

Appendix 5 Subterranean fauna desktop assessment

Memo

To: Cameron McDonald

From: Volker Framenau

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Subject: Subterranean fauna desktop assessment – Shamrock Station Irrigation Project



1 INTRODUCTION

Argyle Cattle Company Pty Ltd (ACC) is seeking to develop a pivot irrigation project on Shamrock Station (the Project). The area will be used to produce irrigated fodder for station use. The Project is located approximately 64 km south of Broome in the Dampierland bioregion of Western Australia.

Current planning of Stage 1 of the Project modelled a continuous supply of 25 L/s of groundwater each to supply 12 production bores for 40 ha centre-pivot irrigators, equating to approximately 9,500 ML/annum (IGS 2017). The cumulative groundwater drawdown (i.e. incl. currently licensed groundwater use by nearby Shamrock Gardens) was modelled to be 1.64–2.59 m at Shamrock Gardens over 10 years (of which 0.77–0.78 m was caused by the Project), with the drawdown decreasing with further distance from the Project.

Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by ACC to conduct a preliminary assessment for subterranean fauna for the Project, in particular if stygofauna was likely to be present and to clarify potential impacts by the Project.

Subterranean fauna are animals, predominantly invertebrates, which have evolved to live underground to escape harsh environmental conditions such as extreme heat and dryness of exposed environments. They are classified into two types:

- troglofauna – animals that live in air-filled subterranean networks
- stygofauna – animals that live in water-filled subterranean networks.

Habitats likely to support troglofauna are karstic limestone, channel iron deposits (CIDs; in particular pisolite in inverted landscape geomorphology), groundwater calcretes above the water table, alluvium/colluvium in valley-fill settings, banded iron formations (BIFs) and weathered and fractured sandstone. Stygofauna are likely where there are groundwater voids present, for example in karst limestone, calcretes, alluvial formations and fractured rock (EPA 2016).

2 METHODS

The presence of subterranean fauna is large determined by geological conditions, including 'vugginess' (presence of cavities) and hydrology, i.e. the presence and quality of groundwater. Therefore, the preliminary desktop assessment reviewed publicly available reports and publications on geological and hydrological conditions at Shamrock Station, as well as subterranean fauna survey reports from the region (Table 2-1).

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Table 2-1 Reports considered in the desktop review

Reference	Title
Gibson (1983)	1:250,000 Geological Series Explanatory Notes. LaGrange, Western Australia. Sheet SE/51-10.
Department of Water (2009)	La Grange Groundwater Allocation Plan. Water resource allocation and planning series. Report no. 25.
Department of Water (2012)	La Grange groundwater allocation plan: Evaluation statement 2011–2012.
Rockwater (2012)	Browse LNG Development. Stygofauna survey final report (2011/2012).
Paul <i>et al.</i> (2013)	A review of the Broome Sandstone aquifer in the La Grange area.
Wright <i>et al.</i> (2016)	Identifying groundwater-dependent wetlands of the Broome Sandstone aquifer in the La Grange groundwater area, Western Australia.
IGS (2017)	Shamrock Station irrigation development. Stage 1 hydrogeological assessment.

3 RESULTS

The Broome Sandstone aquifer is the principal groundwater resource in the West Kimberley (Dampier, Broome and La Grange) (Paul *et al.* 2013). The Project is located within the La Grange Groundwater Allocation Area (in the north subarea) and the proposal targets this aquifer. The La Grange Groundwater Allocation Area extends from just south of Broome at Roebuck Plains (ca. 65 km north of the Project) to 300 km south at Mandora Marsh (ca. 180 km south of the Project). La Grange north subarea occupies roughly the northern half.

3.1 GEOLOGY

Geological cross-sections of the La Grange area are shown in Figure 3-1, of which the E–F and A–B cross-sections are most relevant for Shamrock Station (see figure legend).

The La Grange area occurs within the expansive Canning Basin, which consists predominantly of Palaeozoic sedimentary rocks with a thin Mesozoic and Tertiary cover (Paul *et al.* 2013). Most of the underlying geology of the Canning Basin is covered by Cainozoic colluvium and alluvium. There has been little structural movement of the Canning Basin since the Jurassic. Middle Jurassic to Early Cretaceous units are extensive and generally flat-lying. The main units laid down during these periods are the Wallal Sandstone, Alexander Formation, Jarlemai Siltstone and the Broome Sandstone (Figure 3-1) (Gibson 1983).

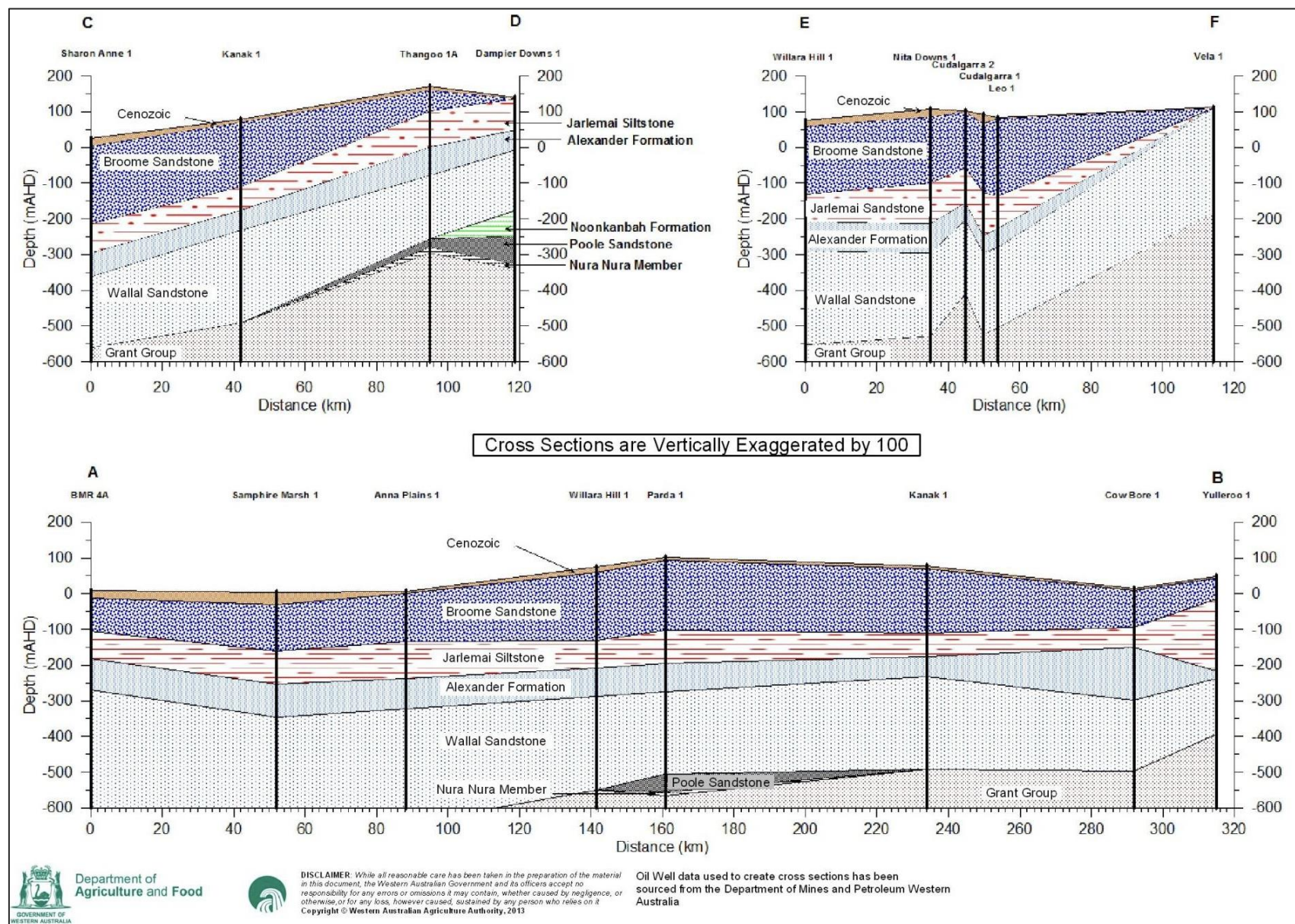


Figure 3-1 Geological cross sections of the La Grange area (from Paul *et al.* 2013)

Cross-section E–F illustrates the geology from approximately Shamrock Station (E) to about 120 km to the east (F); Cross-section A– B illustrates the geology parallel to the coast line from 140 km south of Shamrock Station (A) to approximately 180 km to the north (B).

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The Broome Sandstone is extensive (approximately 30 000 km²) and relatively continuous across the La Grange area, although it is coarsening with depth. It consists of friable fine- to coarse-grained sandstone, which is mainly unconsolidated. It contains minor beds of grey siltstone, claystone and pebble conglomerate, as well as some thin coal seams (Paul *et al.* 2013). In the east of the La Grange area, the Jarlemai Siltstone is exposed (towards F in Figure 3-1), with Broome Sandstone being 'draped' across this unit and increasing in thickness from east to west. At the coast, the Broome Sandstone can be more than 200 m thick (C and E in Figure 3-1). The contact between the Broome Sandstone and the Jarlemai Sandstone is relatively flat, dipping at approximately 0.3% towards the west.

Jarlemai Sandstone and Alexander Formation represent late Jurassic deposits of sand and mud in a marine environment (Gibson 1983). The Jarlemai Sandstone is thought to be an aquitard sealing the Alexander Formation and Wallal Sandstone, both therefore representing a confined aquifer (IGS 2017).

3.2 HYDROLOGY

The aquifer in the Broome Sandstone is extensive with an average saturated thickness of about 150 m. It is unconfined and therefore recharged directly by rainfall through the thin Tertiary or Quaternary sediments over large areas (Rockwater 2012). In contrast, groundwater flow in the Wallal aquifer (incl. Wallal Sandstone and Alexander Formation) takes place under confined conditions and recharge from rainfall is only possible over a limited eastern area where the Jarlemai Siltstone is absent. There is no known hydraulic connection between the Broome and the Wallal aquifers in the La Grange area.

Groundwater flow in the Broome Sandstone aquifer is from east to west, towards the coast (IGS 2017). Depths to groundwater range from less than 1 m to approximately 160 m, with the shallowest depths to groundwater occurring in the coastal areas (Figure 3-2) (Wright *et al.* 2016). Within Shamrock Station, the area with the largest drawdown due to Project water abstraction, the aquifer has an approximate thickness of 100 m, with the groundwater table at approximately 10 m AHD (ca. 30 m below ground level (BGL)).

Groundwater salinity is generally low and ranges from 90–940 mg/L Total Dissolved Solids (TDS) but increases towards the coast and towards the Mandora Marsh wetland system. Groundwater chemistry is mainly sodium chloride (NaCl) type water and pH ranges from 6.4 to 8.4 (IGS 2017).

At the ocean interface, a saltwater toe penetrates the base of Broome Sandstone aquifer due to the higher density of saltwater (orange area in Figure 3-2). This toe interface occurs approximately between 3.5–4.2 km from the coast at the closest point to the Project (IGS 2017).

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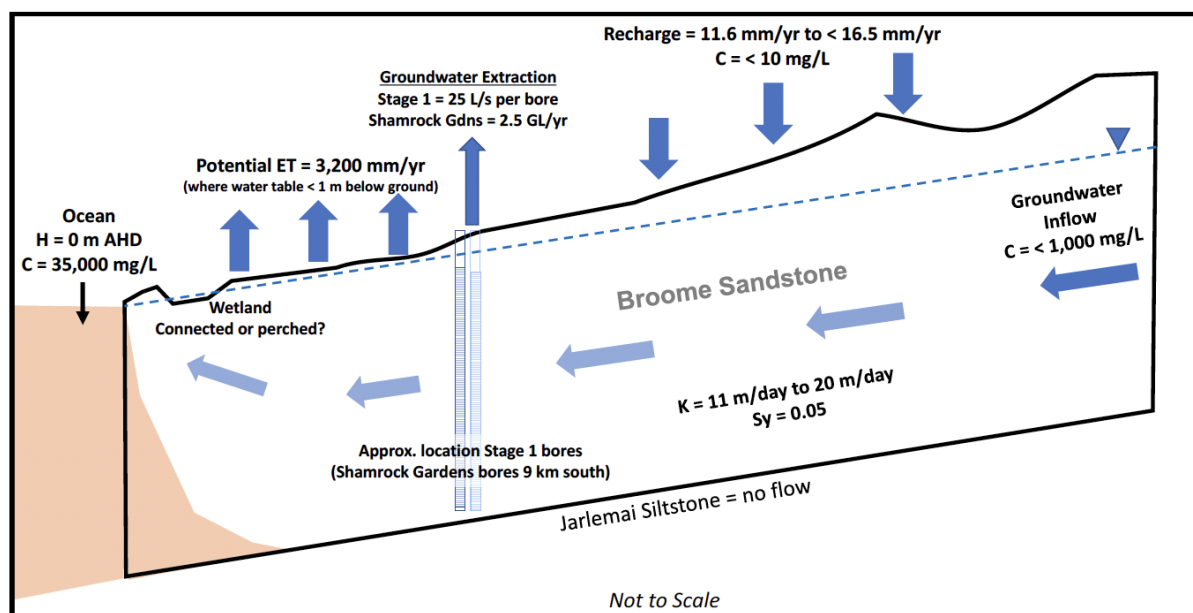


Figure 3-2 Conceptual model for the Broome Sandstone aquifer in the La Grange groundwater area (from IGS 2017)

3.3 SUBTERRANEAN FAUNA

There is little information on subterranean fauna of the Kimberley region and specifically the La Grange area. The alluvial aquifers of the Ord River Irrigation Area are known to contain stygofauna communities in the north-east of the Kimberley, including syncarids, copepods, ostracods, oligochaetes and oribatid mites from alluvial sediments (Cho *et al.* 2005; Humphreys 1999). Stygofauna sampling for the Argyle Diamond Mine in the northeast Kimberley identified at least 15 species of stygofauna (EPA 2005 in Rockwater 2012).

Subterranean fauna surveys in the Broome Sandstone aquifer as part of an industrial development near Broome and reference sites at Nita Station (ca. 70 km south of the Project) recovered a total of at least 18 stygofauna species in six higher taxa (Copepoda, Nematoda, Oligochaeta, Syncarida, Gastropoda, Ostracoda and Rotifera) (Rockwater 2012). A single troglotauna species, an isopod, was collected near Broome in the same study. These records confirmed assumption provided by geological and hydrological studies, i.e. that the porosity of the Broome Sandstone and the quality of the water in the aquifer, in particular its low salinity, are conducive for subterranean fauna, in particular stygofauna, to occur. This study found suitable habitat for stygofauna to be widespread in the Broome Sandstone aquifer and no geological barriers present that would restrict dispersal of the stygofauna community (Rockwater 2012).

The EPA's objective for subterranean fauna is its protection so that biological diversity and ecological integrity are maintained (EPA 2016). Subterranean communities are often restricted to very small areas based on the limited dispersal capabilities of the fauna, with short-range endemism interpreted at a much smaller scales than in terrestrial systems (Eberhard *et al.* 2009). Therefore, activities that may impact on subterranean assemblages require attention at a much smaller scale.

A number of factors contribute to the likelihood of subterranean fauna to occur, including, sediment texture, hydraulic conductivity (controlling food and oxygen supply), depth from surface, water regime (timing, frequency, duration, extent and depth, and variability), energy (food) flow (in the form of dissolved organic matter (DOM), salinity (accepted upper tolerance approximately 70,000 mg/L TDS), dissolved oxygen (DO) and redox status of the groundwater (Subterranean

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Ecology 2010). Independent of all other factors, salinity appears to be the main limiting factor for the occurrence of stygofauna in the aquifers of the study area. The majority of non-marine stygofauna are intolerant to salinity. Most are found in freshwater (<3,000 mg/L TDS) but some will tolerate water with salinities above this level. Stygofauna have been collected in saline waters (3,000-70,000 mg/L TDS) in calcrete formations in the Yilgarn and Nullarbor regions of WA (Cooper *et al.* 2008; Humphreys *et al.* 2004).

Based on geology and hydrology, the Broome Sandstone provides the conditions for both troglofauna and stygofauna to occur in the vicinity of the Project. Subterranean fauna, principally stygofauna, have been found in very similar hydrogeological conditions north of the Project near Broome and south of the Project at Nita Downs Station (Rockwater 2012) and it is likely that stygofauna is also present in similar faunal composition at Shamrock Station. Of potential conservation concern are mainly those taxonomic groups that have previously been shown to have small distributions independent of hydrogeological conditions, such as syncarids in the families Bathynellidae and Parabathynellidae (e.g. Cho *et al.* 2005).

3.4 IMPACT ASSESSMENT

This preliminary impact assessment is conducted under the assumption that subterranean fauna communities are present at Shamrock Station, consistent with a previous survey in Broome Sandstone and its aquifer (Rockwater 2012).

Impacts to subterranean fauna can be classed as either:

- **primary impacts** – impacts that physically destroy the subterranean void networks
- **secondary impacts** – impacts that change the subterranean habitat without physically destroying the void networks.

Primary impacts are obvious, whereas secondary impacts tend to be cumulative and may affect a far greater area than that being developed (Hamilton-Smith & Eberhard 2000). There are commonly two key threatening processes from development activities that impact subterranean fauna through the direct loss of habitat:

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

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Secondary impacts are those that affect the physicochemical properties of subterranean habitats. The nature of these changes can be difficult to measure and there is limited empirical evidence to support or refute these putative impacts. There are two secondary impacts that may be relevant to the Project:

- **Depletion of an aquifer leading to altered relative humidity** – troglofauna are dependent on high relative humidity. Dewatering may impact troglofauna habitat in unsaturated strata above the water table by lowering relative humidity.
- **Contamination** – contamination of subterranean habitats from spills, such as diesel fuel, or excessive nutrient run-off may degrade the quality of subterranean habitats. Such impacts would generally be highly localised and minor in scale; however, major contamination of subterranean habitats may have significant impacts.

3.4.1 Stygofauna

The loss of stygofauna habitat due to a drawdown of the aquifer is considered the main potential impact by the Project.

Groundwater changes based on modelled water abstraction in Stage 1 of the Project are predicted to be about 0.77–0.78 m maximum at Shamrock Gardens over 10 years, which must be considered very small, in particular taking natural variation of the aquifer of about 1–2 m in relation to its saturated thickness of at least ca. 100 m into account (IGS 2017). Loss of aquifer volume will also occur at the seawater interface, where the saltwater toe at the base of the aquifer will intrude a modelled 1.4–3.1 km further inland.

Optimal stygofauna habitat is likely to occur with increasing depth, as the substrate is getting coarser with depth, and therefore a top drawdown will not affect stygofauna. At Broome, most suitable geologies for stygofauna have been found between about 30 m and 50 m, with water levels at about 10–25 m (Rockwater 2012). Comparative stratigraphic geological data are not available for Shamrock Station, but it is very unlikely that a drawdown of less than 1 m will have any significant effect on stygofauna habitat.

Habitat loss due to an increased intrusion of the salt water toe will mainly occur at the bottom of the aquifer, although an accurate quantification of this loss is not possible. Similar to the aquifer drawdown, this change is localised and not considered to have a significant effect on stygofauna habitat in an aquifer of 30,000 km² with apparent little geological barriers for stygofauna to disperse.

Use of farming equipment (hydrocarbon spills), fertilizer and chemical agricultural applications have the potential to contaminate the groundwater, although taking the depth to groundwater into account, the risk is considered very low if properly managed and potential scale of impact very small considering the nature of the Project.

3.4.2 Troglofauna

A previous survey in Broome Sandstone only provided limited evidence of significant troglofauna assemblages to occur, with only a single specimen of a subterranean isopod (*Trogloarmadillo* sp.) collected in a total of 118 samples, although it has to be considered that sampling techniques mainly targeted stygofauna (Rockwater 2012).

Potential impacts of the proposed Project on troglofauna are considered negligible. There will be no direct removal of troglofauna habitat and the small extent of groundwater drawdown relative to saturated thickness of the aquifer is considered highly unlikely to significantly alter relative humidity of troglofauna habitat.

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4 CONCLUSION

The Broome Sandstone and its aquifer are highly likely to host a moderately diverse subterranean fauna, principally stygofauna. Water abstraction will result in the loss of stygofauna habitat by an additional drawdown of 0.77–0.78 m of the aquifer at Shamrock Station (but less further away) within 10 years and an additional intrusion of the saltwater toe of 1.4–3.1 km within 30 years. This predicted loss of habitat within an aquifer of 30,000 km² and an average depth of 150 m, which has no obvious geological barriers for dispersal, should be considered negligible for stygofauna, in particular when considering that stygofauna is less likely to occur in the upper layers of the aquifer which is less porous than at further depth.

Consequently, subterranean fauna should not be considered a key environmental factor for the development of Stage 1 of the Project.

Dr Volker Framenau

Principal Zoologist

Phoenix Environmental Sciences

volker.framenau@phoenixenv.com.au

08 9345 1608

1/511 Wanneroo Road Balcatta WA 6021

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