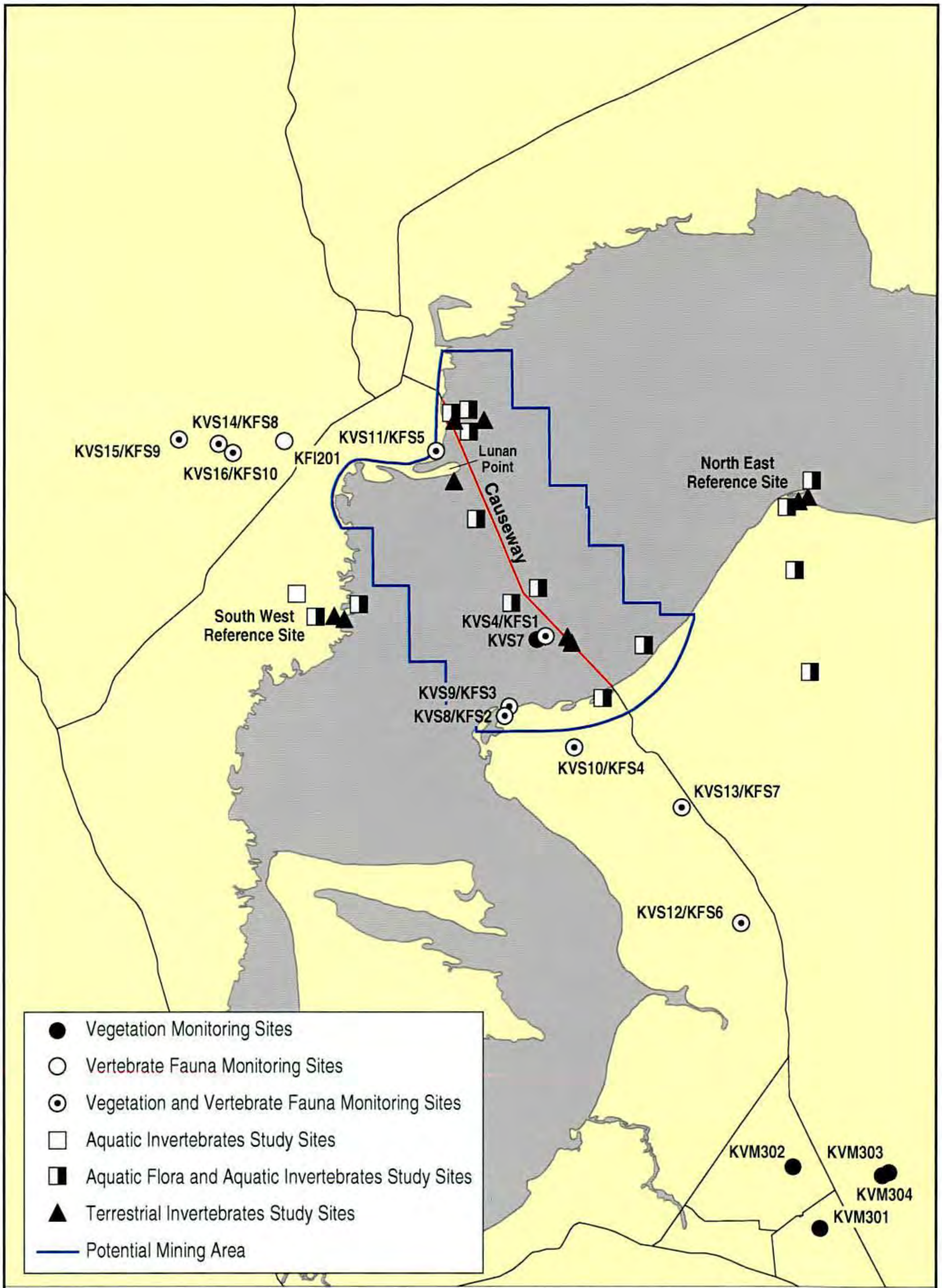
SOURCES OF SALT IN LAKE LEFROY

PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY



Source: Base map from Clarke (1993)

DCM GROUP

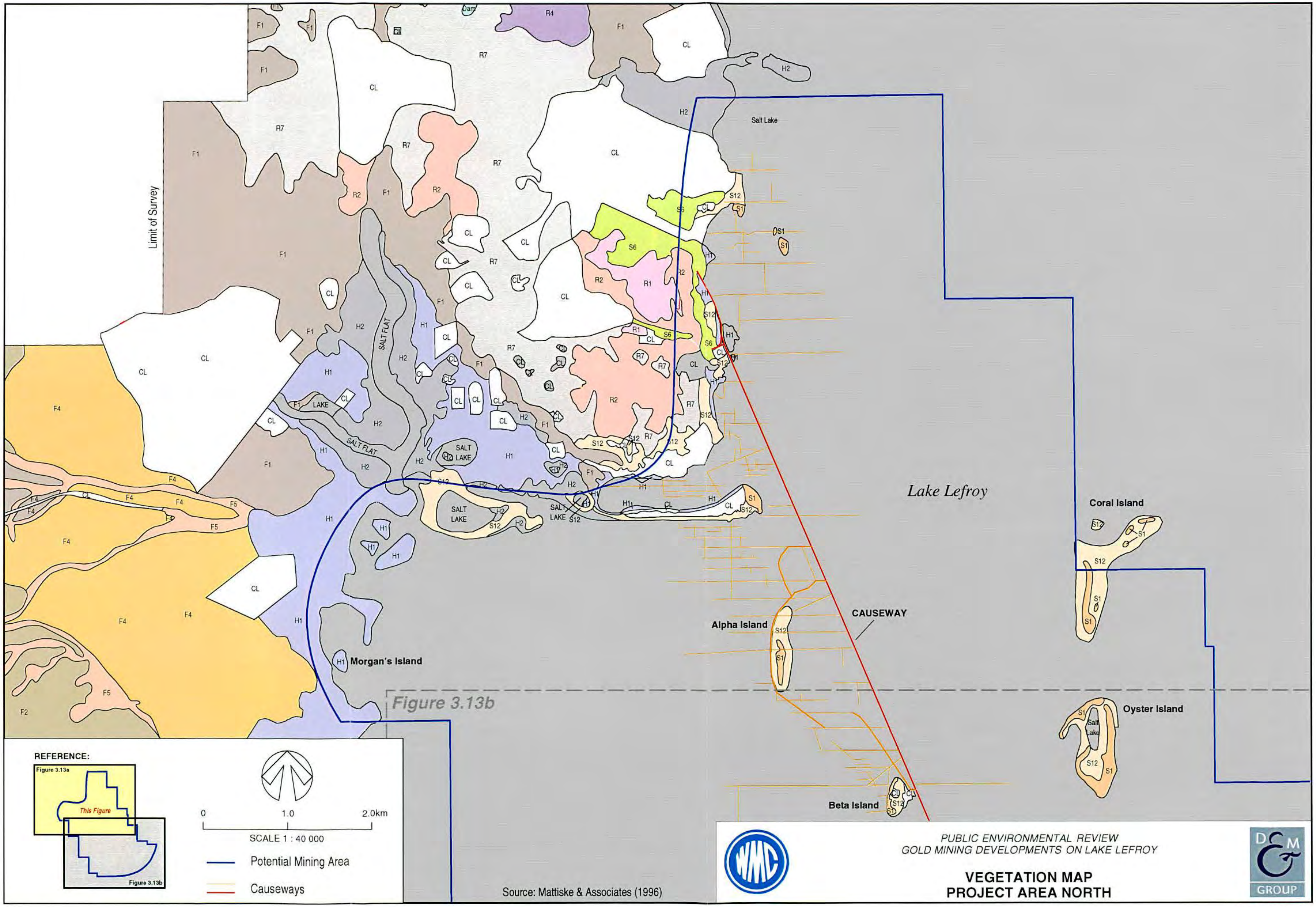


PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

LOCATION OF SAMPLE SITES FOR BIOLOGICAL STUDIES

DEM GROUP

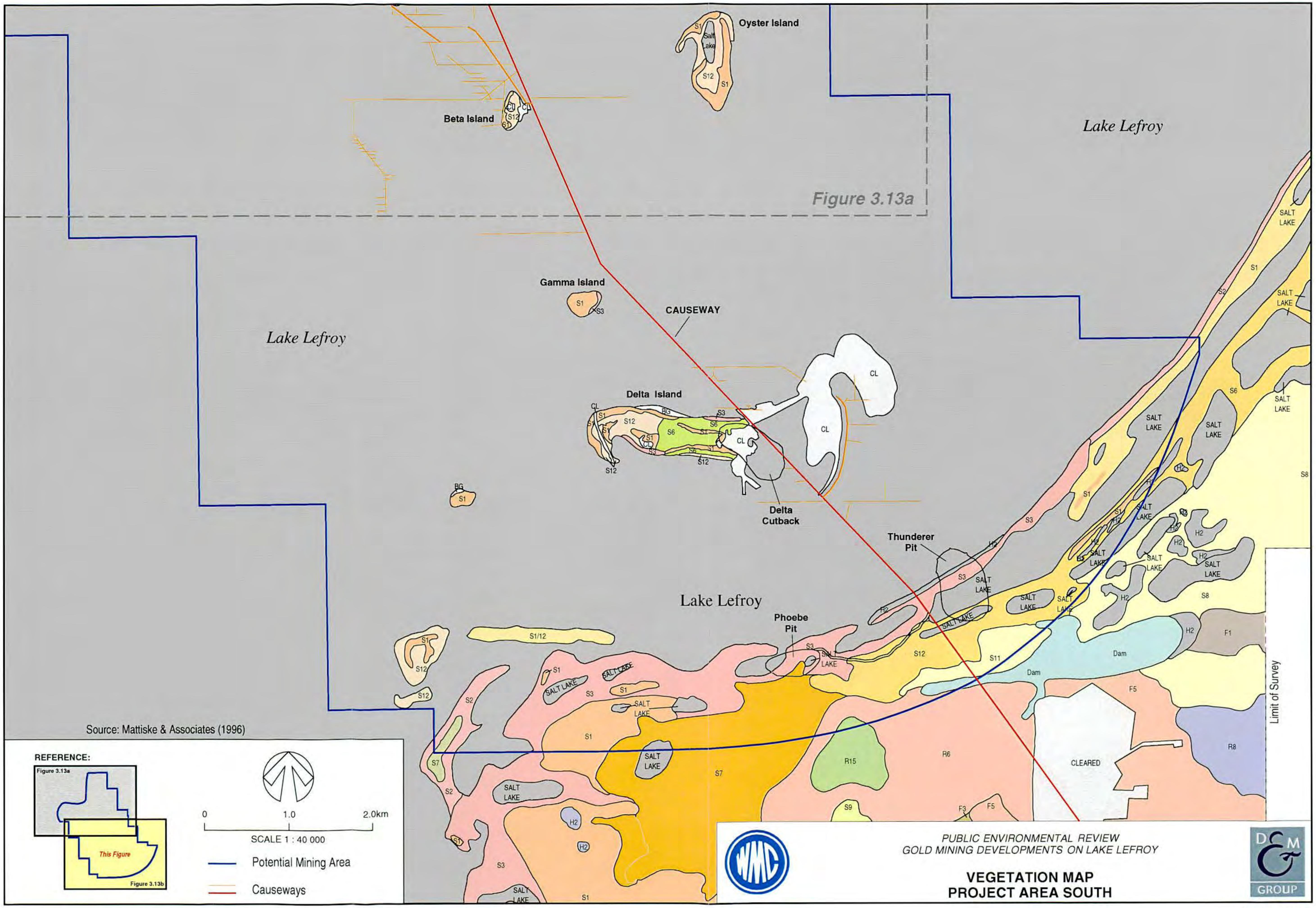
FIGURE 3.12



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

VEGETATION MAP
PROJECT AREA NORTH

FIGURE 3.13a



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

VEGETATION MAP
PROJECT AREA SOUTH

FIGURE 3.13b

S1 Very open Woodland of *Callitris glaucophylla* with occasional *Eucalyptus griffithsii* over patchy shrubs of *Acacia* species and *Jacksonia arida* subsp. *sclerosperma* and *Jacksonia foliosa* over sparse cover of *Triodia irritans* or *Triodia scariosa*.

S2 Open Shrubland dominated by *Jacksonia foliosa* and *Darwinia* aff. *diosmoides*.

S3 Very open low scrub of regenerating shrubs including *Melaleuca* species over Chenopodiaceae spp., mixed shrubs and succulents.

S4 Low Woodland of *Eucalyptus clelandii* and *Eucalyptus leptophylla* over sparse mixed shrubs and relatively dense *Triodia scariosa*.

S5 Open Woodland of *Eucalyptus leptophylla* over sparse mixed shrubs and *Triodia irritans*.

S6 Open Woodland of *Eucalyptus ceratocorys*, *Eucalyptus salicola* and *Eucalyptus* sp. over *Triodia irritans*.

S7 Open Woodland of *Eucalyptus ?ceratocorys* over very sparse mixed shrubs over *Triodia scariosa*.

S8 Open Woodland of *Eucalyptus ?ceratocorys* and *Eucalyptus leptophylla* over mixed open Shrubland of *Melaleuca* and *Eremophila* sp. over *Triodia irritans*.

S9 Open Woodland of *Eucalyptus griffithsii* and *Eucalyptus longicornis* over sparse low mixed shrubs over *Triodia irritans*.

S10 Low Open Woodland of *Eucalyptus lesouefii* over sparse low mixed shrubs over *Triodia scariosa*.

S11 Open Woodland of *Eucalyptus striaticalyx* over very sparse open mixed shrubs and *Triodia scariosa*.

S12 Very open woodland of *Eucalyptus gracilis* and *Eucalyptus* sp. S (Brooker) with occasional *Casuarina cristata* over sparse mixed shrubs and relatively dense cover of *Triodia scariosa*.

H1 Halophytic complex of *Halosarcia* sp.

H2 Halophytic complex dominated by Chenopodiaceae sp. and *Frankenia pauciflora*.

F1 Tall Open Woodland of *Eucalyptus salmonophloia* and *Eucalyptus salubris* with pockets of *Eucalyptus lesouefii* over mixed low *Chenopodiaceae* spp. and sparse shrubs.

F2 Open Woodland of *Eucalyptus salubris* var. *salubris* over *Ptilotus obovatus*, *Acacia hemiteles*, *Eremophila* and mixed Chenopodiaceae spp. over dense daisies and grasses.

F3 Tall Open Woodland of *Eucalyptus salubris* var. *salubris* with very occasional *Eucalyptus salmonophloia* over dense mixed low Chenopodiaceae sp.

F4 Disturbed Open Woodland of *Eucalyptus salmonophloia* over Chenopodiaceae and *Eremophila* sp.

F5 Woodland of *Eucalyptus salubris* var. *salubris* over mixed low Chenopodiaceae and Asteraceae shrubs.

R1 Mixed Open Shrubland over mixed Open Herbland (annual daisies, grasses and Goodeniaceae spp.).

R2 Low mixed Shrubland over mixed Open Herbland (annual daisies, grasses and Goodeniaceae sp.).

R3 Low Shrubland of *Casuarina pauper*, *Dodonaea ptarmicaefolia* and *Eremophila* spp. over mixed Chenopodiaceae sp.

R4 Shrubland of *Acacia acuminata* var. *burkittii* over *Eremophila clarkei* over Open Herblands (annual daisies and grasses).

R5 Mixed Open Shrubland dominated by *Eremophila clarkei* and *Prostanthera grylloana*.

R6 Tall Open Woodland of *Eucalyptus salmonophloia* and *Eucalyptus salubris* over mixed shrubs.

R7 Open Woodland of *Eucalyptus lesouefii* and *Eucalyptus griffithsii* over mixed shrubs and herblands (annual daisies and grasses).

R8 Closed Shrubland of *Eremophila scoparia*, *Eremophila decipiens*, *Acacia erinacea* and *Exocarpos aphyllus* with emergent *Eucalyptus lesouefii* and occasional *Eucalyptus torquata* and *Casuarina cristata*.

R9 Low Woodland of *Eucalyptus torquata* over low mixed shrubs.

R10 Low Woodland of *Eucalyptus lesouefii* and *Eucalyptus transcontinentalis* over mixed low Chenopodiaceae spp.

R11 Closed Shrubland of *Melaleuca sheathiana* with occasional emergent Eucalypts over mixed low Chenopodiaceae spp. and grasses.

R12 Closed Shrubland of *Melaleuca sheathiana* with occasional emergent *Eucalyptus* spp. over mixed low Chenopodiaceae sp.

R13 Mixed Open Woodland of *Eucalyptus campaspe*, *Eucalyptus stricklandii* and *Eucalyptus salubris* over *Eremophila* and low mixed Chenopodiaceae sp.

R14 Woodland of *Eucalyptus stricklandii*, *Eucalyptus celastroides* ssp. *celastroides* and *Eucalyptus lesouefii* over mixed shrubland dominated by *Dodonaea ptarmicaefolia* and *Eremophila* sp. over *Triodia irritans* over mixed Open Herbland (annual daisies and grasses).

R15 Woodland to Very Open Woodland of *Eucalyptus griffithsii* over mixed shrub species.

Cleared

Dam

Salt Lake Bed

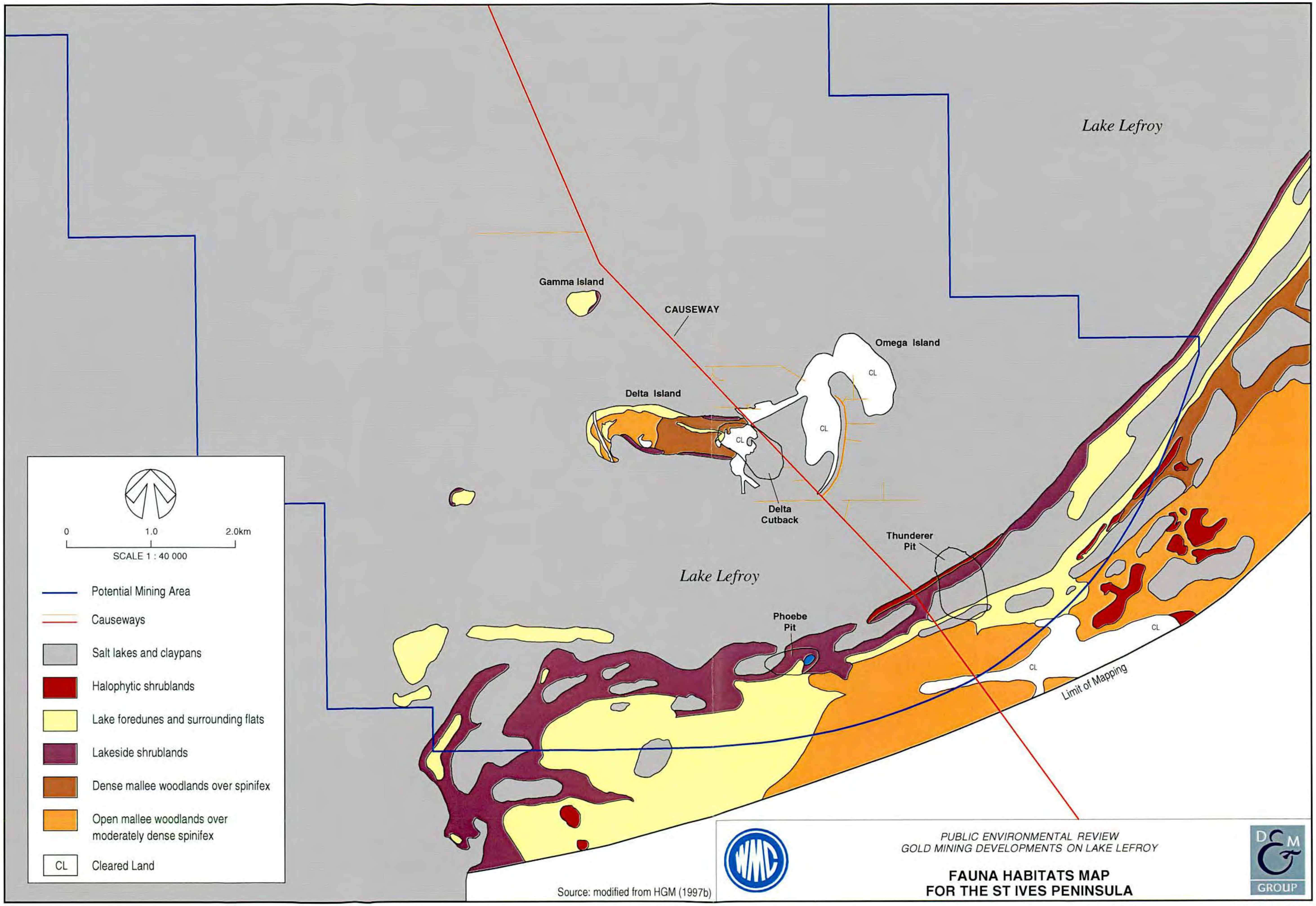
Source: Mattiske & Associates (1996)

PUBLIC ENVIRONMENTAL REVIEW
POTENTIAL GOLD MINING DEVELOPMENT ON LAKE LEFROY

VEGETATION MAP LEGEND

DCM GROUP

FIGURE 3.13c

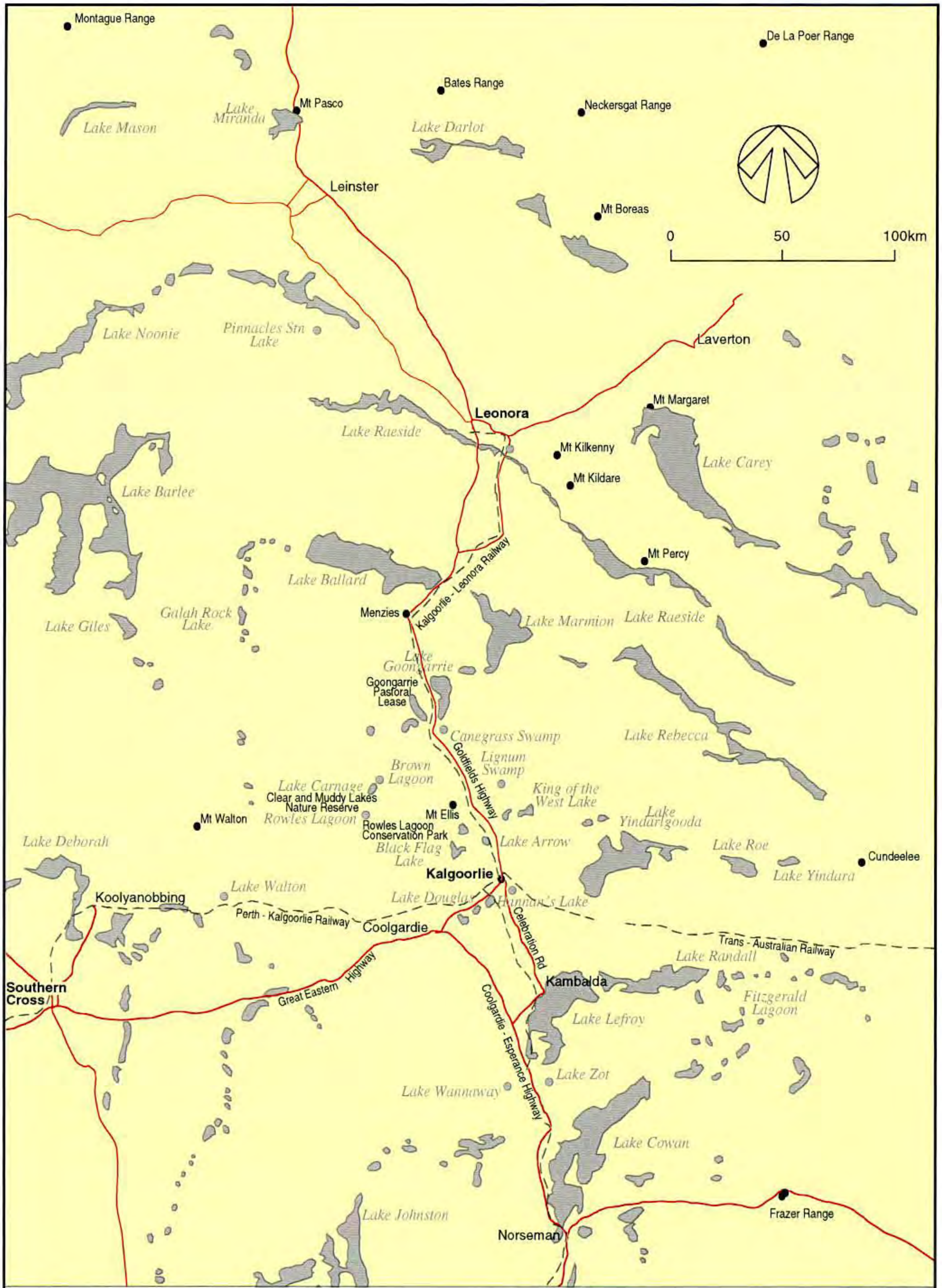


PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

FAUNA HABITATS MAP FOR THE ST IVES PENINSULA

D & M GROUP

FIGURE 3.14



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

WETLANDS IN THE GOLDFIELDS REGION

FIGURE 3.15

PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

CALM LANDS IN THE KALGOORLIE AREA

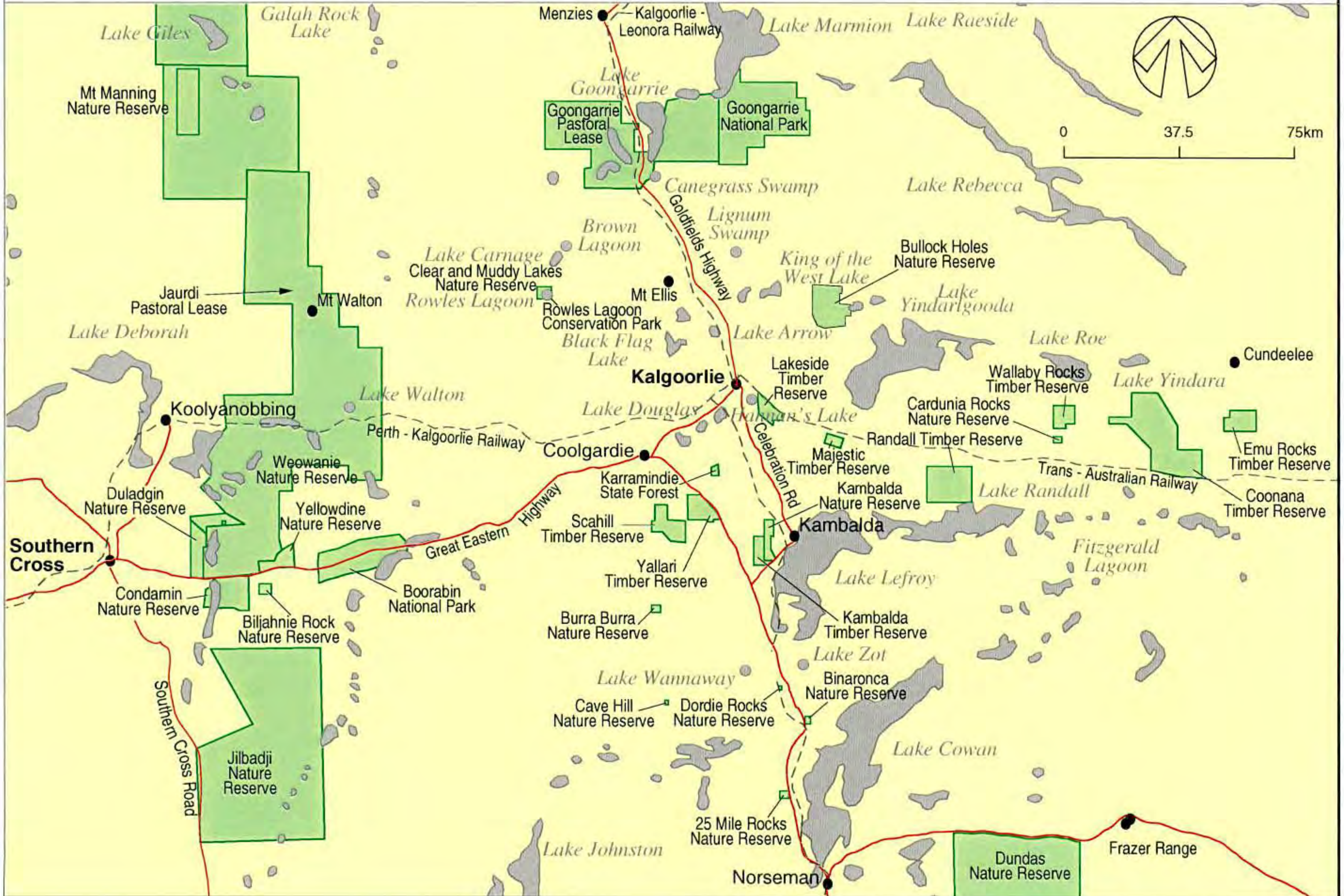
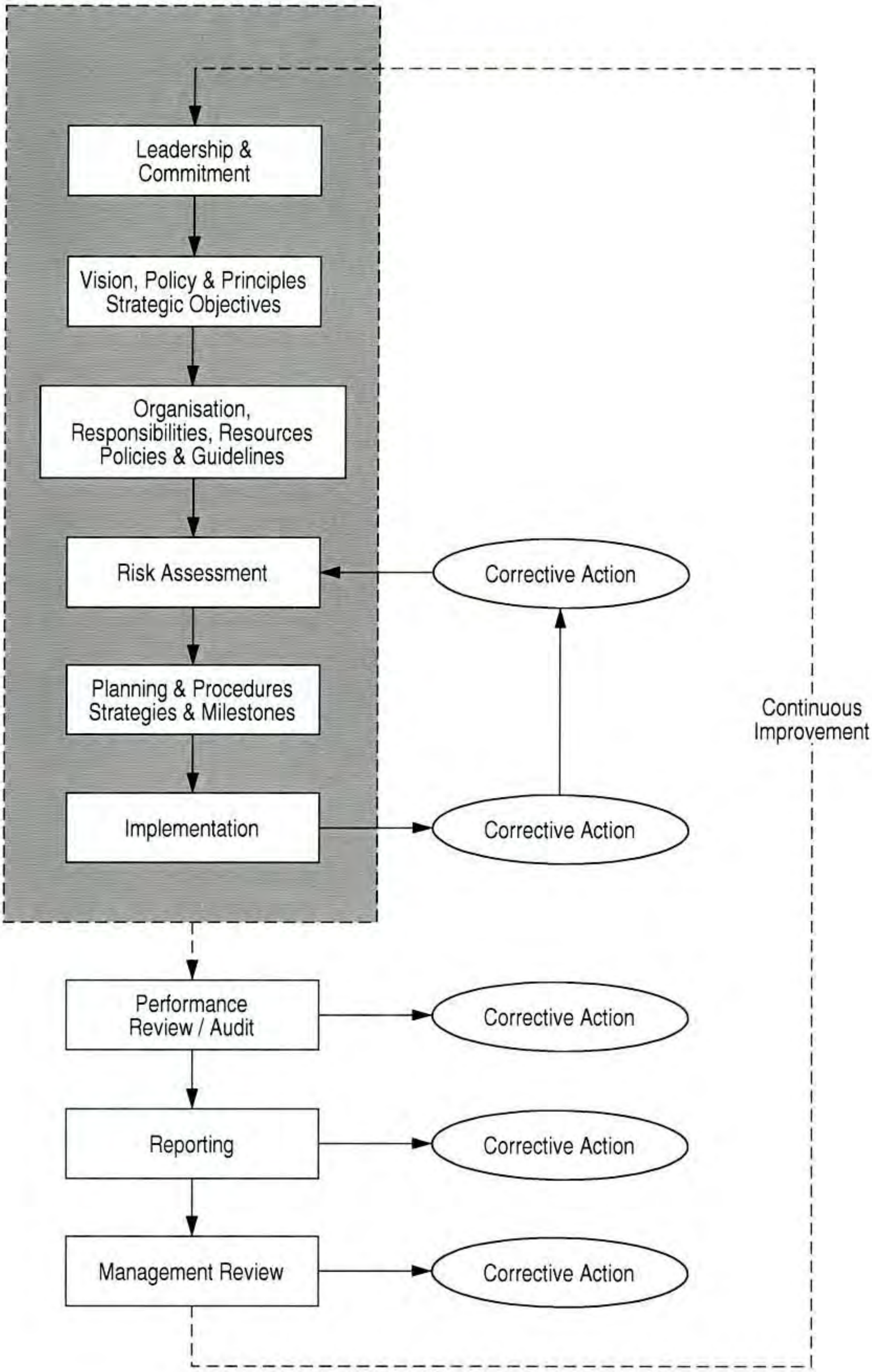


FIGURE 3.16



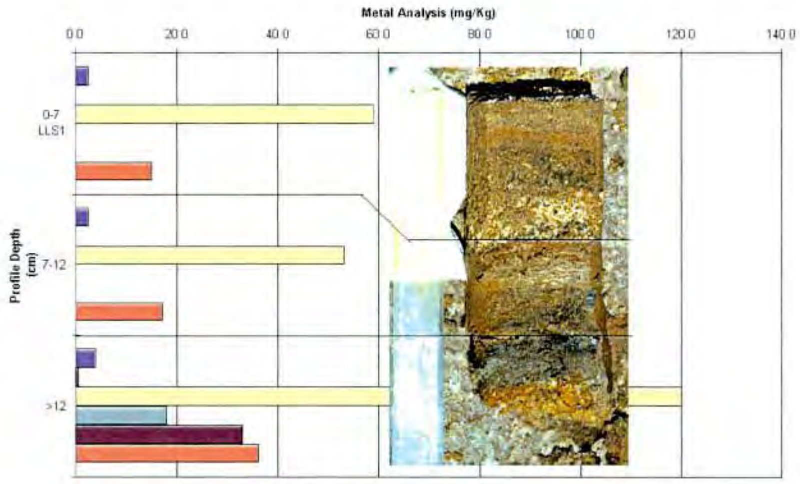
PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

EMS FRAMEWORK

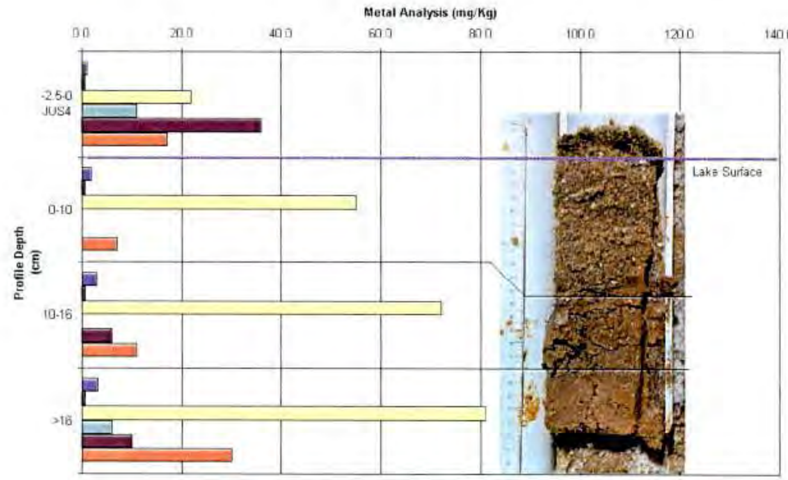
FIGURE 5.1

CONCENTRATION OF METALS IN SEDIMENT SAMPLES FROM LAKE LEFROY AND THE JUNCTION DISCHARGE SITE

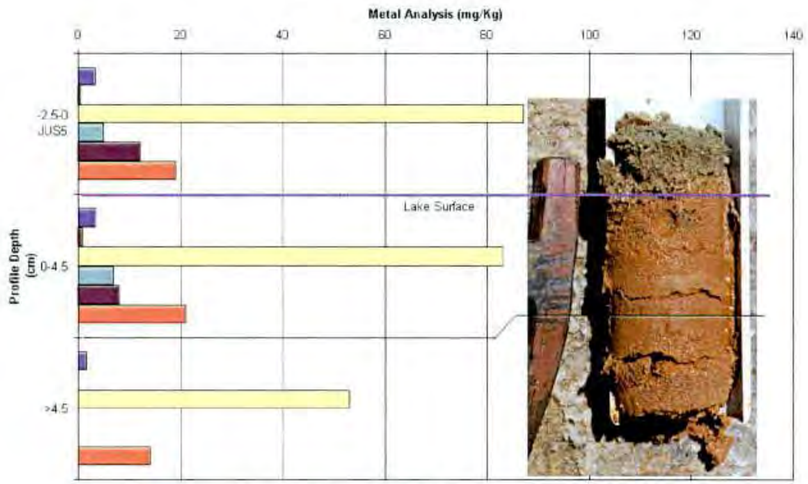
PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY



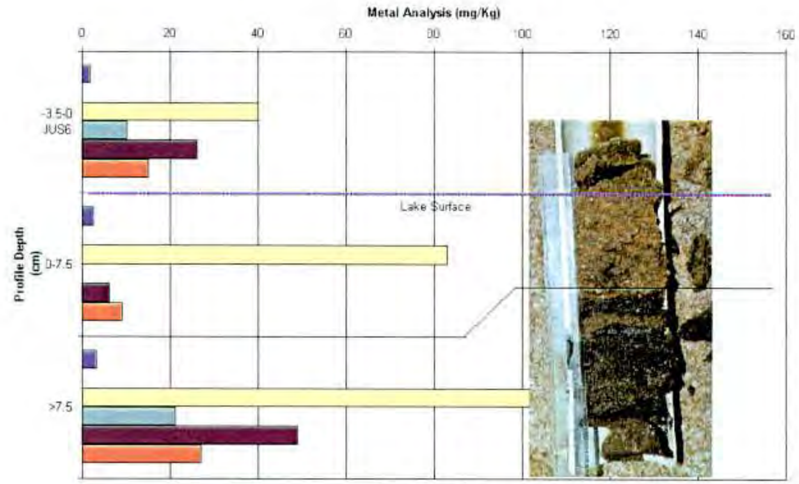
Lake Lefroy Sediment



Junction Outlet Site JUS4



Junction Outlet Site JUS5

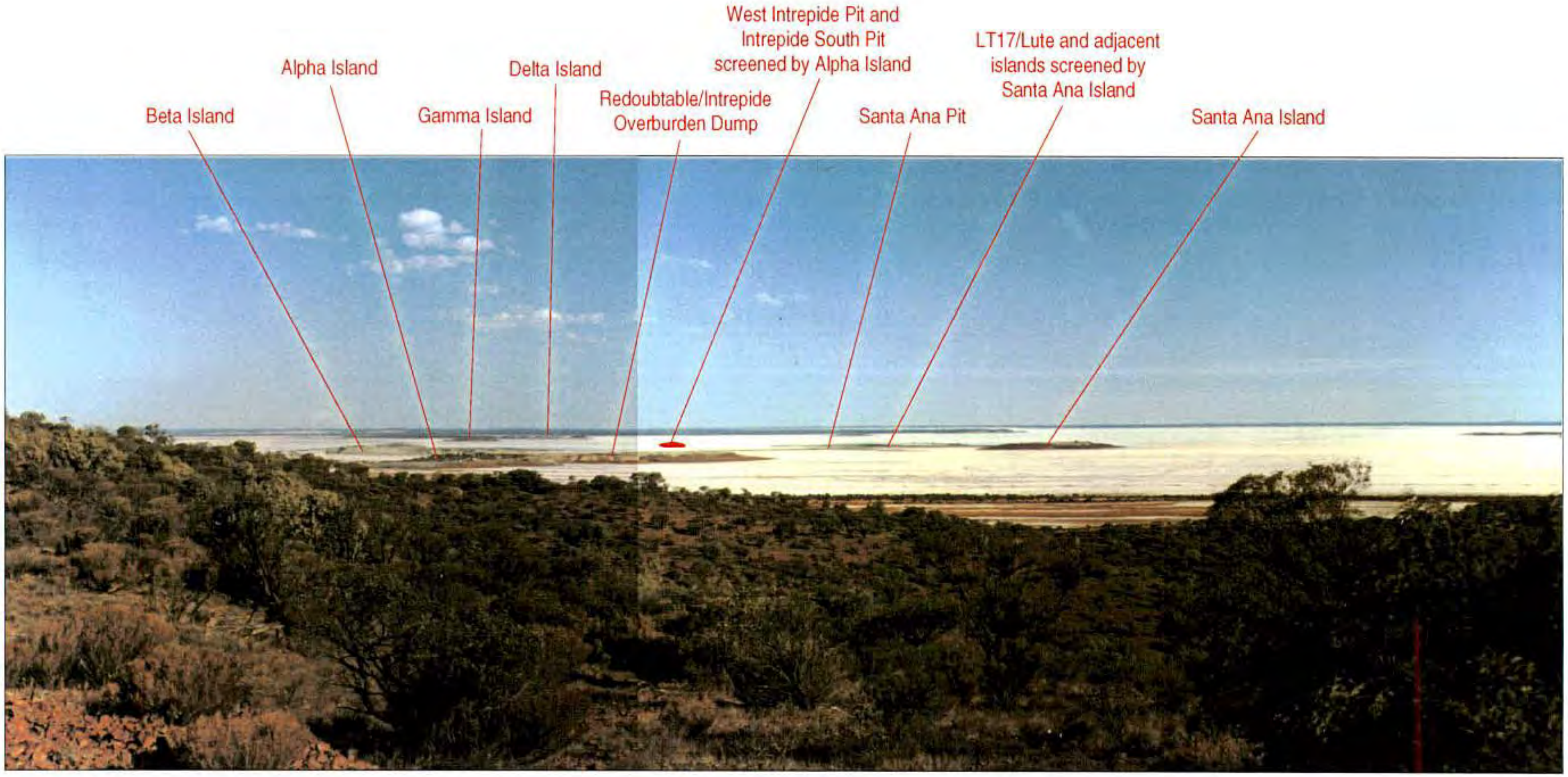


Junction Outlet Site JUS6

Arsenic | Cadmium | Chromium | Copper | Nickel | Zinc

DCM GROUP

FIGURE 5.2



PUBLIC ENVIRONMENTAL REVIEW
GOLD MINING DEVELOPMENTS ON LAKE LEFROY

VIEW OF THE PROJECT AREA FROM THE SOUTHEAST SIDE OF RED HILL

FIGURE 5.3

Plate 2.1: Revenge open cut pit, December 1998.

Plate 2.2: Backfilling of the Redoubtable open cut pit, February 1999.

Plate 2.3: Delta and South Delta open cut pits on Delta Island, September 1993.

Plate 2.4: South Delta open cut pit, May 1999.

Plate 2.5: Epsilon Island, October 1995.

Plate 2.6: Omega Island, May 1999.

Plate 2.7: A settling pond at the Revenge Pit.

Plate 2.8: Discharge of mine water to the Thunderer bund.

Plates 2.9 & 2.10: Dewatering discharge from Argo open cut pit to Lake Lefroy.

Plate 3.1: Lake Lefroy's western shoreline in 1966.

Plate 3.2: Sand dunes on the eastern shoreline of Lake Lefroy with shrub and woodland vegetation.

Plate 3.3: Sand dunes on the eastern side of Lake Lefroy previously disturbed by sand mining.

Plate 3.4: Gamma Island.

Plate 3.5: Delta Island.

Plate 3.6: Turbid runoff to Lake Lefroy following Cyclone Vance, March 1999.

Plate 3.7: Plant Community S1 - Very Open Woodland of *Callitris glaucophylla* with occasional *Eucalyptus griffithsii* over *Acacia* species, *Jacksonia arida* and a sparse cover of *Triodia scariosa* on deep aeolian sands.

Plate 3.8: Plant Community S12 - Very Open Woodland of *Eucalyptus gracilis* and *Eucalyptus trichopoda* with occasional *Casuarina pauper* over sparse mixed shrubs and a relatively dense cover of *Triodia scariosa* on deep aeolian silica sands.

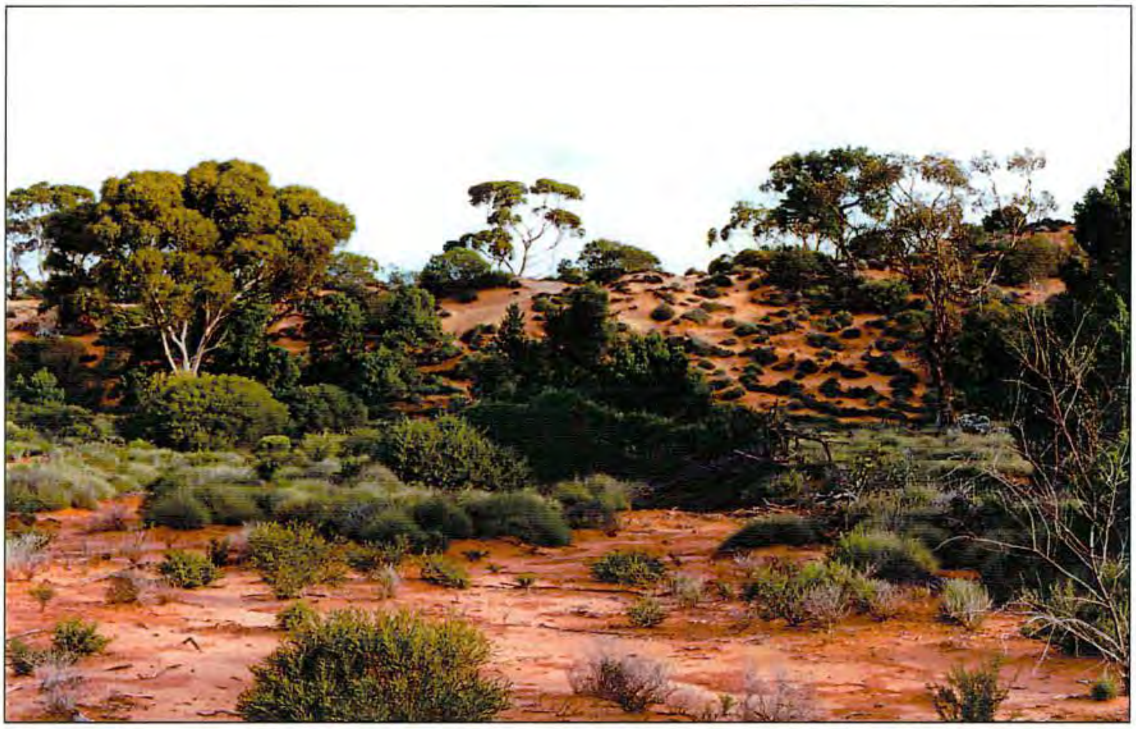


Plate 3.9: Plant Community S6 - Open Woodland of *Eucalyptus platycorys* over very sparse mixed shrubs and spinifex on deep dunal red sands. This photograph was taken on Delta Island.

Plate 3.10: Plant Community S2 - Open Shrubland dominated by *Jacksonia arida* and *Darwinia* aff. *diosmoides* on pale gritty sands on the fringe of Lake Lefroy.

Plate 3.11: Plant Community H2 - Halophytic complex dominated by Chenopodiaceae spp. and *Frankenia pauciflora* on the fringes of the playa lakes.

Plate 3.12: Plant Community H1 - Halophytic complex of *Halosarcia* spp. on the fringes of the playa lakes.

Plate 3.13: *Schizothrix* mats on a playa adjacent to Lake Lefroy.

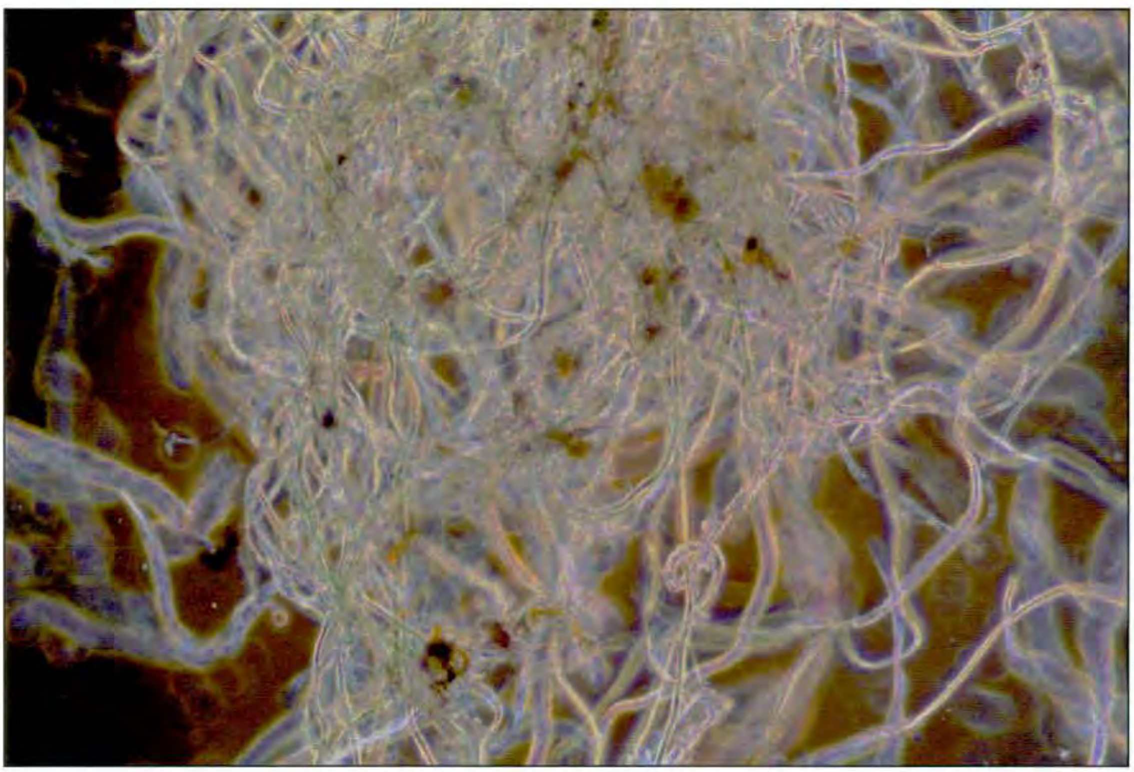


Plate 3.14: Close-up of *Schizothrix* sp. (400x).

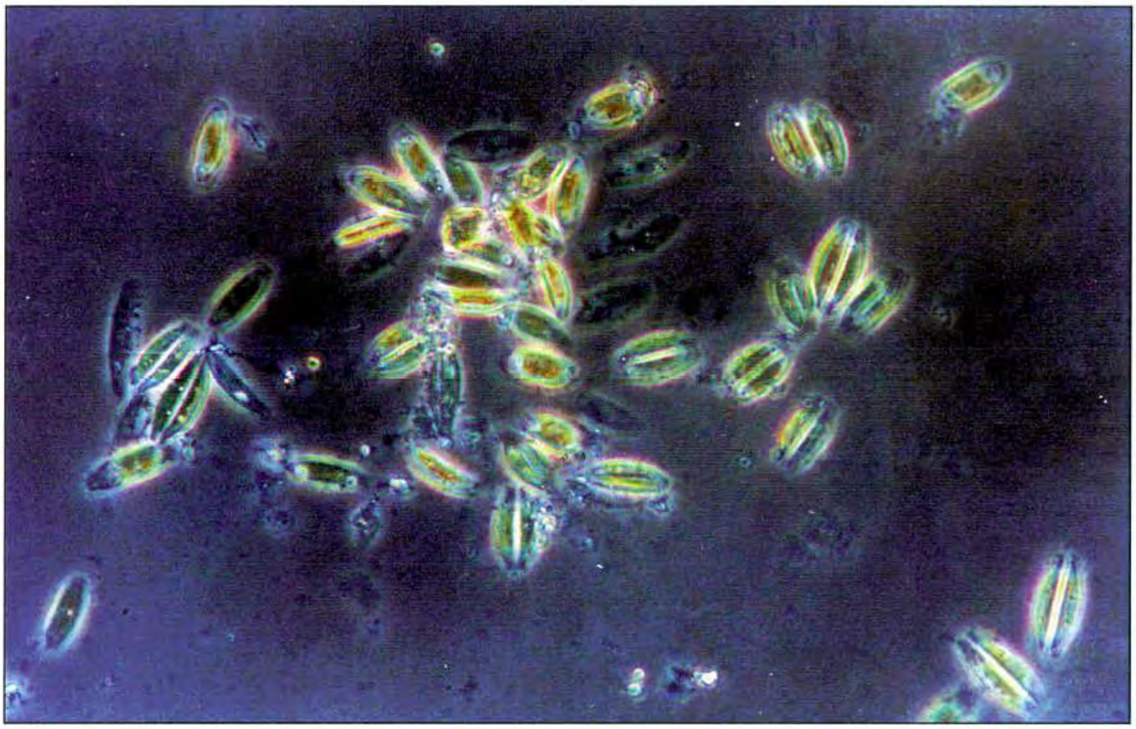


Plate 3.15: The diatom *Amphora coffeaeformis* (400x).

Plate 3.16: Brine shrimp (*Parartemia* sp.) hatched from sediments collected at the Northeast Reference Site at Lake Lefroy (top: female ~14mm long; bottom: male ~17mm long).

Plate 3.17: Excavation of a wolf spider burrow.

Plate 3.18: A wolf spider excavated from the above burrow.

Plate 3.19: The inactive Land Sailing Yacht Club on the southern side of Beta Island.

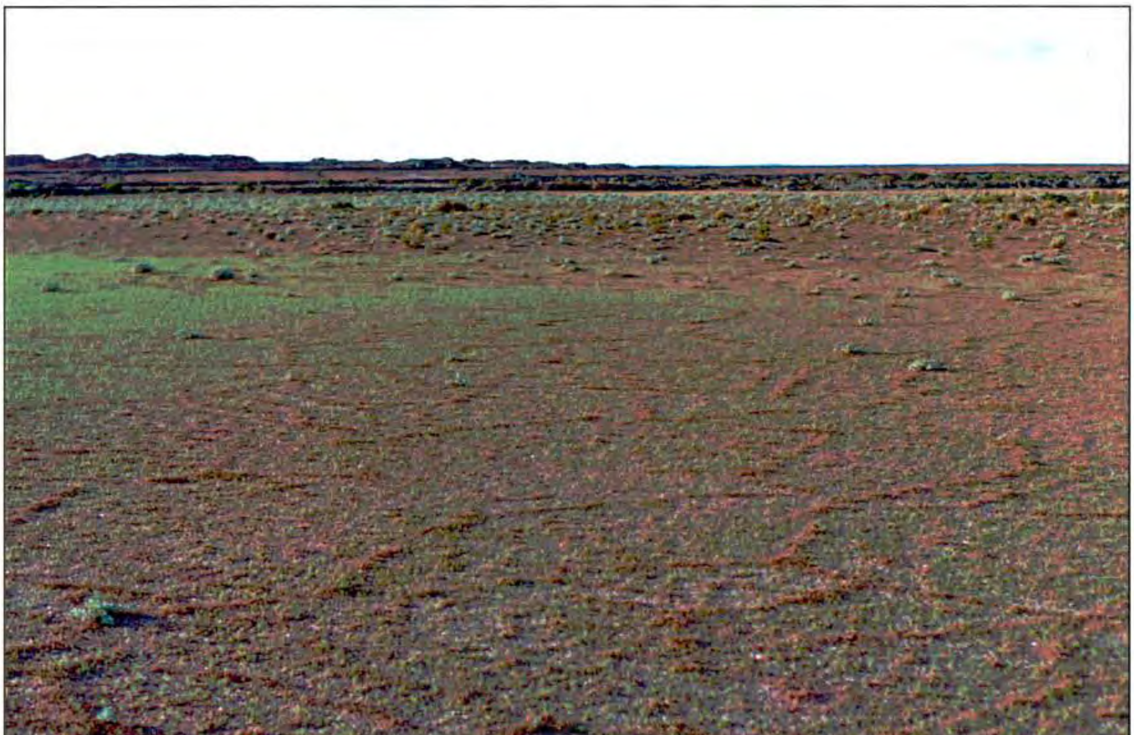


Plate 5.1: Samphires have become established on an area of lake bed on the eastern side of the Revenge haul road that has been cut off from surface water flow.