ECOLOGICAL MONITORING PROGRAM, LAKE WAY
L5206/1987/10

BLACKHAM RESOURCES LIMITED - MATILDA OPERATIONS PTY LTD
MARCH 2017

PREPARED BY

IN ASSOCIATION WITH

Please direct all inquiries to:
Focused Vision Consulting Pty Ltd
47 Riverina Parade, MUNSTER WA 6166
M: 0408 766 346 E: admin@focusedvision.com.au

Document History

Rev.	Author	Endorsed/Reviewed by	Approved for Issue	Date
A	Kellie Bauer-Simpson Principal Ecologist Anton Mittra Senior Biologist Matt MacDonald Principal Ecologist Gabriela Martinez Senior Botanist	Stuart Halse Principal Zoologist Renee Young Senior Ecologist		02/02/2017
B	Kellie Bauer-Simpson Principal Ecologist Anton Mittra Senior Biologist Matt MacDonald Principal Ecologist Gabriela Martinez Senior Botanist	Stuart Halse Principal Zoologist Renee Young Senior Ecologist	Kellie Bauer-Simpson Principal Ecologist Director, Focused Vision Consulting Pty Ltd	06/02/2017
0	Kellie Bauer-Simpson Principal Ecologist Anton Mittra Senior Biologist Matt MacDonald Principal Ecologist Gabriela Martinez Senior Botanist	Stuart Halse Principal Zoologist Renee Young Senior Ecologist Dale Carter Environmental Coordinator Blackham Resources	Kellie Bauer-Simpson Principal Ecologist Director, Focused Vision Consulting Pty Ltd	28/03/2017

Table of Contents

Figures

EXECUTIVE SUMMARY

Blackham Resources Limited (Blackham) is developing the Matilda Gold Project at Wiluna, Western Australia. The Project will involve mining of gold-bearing ore from pits and dewatering will be required prior to and during mining to enable dry-pit operations, with excess mine water discharged into nearby Lake Way.

The Department of Environment Regulation (DER) amended prescribed premises licence L5206/1987/10 on 10 June 2016 and improvement program conditions were added. One added condition required Blackham to undertake and report on an annual monitoring program to assess the ecological impacts associated with mine dewater discharge into Lake Way. The program is required to assess diversity, abundance and function of benthic microalgae and aquatic invertebrate species; as well as riparian vegetation at control (reference) and (potential) impact sites.

The results and information collected from these studies will be used to support ongoing management strategies and reported to the DER (and potentially other agencies) on an annual basis.

Six monitoring sites on the shores of Lake Way (three impact sites; LW01, LW Pipe 2, LW06 and three reference sites; LW04, LW07 and LW08) were established and sampled in November 2016, and this report presents findings of this baseline monitoring event.

The key results of the baseline monitoring are as follows:

- Concentrations of nickel at impact sites were significantly higher than at reference sites. Impact sites tended to have higher metal concentrations of most other metal analytes but the differences from reference sites were not significant and some reference sites exceeded guideline values.
- Significant negative correlations between concentrations in sediments and distance from the historic discharge point were found for manganese, nickel, thallium and zinc, with high correlation coefficients suggesting historic mine water discharge is the source of metals, although trigger values for these analytes were not exceeded.
- Arsenic concentrations exceeded the relevant ISQG-low trigger value at LW01, and the ISQG-high value at LW Pipe 2. These exceedances may warrant further investigation (DEC 2010). Low to moderate concentrations of arsenic were recorded at all other sites.
- Concentrations of chromium exceeded the relevant trigger value at LW01 and LW06, while moderate concentrations of this analyte were recorded at all other sites.
- Concentrations of mercury exceeded the relevant trigger value at two reference sites (LW04 and LW08) and two impact sites (LW01 and LW06), with remaining sites having low to moderate concentrations of mercury.
- Hatching trials for aquatic invertebrates yielded approximately 569 animals belonging to three species from three orders of typical salt-lake fauna:
  - A new species of seed shrimp belonging to an undescribed genus of Cyprididae was the most abundant recorded taxon. This ostracod species is currently only known from Lake Way.
  - A total of 56 specimens of the brine shrimp *Parartemia laticaudata* were recorded across three sites (LW01, LW Pipe 2 and LW04), but this species is thought to probably be present in low numbers at all sites as indeterminate specimens (Anostraca sp.).
  - The rotifer, Bdelloidea sp. 2:2 was only recorded in low-moderate abundance at a single site (LW Pipe 2) during low salinity trials.

- Hatching trial results are considered likely to underestimate the complete Lake Way aquatic invertebrate fauna assemblage.
- A total of 274 diatom specimens representing 13 species from five orders and eight genera were recorded from monitoring sites at Lake Way. The impact site LW01 hosted the greatest abundance and richness, with 228 specimens from eight species recorded. Other sites were far less productive, with yields of two to14 specimens from one to five species.
- Low counts of diatoms are considered normal for inland saline lakes, where low productivity and cell dissolution often lead to low cell counts.
- All of the transects encompass Chenopod shrublands at the lake edge, with two impact and two reference transects transitioning to Acacia dune vegetation along their length, but with one impact and one reference transect represented by samphire for their entire 300 m length.
- The only parameters for which any significant differences in collected data were determined to exist were for:
  - alive plant density, between all of the transects
  - plant health, between all of the transects
  - plant health, between impact and control transects.
- Transect LW07 (reference) is the only transect, found to differ significantly in plant density from impact transects LW01 and LW06 and the impact transect LW04, due to the high density of a single species, *Sclerolaena bicornis* growing at the end of the transect, which is not typical for most of the local vegetation.
- Plant health between all of the transects and between transect type (impact vs reference) was determined to provide significantly different results. Differences between transect types reveal greater plant health scores in particular for reference transect LW08, which is one of the farthest from the historic location.
- Site LW04 is likely to have been adversely affected by exploration and related activity in the immediate vicinity which was apparent on site during the baseline field assessment. Despite these potential impacts, LW04 is considered a suitable comparison site for impact site LW Pipe 2.
- Overall, impact and reference transects were also found to be significantly different in terms of plant health scores, with reference sites recording higher better mean health scores, likely due to residual and legacy impacts from historic discharge, and potential other impacts from mining activities in the north-eastern sections of Lake Way.

Subsequent monitoring data will provide further analysis opportunities where comparative analysis of the same sites over time will become possible.

Following the baseline monitoring of sediment, aquatic invertebrates, diatoms and riparian vegetation at Lake Way in 2016, the following recommendations are suggested:

- Monitoring of metal concentrations in lake sediments and/or surface water, especially those analytes that either exceed ISQG triggers or are negatively correlated with distance from the discharge point, should continue during and after dewatering discharge.
- An increase in the spatial intensity of monitoring should be considered, should metal concentrations breach guideline values.
- A separate study be considered that investigates the current concentrations of metals within and within close proximity of the historic discharge drain, and the degree to which existing build-up may

drain into Lake Way following rainfall and flooding, to ascertain any existing or ongoing impacts from historic activities that would not be attributable to proposed new discharging of pit dewater.

- Surface water monitoring after the lake receives significant inflow, including comprehensive assessments of water quality, aquatic fauna and flora, should be implemented as a priority, ideally prior to dewatering discharge. This will allow a greater understanding of the Lake Way ecosystem and will provide more comprehensive baseline for periods of inundation following discharge.
- In the absence of flooding, monitoring as per the present study should continue on an annual basis to provide information on the spatial and temporal changes that may be occurring as a result of dewatering discharge.
- A focus on dominant species is recommended for monitoring the vegetation communities that occur along the transects, as was carried out during the baseline field assessment, as this methodology was found to detect more subtle changes in vegetation communities than more broad-scale mapping of previous assessments.
- It is recommended that during subsequent monitoring events, vegetation condition also be mapped along the transects to enable a finer-scale set of data relating to changes in condition to be used to detect changes.
- It is recommended that subsequent monitoring events consider field assessment during the main flowering period for the region, typically during March, following the majority of annual rainfall from cyclonic activity in January and February, in order to record grasses and other annual or ephemeral species in better health and in more identifiable states.

1 INTRODUCTION

1.1 BACKGROUND

Blackham Resources Limited (Blackham) is developing the Matilda Gold Project (the Project) at Wiluna, Western Australia. The Project will involve mining of gold-bearing ore from pits at Williamson, Matilda (Wiluna South), Galaxy and the Wiluna mine and transporting it to the Wiluna Gold Mine processing plant. Dewatering will be required prior to and during mining to enable dry-pit operations, with excess mine water discharged into nearby Lake Way, one of many ephemeral salt lakes associated with the internally-draining palaeoriver system of the Yilgarn region (Bennelongia 2017).

Prescribed premises licence L5206/1987/10 (held by Matilda Operations Pty Ltd, a wholly owned subsidiary of Blackham) was amended on 10 June 2016 to authorise construction and operation of a new tailings storage facility (TSF J) and associated additional monitoring bores; also, to increase the licensed production capacity of the process plant to 1,800,000 tonnes per annum through additional plant and upgrades/ refurbishment of existing infrastructure.

The Department of Environment Regulation (DER) removed certain conditions it considered redundant and improvement program conditions were added. Condition IR2 in Table 4.1.1 of Section 4 of the Improvement Program states:

> *The Licensee shall submit to the CEO a monitoring plan to conduct an annual assessment of the ecological impacts associated with the mine dewater discharge to Lake Way. The plan shall assess diversity, abundance and function of benthic microalgae and aquatic invertebrate species at control and impacted sites at Lake Way. The biannual monitoring plan shall also include an assessment of any impacts to riparian vegetation from the dewater discharge.*

Focused Vision Consulting (FVC) was commissioned in September 2016 by Blackham to develop a monitoring plan to address requirements of Improvement Program Condition IR2 and assess the ecological impacts associated with dewater discharge to Lake Way (FVC, 2016). The monitoring plan prescribed that the focus of monitoring program would be:

- benthic microalgae (diatoms)
- aquatic invertebrates
- vegetation.

The results and information collected from these studies will be used to support ongoing management strategies and reported to the DER (and potentially other agencies) on an annual basis.

This report presents findings of the baseline monitoring event undertaken at Lake Way in November 2016.

1.2 LOCATION

The Matilda Gold Project is located near Wiluna in Western Australia's north-eastern goldfields, approximately 835 km north-east of Perth (or 1,127 km by road) and 525 km north of Kalgoorlie (**Figure 1**).

Figure 1
Project Location

FOCUSED VISION consulting

1.3 SCOPE OF WORK

The scope of work included:

- preparation of a monitoring program that addresses requirements of Improvement Program Condition IR2 in L5206/1987/10
- undertaking the initial/baseline surveys/studies as outlined in the monitoring plan, including sampling at six sites; three impact and three reference sites (**Figure 2**)
- preparation of a report that summarises the results and includes:
    - background on the project and context/requirement for the monitoring
    - a description of the sites monitored and the methodologies used
    - results of sampling invertebrates, water and sediment
    - results of the vegetation monitoring, including all quadrat data from each transect, species lists and analysis
    - discussion of the significance of the sampling results
    - recommendations for future monitoring events (including comparative analysis).

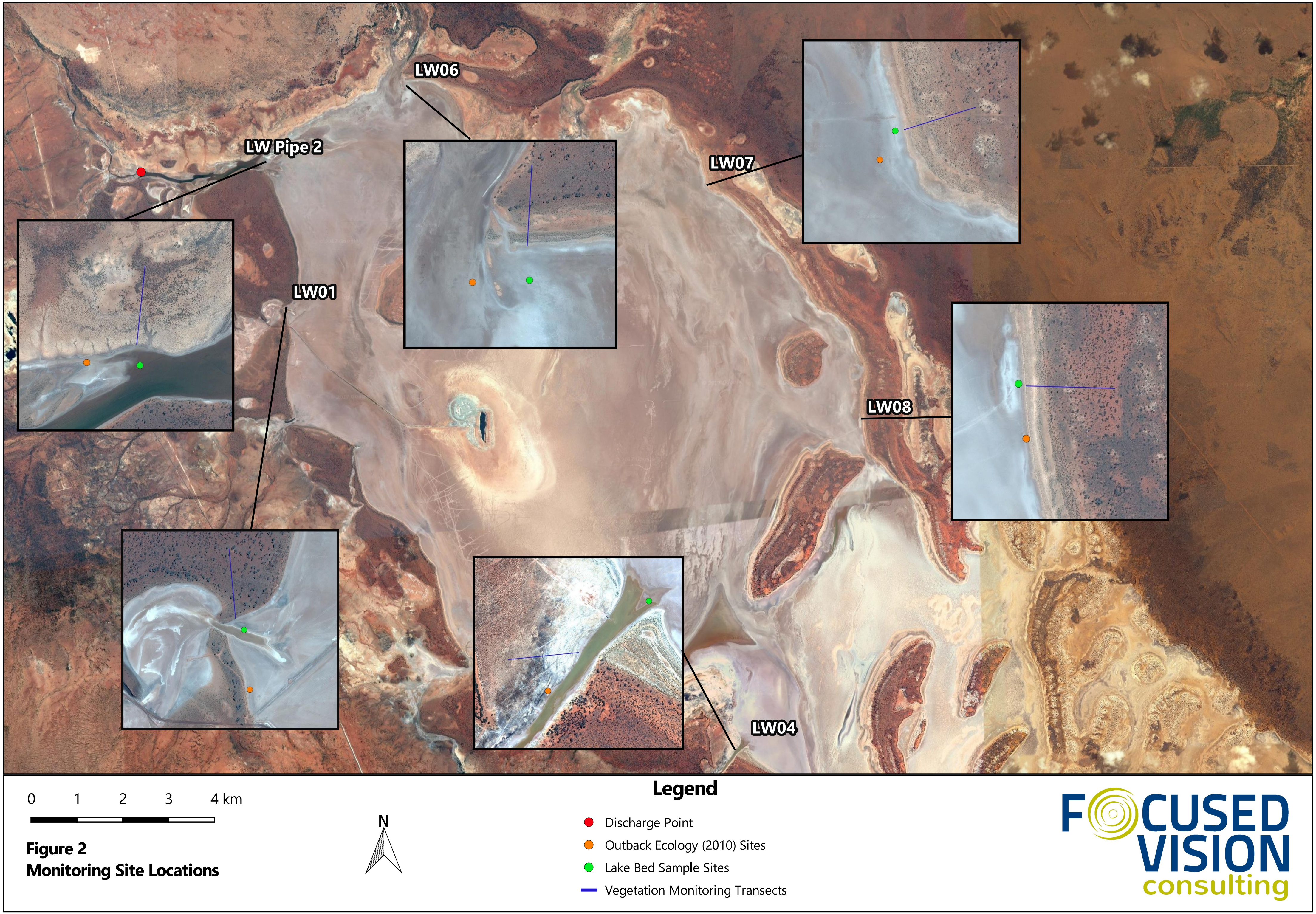


Figure 2
Monitoring Site Locations

2 BACKGROUND

2.1 PREVIOUS ASSESSMENTS

2.1.1 Outback Ecology (2010)

Outback Ecology (2010) completed an ecological assessment of Lake Way in November 2009 for Apex Gold Pty Ltd to determine the impact of dewatering discharge on the ecology of the lake. Surface water quality, sediment quality, diatoms and resting aquatic fauna were examined at eight sites, six of which correspond to the current monitoring program (**Figure 2**).

It was noted by Outback Ecology (2010) that historical data for water and sediment quality are lacking, except at Apex Gold monitoring sites LW-A3 (water quality) and LW-A4 (sediment quality), which are both located within the discharge creekline, approximately 2.5 km west of current monitoring site LW Pipe 2 (**Figure 2**). No environmental or ecological data are available for the period between Outback Ecology (2010) and the current study (2016).

2.1.2 Outback Ecology (2007)

Outback Ecology undertook a baseline flora and vegetation survey over the Toro Energy Ltd (Toro) Lake Way and Centipede project areas in October 2007. The study incorporated 108 quadrats, with 46 located at Centipede and 62 located at the Lake Way project area.

Based on data collected from these quadrats, a total of 22 vegetation associations were described, comprising the following six broad groups:

- playa vegetation
- fringing vegetation
- dune vegetation
- plains vegetation
- calcrete vegetation
- clay-pan vegetation.

At the time of the assessment, no Threatened Ecological Communities (TECs) were known to occur within the areas surveyed, but a total of 17 'at risk' ecosystems were identified to occur within the Murchison 1 Bioregion. One of these, "*Melaleuca* sp. Nov. (*M. xerophila*) Low Closed to Open Forest Strand Community near Wiluna" was identified as occurring within the Centipede and Lake Way project areas. The vegetation was documented to be in mostly very good to excellent condition, with none of the vegetation assessed as being in degraded or completely degraded condition.

Outback Ecology did not report that any flora of conservation significance were recorded during the assessment.

2.1.3 Niche Environmental Services (2011)

Niche Environmental Services (Niche) undertook an assessment of the flora and vegetation Toro Energy Wiluna Uranium Project (Lake Way, Centipede and West Creek borefield) in 2010. Niche recorded the following vegetation zones at Lake Way:

- *Tecticornia* spp. vegetation on the playa
- fringing vegetation between the playa and the dune – Closed Low Forest of *Melaleuca xerophila*
- claypans with halophytic vegetation
- a low dune system of *Eucalyptus eremicola* subsp. *peeneri* and *Acacia ayersiana*
- a calcrete platform – Low Woodland of *Eucalyptus gypsophila*.

Of these recorded vegetation zones, the playa, fringing and claypan vegetation was determined to be groundwater dependent.

At the time of the assessment, no TECs were known to occur at Lake Way, and two vegetation relevant Priority Ecological Communities (PECs) were known; both complexes on banded ironstone formations. Neither are relevant to the immediate vicinity of Lake Way.

Six species of Priority flora were recorded during the survey of Lake Way, Centipede and the West Creek borefield; *Eremophila arachnoides* subsp. *arachnoides* (P3); *Eremophila congesta* (P1); *Stackhousia clementii* (P3); *Tecticornia* sp. Lake Way (P1); *Homalocalyx echinulatus* (P3); and *Mirbelia stipitata* (P3).

2.1.4 APM (2015)

A level 1 biological survey was undertaken across the Matildla Gold project area by Animal Plant Mineral Pty Ltd (APM) in 2015 (APM 2015). APM reported that no unique ecological attributes or attributes of conservation significance were determined to be present in the project area, other than the Priority flora species, *Eremophila congesta* (P1) and *Eremophila pungens* (P4). The PEC Wiluna West vegetation complex was not identified within any of the surveyed areas and the plant communities identified were not found to corresponded to any known listed TECs.

APM reported that considering all aspects of flora, vegetation and fauna, the proposed clearing for the Matilda Gold project is not at variance with any of the ten clearing principles.

2.2 CLIMATE

The Murchison region experiences an arid climate which is characterised by hot and dry summers with temperatures ranging from 5.5 ºC to 38 ºC; and mild winters. Wiluna (013012) is the closest meteorological recording station to the project area with an average annual rainfall of 260.3 mm (BoM 2017)., The area is influenced by the northern cyclonic season (November to April) when most of this rainfall is received (BoM 2017).

2.3 IBRA REGION

There are 89 recognised Interim Biogeographic Regionalisation for Australia (IBRA) regions across Australia that have been defined based on climate, geology, landforms and characteristic vegetation and fauna (DotE, 2017). The project area lies within the Murchison IBRA region and, at a finer scale, within the Eastern Murchison subregion (MUR1), which encompasses the northern parts of the Southern Cross and Eastern Goldfields Terrains of the Yilgarn Craton (Cowan, 2001).

2.4 LANDFORMS, GEOLOGY AND SOILS

The Eastern Murchison is characterised by an internally draining palaeoriver system and associated salt lakes, extensive areas of elevated red desert sandplain with limited dune development, and low hills and mesas interspersed with alluvial and colluvial flats (Cowan 2001; Bastin 2008).

Lake Way is an ephemeral saline playa with an area of approximately 270 km^2 that is a surface expression of the Carey Palaeoriver. The lake becomes fully inundated only after substantial rainfall events, generally every five to 20 years. Drainage occurs in a south-easterly orientation along the Carey Palaeoriver during periods of surface flow. Hydrology is mainly influenced by recharge and flooding following rainfall, regional groundwater flow and high evaporation rates of surface waters (Outback Ecology 2010).

Lake Way has low topographic relief and is underlain by fractured, weathered and saturated Archaean bedrock, in turn covered by widespread alluvium and colluvium. The water table sits less than 1 m below the lake bed and ranges from <3,000 ppm TDS in adjacent tributaries to hypersaline (50,000–200,000 ppm TDS) in the main palaeochannel.

2.5 LAND USE

Over 85 % of the region is pastoral land used for grazing livestock, whilst there are also considerable mining interests in the region, mainly for gold and nickel (Bennelongia 2017).

2.6 AQUATIC INVERTEBRATES

Aquatic invertebrates including insects, crustaceans, annelid worms, nematodes, flatworms and rotifers play important roles in linking nutrient resources from primary production to higher trophic levels (Wallace and Webster 1996) and often reflect site-specific environmental and biological conditions, owing to their largely sedentary habits (Cook 1976). There is a long history of using invertebrate communities as monitoring tools in wetlands (Hellawell 1986) due to the predictable way in which their diversity, composition and even animal size respond to disturbances (Gray 1989; Boyle and Fraleigh 2003). Aquatic invertebrates have been used as indicators of a range of stressors including organic pollution (Rae 1989), heavy metals (Poulton *et al.* 1995) and acidification (Davy-Bowker 2005).

Sampling surface water in ephemeral wetlands is not always practical because of sporadic, unpredictable flow regimes and logistical constraints. This is the case at Lake Way, which is rarely inundated due to low rainfall and high rates of evaporation. However, some aquatic invertebrates survive adverse environmental conditions through various mechanisms of dormancy, reactivating with the onset of favourable conditions, or in response to specific cues (Radzikowski 2013). Hatching trials, in which dry wetland sediments are rehydrated under laboratory conditions to encourage hatching of drought-resistant eggs and spores, provides an alternative method of assessing aquatic invertebrate communities. This allows monitoring to continue during periods when surface waters are absent, although it provides results for only part of the community (some crustacean groups and rotifers, in particular).

Several hatching trials have been undertaken in arid regions of Western Australia to inform environmental approval processes for mining developments or as part of ecological monitoring programs (e.g. Bennelongia 2012; Rodman *et al.* 2016). The success of these trials has varied due to the technical difficulties of simulating complex natural conditions and encouraging the activation and growth of dormant stages in the laboratory (see Cáceres and Schwalbach 2001). *In situ* sampling of aquatic fauna during inundation is usually preferable and is likely to yield a more thorough representation of actual diversity. However, improved techniques have recently led to diverse suites of fauna being recorded in laboratory trials (Rodman *et al.* 2016) that may provide better information about some components of the aquatic community.

2.7 DIATOMS

Diatoms are eukaryotic microalgae of the phylum Bacillariophyta (Sze 1986) that comprise part of benthic microbial communities and often dominate the photosynthetic output of shallow ephemeral wetlands, including saline lakes (Bauld 1981, 1986; Boggs *et al.* 2007). They have siliceous cell walls called frustules that are often spectacularly ornamented and can thicken in adverse conditions, such as the onset of drought, to facilitate periods of prolonged resting (Montresor *et al.* 2013). These resting stages are typified by lack of cell division, concentrated cytoplasm, lowered photosynthetic and respiratory rates, and a high carbon:chlorophyll ratio (Anderson 1975, 1976; Hargreaves and French 1983; Kuwata *et al.* 1993). Resting diatoms are able to 'germinate' and re-establish vegetative growth when favourable conditions resume (Montresor *et al.* 2013).

As primary producers, diatoms serve an important basal role in wetland food webs. Diatom communities have been found to exhibit changes in composition, diversity and biomass in response to shifting water chemistry, temperature, nutrient levels and pollution, amongst a range of other factors, and may react to short-term impacts and sudden environmental changes owing to their rapid life histories. Therefore, they have frequently been used as bio-indicators in monitoring programs (Li *et al.* 2010).

2.8 VEGETATION

The project area is situated within the Austin Botanical District of the Murchison Region which consists predominately of low mulga (*Acacia aneura*) woodlands on plains, often rich in ephemerals, hummock grasslands, saltbush shrublands and *Halosarcia (Tecticornia)* shrublands on calcareous soil and samphire vegetation associated with saline areas such as salt lakes (Cowan 2001; Bastin 2008). Tree steppes of *Eucalyptus* spp. and *Triodia basedowii* occur on sandplains (Beard 1990).

The range of previous flora and vegetation studies conducted at Lake Way (Section 2.1) are consistent in having recorded a range of key vegetation types within and surrounding Lake Way, that all centre on the lake ecosystem and landform, with the following three being specifically relevant to the vegetation aspect of the monitoring program:

- playa vegetation
- fringing vegetation
- dune vegetation.

3 METHODOLOGY

3.1 DESKTOP REVIEW

A review of available relevant information provided by Blackham was undertaken. The information reviewed included the following technical reports:

- Outback Ecology Services (2007) *Lake Way and Centipede Baseline Vegetation and Flora Survey*. Unpublished report prepared for Toro Energy Limited
- Outback Ecology Services (2010) Biological Assessment of Lake Way 2009. Unpublished report prepared for Apex Gold Pty Ltd.
- Niche Environmental Services (2011) *Assessment of the Flora and Vegetation at the Toro Energy Wiluna Uranium Project: Lake Way, Centipede and West Creek borefield.* Unpublished report prepared for Toro Energy Limited
- Animal Plant Mineral (2015) *Level One Biological Survey, Matilda Gold Project, Murchison Western Australia.* Unpublished report prepared for Blackham Limited.

3.2 FIELD ASSESSMENT, ANALYSIS AND REPORTING

The field assessment for all vegetation monitoring was carried out by FVC's Principal Ecologist, Kellie Bauer-Simpson, and the sampling of sediments, aquatic invertebrates and diatoms (benthic microalgae) was carried out by Bennelongia's Senior Biologist, Anton Mittra. All field assessments were carried out between 2-4 November 2016.

The monitoring sites were selected from the Outback Ecology (2010) study, the locations of which are shown in **Figure 2** and listed as follows:

- LW01 (impact site – 229080mE, 7038163mN)
- LW Pipe 2 (impact site – 227811mE, 7041601mN)
- LW06 (impact site – 231496mE, 7043256mN)
- LW04 (reference site – 238642mE, 7028522mN)
- LW07 (reference site – 238095mE, 7041120mN)
- LW08 (reference site – 241619mE, 7035720mN).

Monitoring sites were located as close as possible to the previous Outback Ecology (2010) study sites (listed above), to allow comparisons with historic data using future results. At the relevant locations, lake bed sampling focused on depressions in the lake crust, where results may be optimised; and vegetation transects were aligned in a way that optimised sampling of the representative vegetation units as they transition away from the lake.

Invertebrate hatching trials were carried out by Anton Mittra, with invertebrate identifications carried out by Anton Mittra and Dr Stuart Halse. Diatoms were sorted and identified by Professor Peter Gell (Federation University Australia). Soil samples were analysed at ChemCentre (Bentley, Western Australia). Reporting and mapping for lakebed monitoring were completed by Anton Mittra and Mike Scanlon, respectively, and were reviewed by Dr Stuart Halse.

Flora collections from the vegetation monitoring were identified by FVC's specialist taxonomist, Dr Udani Sirisena, with some specialist samphire identifications completed by Kelly Shepherd (WA Herbarium). Statistical analysis of vegetation data was carried out by Dr Matthew McDonald from Spectrum Ecology and vegetation reporting and mapping was carried out by FVC's Kellie Bauer-Simpson and Will Bauer-Simpson, respectively. The vegetation monitoring aspects of the report were reviewed by Dr Renee Young.

3.2.1 Sediments, Aquatic Invertebrates and Benthic Microalgae

Sediment, aquatic invertebrates and diatoms were monitored at the six sites: three within the potential zone of influence of discharge (impact sites) and three in locations around the lake with similar topography but outside the influence of discharge (reference/control sites). The specific locations of the collection of sediments for analysis and hatching trials is presented in **Table 1** and **Figure 2**.

Table 1: Locations of Lakebed Monitoring Sites

Site Type	Site	Easting (mE)	Northing (mN)	Sample Date	Aquatic Invertebrates	Benthic Microalgae	Soil
Impact	LW01	229054.88	7038421.13	3/11/2016	Rehydration/hatching	✓	✓
	LW Pipe 2	228012.45	7041589.38	3/11/2016	Rehydration/hatching	✓	✓
	LW06	231709.61	7043264.32	4/11/2016	Rehydration/hatching	✓	✓
Reference	LW04	239071.85	7028904.93	3/11/2016	Rehydration/hatching	✓	✓
	LW07	238156.37	7041236.24	2/11/2016	Rehydration/hatching	✓	✓
	LW08	241592.01	7035911.11	2/11/2016	Rehydration/hatching	✓	✓

Samples for sediment metals analysis, diatoms and hatching trials were collected at each of the sites and descriptions of the physical attributes of each site were also compiled.

During the time of the field sampling, 6.4 mm of rain fell at Wiluna, but this did not result in significant pooling of water within Lake Way.

3.2.1.1 Sediment

At each site, approximately 250 g of lake sediment from the top 20 cm was removed with a trowel and stored in zip-lock bags. Salt crust was removed prior to sampling as recommended by the ChemCentre to avoid dominance by Na and Cl in analyses. Analyses for particle size distribution and metal concentrations (As, Cd, Cr, Cu, Pb, Hg, Ni, Zn, Sb, Tl, Mn, and Se) were performed by the ChemCentre.

Metal concentrations were interpreted in the context of Interim Sediment Quality Guidelines (ISQG) (ANZECC/ARMCANZ 2000; encompassing both ISQG-low (trigger value) and ISQG-high) where possible. Mean concentrations of each metal at reference and impact sites were compared with t-tests. Homogeneity of variance was tested with F-tests prior to comparing sample means. Welch t-tests were used where variances significantly differed between groups. Analyses of Pearson's correlation between the distance to each site from the discharge outlet (**Figure 2**) and metal concentrations were performed to investigate spatial trends for each analyte.

Multivariate analyses in PRIMER 6 were used to further explore spatial variation in metal concentrations of sediments:

- Multidimensional scaling (MDS) ordination based on Euclidean distance between sites was used to identify groupings of samples.
- ANOSIM was used to determine whether groupings were statistically significant. ANOSIM (**an**alysis **o**f **sim**ilarity) can be considered an analogue of univariate ANOVA (**an**alysis **o**f **va**riance) and is typically interpreted through *R*-statistic values, where:
    - *R*-statistic >0.75 = groups well separated

    - >0.5 = some overlap but groups clearly separated
    - <0.3 = groups similar.
- Where significant separations were identified, SIMPER was used to calculate the contribution made by each variable to overall variation between groups.

Variables found to be abnormally distributed via draftsman plots were appropriately transformed, and all variables were normalised prior to further analyses. A significance level of α=0.05 was used for all statistical tests. Values below limits of detection were replaced with a value of half the limit.

3.2.1.2 Aquatic Invertebrates

Hatching trials were conducted to assess aquatic invertebrate communities at monitoring sites in the absence of surface water. The top 1–2 cm of sediment, including salt crust and underlying soil, was collected from three 10 cm x 20 cm locations within each site and stored in plastic containers with perforated lids to allow airflow. Samples within each site were predominantly taken from depressions and potential pools to maximise the likelihood of capturing an adequate representation of resting fauna present.

In the laboratory, approximately 25 g of sediment from each sample were placed in aluminium trays and rehydrated with approximately 1 L of deionised water. Trays were kept under an east-facing window (12.75 to 13 hours of light per day) and equipped with air stones for aeration. Electrical conductance (EC) was measured in each container after 24 hours and water added as necessary to formulate an environment of as close as possible to 5 g L^{-1} total dissolved solids (TDS) (approximately 7.8 mS cm^{-1}) to encourage hatching in a range of species. Water was topped up every one to two days to account for evaporation and to maintain constant salinity. Hatching and development of animals was monitored daily by pipetting small volumes of water, as well as any visible animals into petri dishes and examining these under a microscope.

Each trial was monitored for two weeks, after which animals were counted, preserved in ethanol and identified to species-level where possible. Due to the high salinity of the collected sediments, a second hatching trial was undertaken using the same methods, with the quantity of sediment reduced in order to reduce salinity to <3 g L^{-1} TDS (approximately 5 mS cm^{-1}) and further promote hatching. Records of additional taxa from the second trial were added to results of the initial trial.

3.2.1.3 Diatoms

To discern and identify any diatoms present at monitoring locations, approximately one teaspoon of lake sediment was collected via scraping, preserved in ethanol and refrigerated as soon as possible. Salt crust was removed prior to sampling. Samples were sorted and identified by Professor Peter Gell at Federation University, Victoria.

3.2.2 Vegetation

The vegetation monitoring sites were established in locations adjacent to lakebed sampling sites, in proximity to the previous ecological health monitoring sites assessed in 2009 (Outback Ecology 2010), as shown in **Figure 2**. The monitoring sites comprised a series of six transects extending perpendicular from the lake edge, or aligned to progress towards non-riparian vegetation, for 300 m, with quadrats spaced every 20 m along the length of each transect. The six transects installed comprised of three sites within the potential impact zone, and three reference transects.

Occasionally transects passed immediately adjacent to the previous monitoring sites, or were required to be situated a short distance from the location of the previous monitoring sites, in order to commence at the edge of the lake, closely align with the current program lake bed sampling sites, or to best progress from riparian to non-riparian vegetation.

Transects commenced at the edge of the Lake Way playa, where vegetation was first evident, or on the playa if vegetation was present and extended to the fringing non-riparian, dune or upland vegetation, where possible (where this was achievable within 300 m). Two transects, one impact (LW Pipe 2) and one reference (LW04) did not extend into non-riparian vegetation, because in these locations, the upland vegetation commences at a significant distance from the lake edge. Aligning with lake bed monitoring sites was considered to be a more important focus than installing transects where upland vegetation was encountered for all transects.

Transects were pegged with wooden survey pegs, with a marker peg at the start and end of the 300 m long transect, plus every 20 m between, determined by measuring tape. A photograph along the transect was taken from each end and GPS co-ordinates also recorded.

The vegetation types along each transect were mapped based on distance along the transect, by noting dominant flora species in each identified community, as well as the structure (density of each strata) and described to Level III of the National Vegetation Information System (NVIS) methodologies. Vegetation types identified along transects were also matched to vegetation types mapped by Outback Ecology (2007), based on dominant species composition, structure and physical appearance from compared photographs. This produced a 2D linear vegetation map for each transect and has formed a basis to detect change during future monitoring events.

Flora species not certainly identifiable in the field were collected, pressed and dried for later identification by specialist taxonomists.

Quadrats measuring 2 m x 2 m were recorded every 20 m (15 quadrats per transect). The data collected from within each quadrat included:

- flora species present, and for each:
    - number of alive plants rooted within the quadrat
    - number of dead plants rooted within the quadrat
    - percentage foliage cover of alive plants (rooted in the quadrats and from overhang)
    - percentage foliage cover of dead plants (rooted in the quadrats and from overhang)
    - whether plants of each species were fruiting or flowering
    - health/vigour rating:
        - healthy (5)
        - slightly stressed (4)
        - stressed (3)
        - very stressed (2)
        - dead (recently died) (1)
        - dead (apparent historic death) (0)
- percentage cover of litter
- percentage of bare ground
- any other observations.

Collected data was analysed to compare species richness, plant density/foliage cover and plant/vegetation health, between:

- all of the transects
- types of transects; impact vs reference/control
- quadrats based on their positon along the transect (distance from the lake edge).

Vegetation monitoring data was analysed using a one-way ANOVA, which is a statistical procedure for testing the null hypothesis that several samples are taken from populations with the same mean. The samples are assumed to be close to normally distributed and have similar variances. If the sample sizes are equal, as is the case in this study, these two assumptions are not critical. If the assumptions are strongly violated, the non-parametric Kruskal-Wallis test should be used instead. The Kruskal-Wallis test is a non-parametric ANOVA, comparing the medians of several groups.

If the ANOVA shows significant inequality of the means (small p; with a p value less than 0.05 indicating significant difference), this indicates only that there is one or more significant comparisons, but does not indicate which comparisons are significant. Tukey's "post-hoc" pairwise comparisons were used to identify which of the comparisons were significant, if found to be significantly different.

It is anticipated that as future monitoring data is obtained, repeated ANOVA analyses can be performed, which would be similar to the analysis utilised for this baseline study, but with time as an additional factor and data from subsequent monitoring events.

4 RESULTS AND DISCUSSION

4.1 SEDIMENT

4.1.1 Metals

Impact sites mostly recorded higher metal concentrations than reference sites (**Table 2** and **Figure 3**), although no significant differences were detected for any metal except Ni. Significantly higher levels of Ni were recorded at impact sites ($\bar{x}$= 22.33 mg kg^{-1}) than reference sites ($\bar{x}$= 10.33 mg kg^{-1}; t= 3.67, p = 0.04).

Concentrations of arsenic exceeded the relevant ISQG-low trigger value at LW01, and the ISQG-high value at LW02, the closest site to the dewatering discharge outlet. Low to moderate concentrations of arsenic were recorded at all other sites (**Table 2**). Concentrations of chromium exceeded the relevant trigger value at LW01 and LW06, while moderate concentrations of this analyte were recorded at all other sites. Concentrations of mercury exceeded the relevant trigger value at two reference sites (LW04 and LW08) and two impact sites (LW01 and LW06), with remaining sites having low to moderate concentrations of mercury (**Table 2**). All other metals were recorded at concentrations below ISQG trigger values, including levels of cadmium and thallium that were below the respective limits of detection at several locations (predominantly reference sites; **Table 2**).

Table 2: Metal concentrations in sediments

Metal	Limit of Detection	ISQG-Low (Trigger value)	ISQG-High	Reference			Impact		
				LW04	LW07	LW08	LW01	LW02	LW06
As	0.2	20	70	4.1	9	2.3	27	150	11
Cd	0.05	1.5	10	<0.05	<0.05	<0.05	0.09	0.25	<0.05
Cr	0.05	80	370	59	66	46	120	47	140
Cu	0.1	65	270	4.8	16	10	18	12	18
Hg	0.02	0.15	1	3.3	0.09	0.94	0.21	0.09	0.83
Mn	0.2	-	-	39	180	110	140	250	190
Ni	1	-	-	5	16	10	23	26	18
Pb	0.5	50	220	3.2	5.2	3.4	7.5	3.9	9.7
Sb	0.05	2	25	0.35	0.28	0.14	1.8	13	0.89
Se	0.05	-	-	0.57	0.39	0.17	0.35	0.98	0.76
Tl	0.05	-	-	<0.05	0.09	<0.05	0.1	0.17	0.06
Zn	5	200	410	9	27	18	32	27	27

Grey shading and red text denote value/s exceeding low and high ISQG values (ANZECC/ARMCANZ 2000), respectively.
All values are mg kg^{-1}.

Metals and metalloids are commonly bioaccumulative and non-biodegradable, and therefore have the potential to be particularly significant pollutants (Velma et al. 2009). Arsenic is a widespread pollutant in various regions worldwide (Flora *et al.* 2005) and is known to cause increased oxidative stress and altered antioxidant enzyme activity in aquatic fauna (Ventura-Lima *et al.* 2011). Chromium is also recognised as a toxicant to aquatic biota, exerting acute and chronic effects on enzyme function, growth and survival (Velma *et al.* 2009).

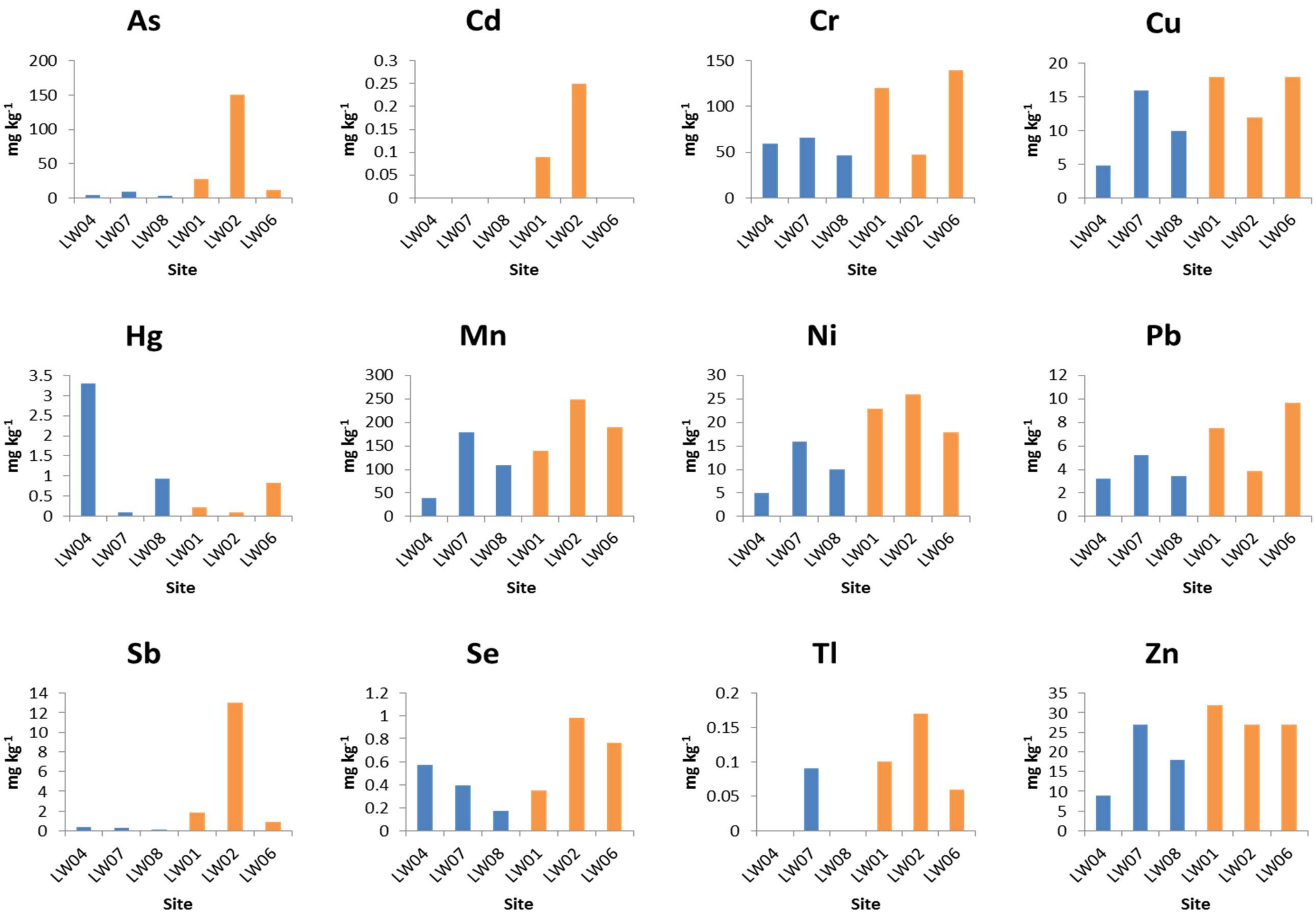


Figure 3 Concentrations of metals in sediments

Blue and orange bars show reference and impact sites, respectively

Significant negative correlations between distance to each site from the discharge point and metal concentration were found for manganese ($r = -0.84$, $df = 4$, $p = 0.04$), nickel ($r = -0.99$, $df = 4$, $p < 0.001$), thallium ($r = -0.86$, $df = 4$, $p = 0.03$) and zinc ($r = -0.88$, $df = 4$, $p = 0.02$) (**Figure 4**). The high respective correlation coefficients for these metals suggests that the historic discharge of mine water is the principal factor causing elevated concentrations of these analytes, although ISQG values for these metals were not exceeded at any site. Concentrations of the remaining metals were not significantly correlated with distance from the discharge.

Based on concentrations of all metals, sites showed no significant separation in MDS ordinated space (**Figure 5**), with LW07 (reference) more similar to LW01 and LW06 (both impact) than to other reference sites. ANOSIM confirmed that there was no significant overall separation of reference and impact sites based on metal concentrations, although the *R*-statistic was reasonably high (*R*-statistic= 0.56, significance of sample statistic = 10 %). Replication of sampling over time (i.e. future monitoring events), including potentially the collection of additional baseline data prior to discharge, would help to elucidate any patterns that do exist among sites using multivariate analysis.

4.1.2 Particle Size Distribution

Sediment particle size composition was not found to differ markedly between reference and impact sites, although some variation between individual sites was apparent (**Figure 6**). Sediment composition at impact site LW01 (**Figure 2**) was dominated by fine particle grades (clay, silt and sand), while those at reference site LW04 (**Figure 2**) were dominated by medium and coarse sand (**Figure 6**). Sediments at other sites were intermediate, comprising mixtures of a range of particle grades (**Figure 6**).

The overall consistency between reference and impact sites provides a good baseline against which to monitor possible post-discharge changes in sediment composition, e.g. deposition and accumulation of fine sediments. Reference sites are spatially isolated from the proposed discharge point and are unlikely to be affected by possible deposition of fine sediments that could be associated with discharge flow.

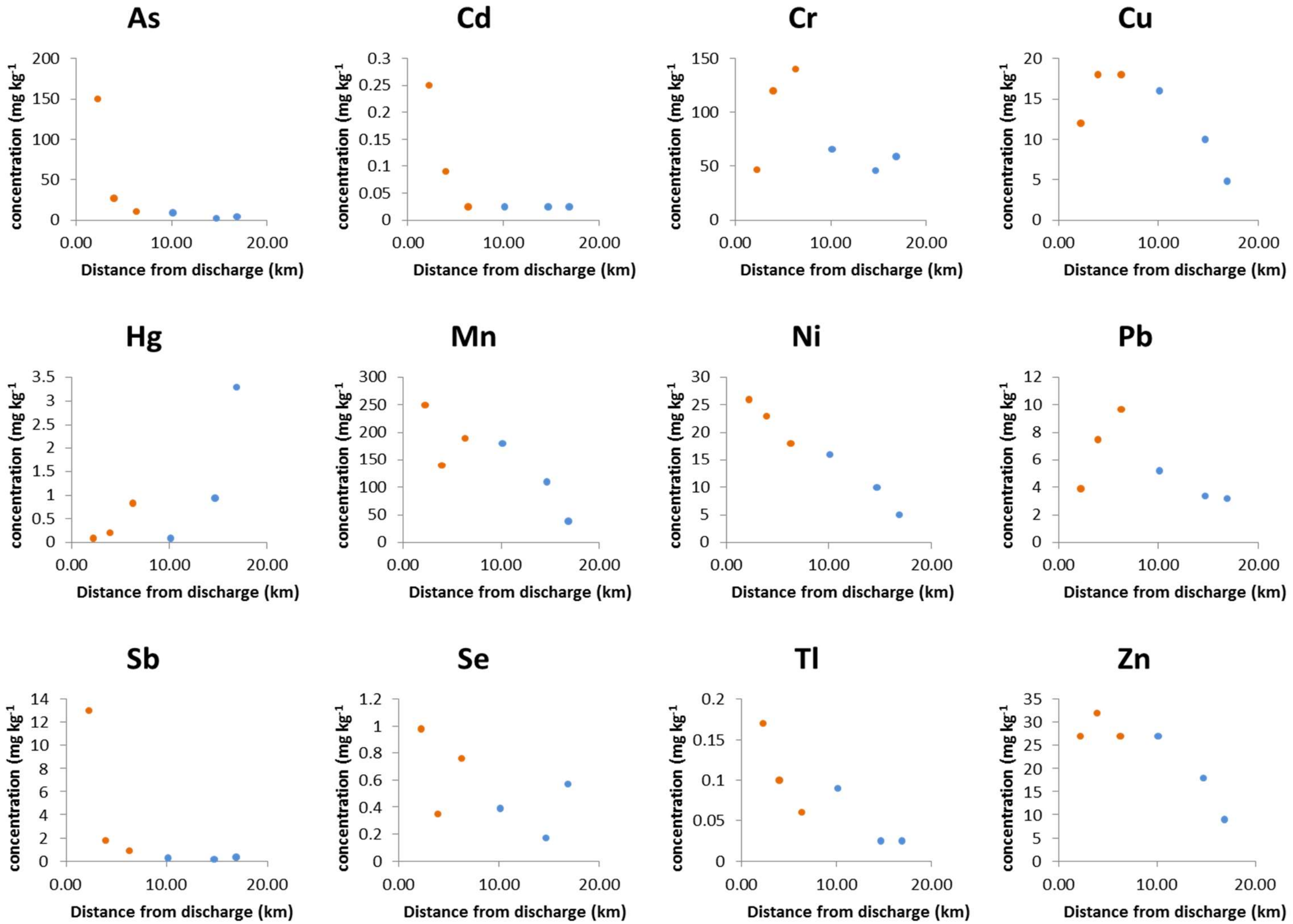


Figure 4 **Concentrations of metals in sediments relative to distance from the discharge point**
Blue and orange points show reference and impact sites, respectively

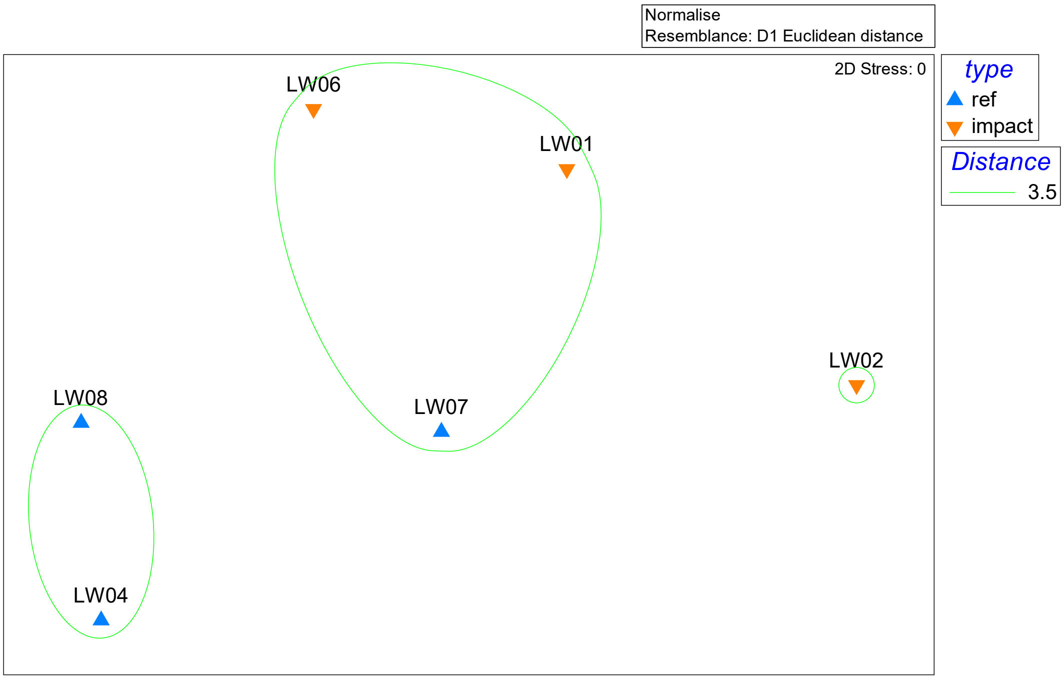


Figure 5 2D MDS plot of monitoring sites based on concentrations of metals

Green lines show Euclidean distance of ≤3.5 based on cluster analysis

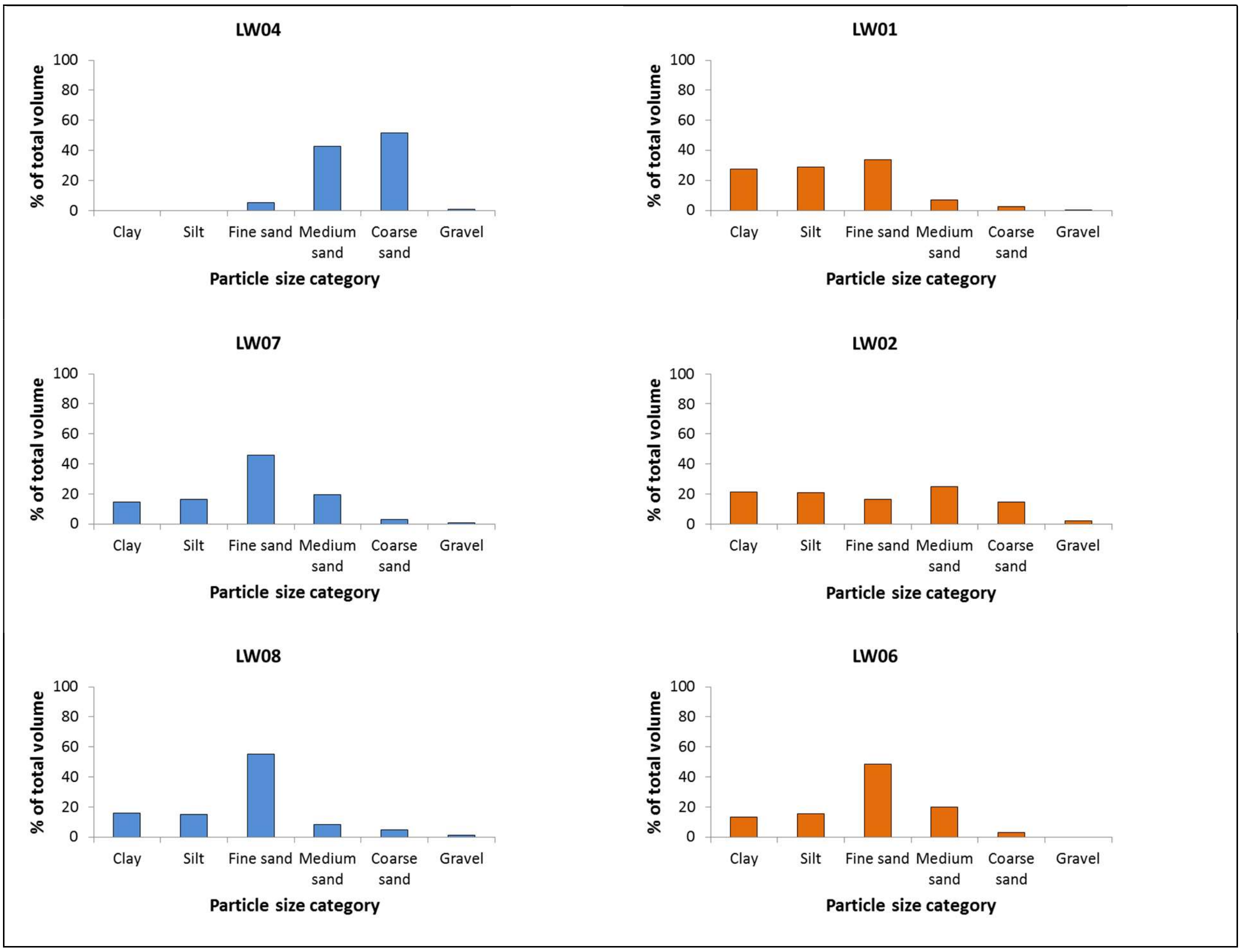


Figure 6 Sediment particle size distribution at reference (left) and impact (right) monitoring sites

Clay <4 µm; silt 4–62 µm; fine sand 62–250 µm; medium sand 250–500 µm; coarse sand 500–2000 µm; gravel >2000 µm

4.2 AQUATIC INVERTEBRATES

4.2.1 Abundance and Diversity

All sites and all but one replicate sample yielded animals from the hatching trials, with approximately 569 animals belonging to three species and three orders recorded (**Table 3**).

Table 3: Invertebrates yielded from hatching trials

Higher Classification	Lowest Identification	Impact			Reference			No. of sites where present
		LW01	LW02	LW06	LW04	LW07	LW08	
ROTIFERA								
Bdelloidea	Bdelloidea sp. 2:2	0	10*	0	0	0	0	1
ARTHROPODA Crustacea Branchiopoda								
Anostraca	Anostraca sp.	1	0	3	1	3	2	5
Paratemiidae	*Paratemia laticaudata*	20	36	0	0	0	0	2
Ostracoda Podocopa								
Cyprididae	Cyprididae gen. nov. sp.	270*	2	0	200*	18	3	5
Total no. of species		**2**	**3**	**1**	**2**	**2**	**2**	
Total abundance		**291***	**48***	**3**	**201***	**21**	**5**	

Values are abundance or estimates of abundance (*). Results combine three replicate samples for each site.

Animals in some samples perished during the trial and failed to reach maturity, but given that trials were monitored daily, it was possible to include these records in final results. Specimens that did not reach maturity could not be identified to species level, but it is considered highly likely that they correspond to recorded species in the same taxonomic unit (e.g. Anostraca sp. is likely to be *Paratemia laticaudata,* which belongs to that order of crustacean).

Recorded species included a brine shrimp (Anostraca), a seed shrimp (Ostracoda) and a bdelloid rotifer (Rotifera: Bdelloidea). Brine shrimps of the genus *Parartemia* and ostracod eggs were previously recorded at Lake Way by Outback Ecology (2010) and it is considered likely that species recorded in both studies correspond. The recorded taxa are typical components of salt lake fauna throughout Western Australia, which tend to be depauperate in comparison with other surface water systems. Consistent with the expected halophilic biology of salt lake taxa, the vast majority of brine shrimp and seed shrimp specimens were hatched during the first hatching trial at EC between approximately 15 mS cm^{-1} and 25 mS cm^{-1}. Contrastingly, all rotifer specimens were recorded in the second trial at an EC value of 2.7 mS cm^{-1}. The biology of each of the recorded taxa are briefly described below, while the compositions of assemblages at each site are provided in **Figure 7**.

4.2.1.1 Anostraca

Fairy shrimp and brine shrimp (Branchiopoda: Sarsostraca: Anostraca) are medium-sized (8–50 mm) crustaceans that typically inhabit fresh to hypersaline ephemeral water bodies in arid and semi-arid landscapes. The distribution of most species is spatially irregular, with many species occurring sporadically over large ranges (Timms 2012) as a result of dispersal by highly mobile predatory vectors such as diving beetles (Beladjal and Mertens 2009) and waterbirds (Green *et al.* 2005). Anostracans survive periods of drought as drought-resistant eggs, with embryos remaining viable in a state of suspended animation for up to decades until inundation. To avoid excessive competition within a population at a given time, only a proportion of eggs hatch during each flooding event. Anostracans are filter feeders, using setose appendages on the thorax to collect algae, protozoans, bacteria and particulate detrital.

A single anostracan species, *Parartemia laticaudata* Timms 2010 (Parartemiidae) was recorded during hatching trials. It reached maturity in three samples across two sites, LW01 and LW Pipe 2, where 36 and 20 specimens were recorded, respectively. A further 10 samples across all six sites yielded immature anostracans most of which perished before the end of hatching trials but were considered likely to be *P. laticaudata*. Other than at LW01 and LW Pipe 2, anostracans were recorded in low numbers (**Table 3**).

P. laticaudata is distinguishable by its unusually wide abdominal segments, especially in males. Although infrequently recorded, the species has a wide distribution across central and north-western Western Australia including Onslow, Shark Bay, Lake Raeside and Lake Disappointment (Timms 2012). Based on levels previously recorded at LW01 and LW Pipe 2 of 104 g L^{-1} and 141 g L^{-1}, respectively (Outback Ecology 2010), the record of *P. laticaudata* at Lake Way falls within the species' known salinity range of 8–141 g L^{-1} (Timms 2012).

4.2.1.2 Cyprididae gen. nov. sp.

Ostracods, including those of the family Cyprididae, are easily identifiable by the hugely enlarged valves of the carapace which engulf the entire body. They are filter feeders, and although they can swim through open water they are typically benthic, inhabiting soft sediments at the bottom of wetlands (Gooderham and Tsyrlin 2002).

The ostracods recorded in the present study are significant as they belong to an undescribed species and genus. It is therefore difficult to determine the distribution of the species; it is currently known only from the present study at Lake Way but may also occurs in other salt lakes of the region. The species was recorded in high numbers (>200 individuals) at both LW01 (impact) and LW04 (reference) and was also present at LW Pipe 2, LW07 and LW08.

4.2.1.3 Bdelloidea sp. 2:2

Bdelloids (Rotifera: Bdelloidea) are microscopic (150–1500 µm), parthenogenic and typically benthic rotifers that scrape or filter feed using two ciliated discs that comprise a rotary structure called the corona. Ciliary beating of the corona also allows animals to swim for short distances, although leech-like crawling is more common and gives the group its name (the Greek *bdella*, meaning 'leech'). A muscular pharynx, or mastax, is present and comprises two articulated trophi that are equipped with a variable number of tooth-like structures, the number of which can help diagnose morphospecies.

A single morphospecies of rotifer, Bdelloidea sp. 2:2, was recorded from 10 or so individuals at a single impact site, LW Pipe 2. The numeric component of the morphospecies code refers to the presence of two teeth on each trophus of the digestive organ. Similar morphospecies have been widely recorded as Bdelloidea sp. 2:2 across Western Australia by Bennelongia and others (Bennelongia, unpublished data). However, the taxonomy of bdelloids is incomplete and further taxonomic work would be required to determine the affinity and distribution of the recorded species.

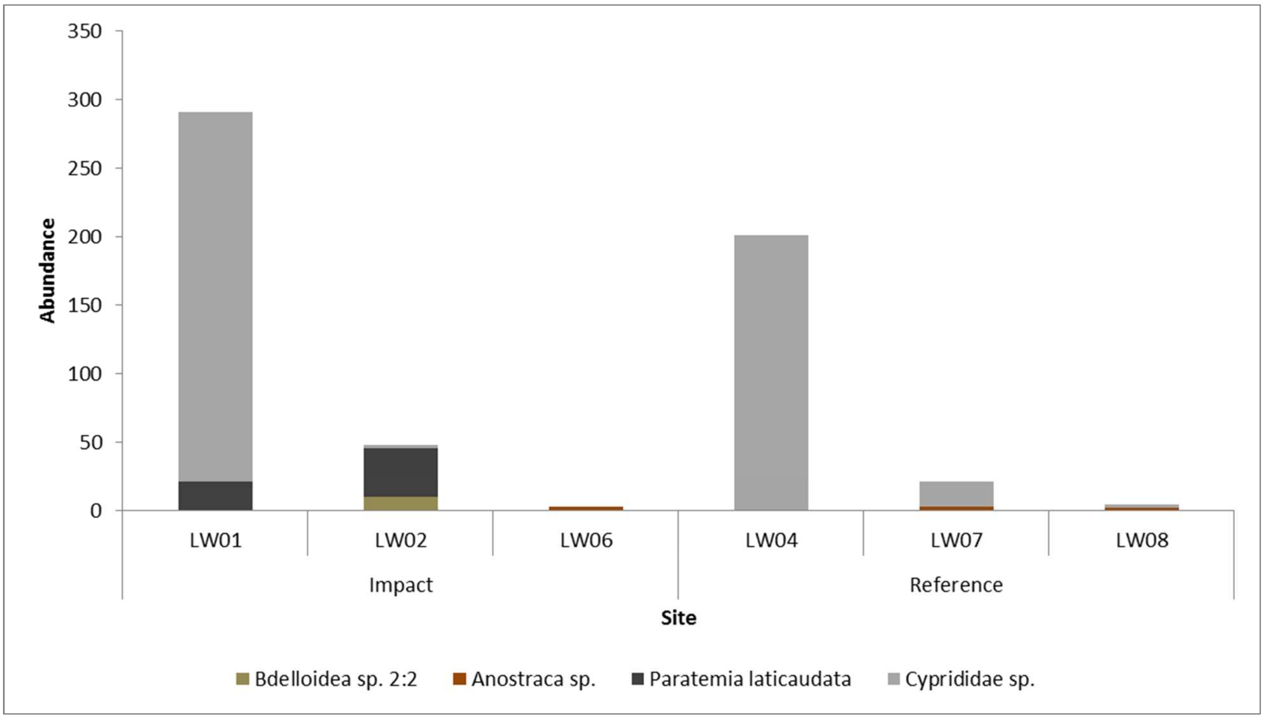


Figure 7 Composition and abundance of resting invertebrate assemblages from hatching trials

4.2.2 Patterns in Invertebrate Assemblages

The lack of clear differences between the assemblages at all reference and all impact sites in ordinated space (**Figure 8**) was supported by ANOSIM (*R*-statistic= 0.04, significance = 40 %). This may partly be the result of yields in hatching trials being higher from sites on the western side of Lake Way, including the impact sites LW01 and LW Pipe 2, and the reference site LW04. This trend was reflected in MDS ordination (**Figure 8**), and although ANOSIM results were not significant (*R*-statistic= 0.46, significance = 10 %), the relatively high *R*-statistic suggests reasonably clear separation. Replicating samples over future monitoring rounds would increase the power of these analyses and may enable detection of significant spatial structuring in community composition.

Sediments from both LW01 and LW04 produced high densities of cypridid ostracods, while those from both LW01 and LW Pipe 2 produced moderately high densities of the brine shrimp *Parartemia laticaudata*. Samples from remaining sites located on the western and northern shores (**Figure 2**) yielded animals, but in reduced densities, with all brine shrimp in these samples failing to reach maturity and ostracods recorded in low to moderate numbers.

The spatial trend towards higher yields from western sites supports the previous suggestion (Outback Ecology 2010) that prevailing winds, drainage and geomorphology favour the deposition of resting stages (i.e. eggs) along the western shoreline. In addition to wind direction, sites with higher yields are located within or near tributaries (LW02 and LW04), or in the case of LW01, near or within a low-lying embayment. These sites would tend to hold water for longer periods than flatter, more exposed sites on the eastern shore (LW07 and LW08), and therefore probably support more abundant invertebrate assemblages during inundation. The reasons for poor yields from LW06, which occurs near a tributary, are unclear. It is possible that sampling points at LW06 simply happened to occur away from areas of pooling and therefore failed to adequately capture resting stages present at the time of sampling.

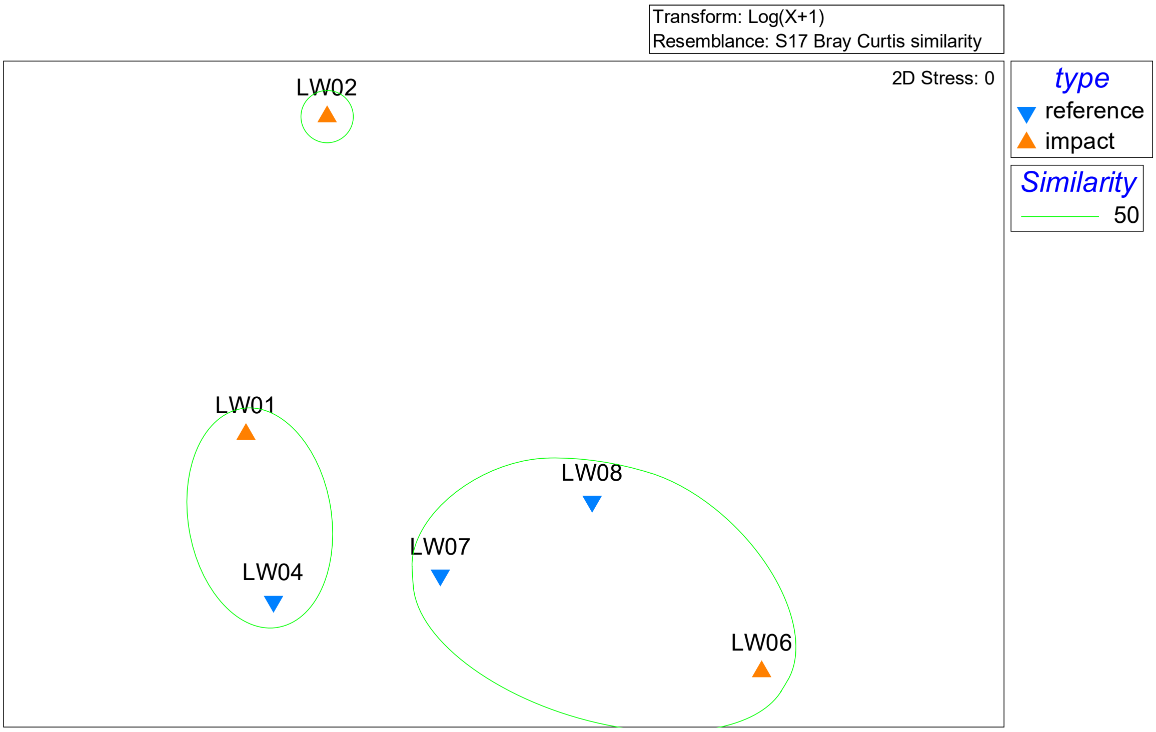


Figure 8 2D MDS plot of monitoring sites based on assemblages of resting stage invertebrates
Green lines show similarity of ≥50 % based on cluster analysis

4.3 DIATOMS

4.3.1 Diversity and Abundance

A total of 274 diatom specimens representing 13 species from five orders and eight genera were recorded from monitoring sites at Lake Way (**Table 4**). The impact site, LW01, hosted the greatest richness, with eight species, followed by impact sites LW06 (five species) and LW Pipe 2 (four species), and reference sites LW07, LW08 (both three species) and LW04 (one species). LW01 also recorded a far higher abundance than other sites (**Table 4**). The composition and abundance of diatom assemblages recorded is represented in **Figure 9**.

Ditom counts were generally low, which is considered normal for saline lakes, where cell dissolution often leads to low cell counts (P. Gell, *pers. comm.*). The average number of species was greater at impact sites (5.67 ± 1.20) than at reference sites (2.33 ± 0.67), and impact sites also held considerably greater abundance, with an average of 85.3 ± 71.3 specimens per site compared with 6.0 ± 2.1 specimens at reference sites. These differences in richness and abundance were largely driven by high yields at the impact site LW01.

Table 4: Abundance of diatom species recorded

Higher Classification	Lowest Identification	Impact			Reference			No. of sites where present
		LW01	LW Pipe 2	LW06	LW04	LW07	LW08	
Bacillariophyceae								
Cymbellales								
Cymbellaceae	*Encyonema* aff. *silesiaca*						2	1
Fragilariales	*Fragilariforma virescens*			6				1
Fragilariaceae	*Hantzschia* aff. *petitiana*	86	3					2
Naviculales	*Luticola mutica*	1						1
Diadesmidaceae	*Navicula* aff. *heimansioides*		1	3		2	3	4
	Navicula incertata	25	8			1		3
	Navicula perminuta	11	2		2		4	4
	Navicula salinicola	28		2		4		3
	Navicula aff. *subtillissima*			2				1
Tabellariales								
Tabellariaceae	*Tabellaria flocculosa*			1				1
Thalassiophysales								
Catenulaceae	*Amphora coffeaeformis*	75						1
	Amphora aff. *montana*	1						1
Stephanodiscaceae	*Cyclotella* aff. *caspia*	1						1
Total abundance		**228**	**14**	**14**	**2**	**7**	**9**	
Total no. of species		**8**	**4**	**5**	**1**	**3**	**3**	

The most abundantly recorded species was *Hantzshcia* aff. *petitiana*, which yielded 86 specimens at LW01 and three specimens at LW Pipe 2 (**Table 4**). This marine species belongs to a genus commonly found in salt lakes (Taukulis and John 2009; Guiry and Guiry 2017) and two congeners have previously been recorded at Lake Way (Outback Ecology 2010). Several other halophilic species typical of salt lakes (Guiry and Guiry 2017; P. Gell, *pers. comm.*), including *Amphora coffeaeformis*, *Navicula salinicola*, *N. incertata* and *N. perminuta*, were also recorded in moderate abundance at LW01. Overall, assemblages at the majority of sites are typical of shallow saline lakes in Western Australia and comprise mainly halophilic species that occur more widely in marine and estuarine settings (Guiry and Guiry 2017; P. Gell, *pers. comm.*)

The assemblage at LW06 is unusual in that, apart from *Navicula salinicola*, four of the five recorded species are typically regarded as freshwater taxa (Guiry and Guiry 2017). LW06 is situated at the mouth of a tributary on the northern edge of Lake Way and species composition suggests a significant freshwater inflow, although electrical conductivity of sediment at this site was previously found to be saline at 21.7 mS cm^{-1}. The freshwater diatoms recorded at this site are likely to be remnants from periods of substantial inundation and surface flow, when EC was probably considerably lower than estimates from lake sediments as a result of freshwater runoff.

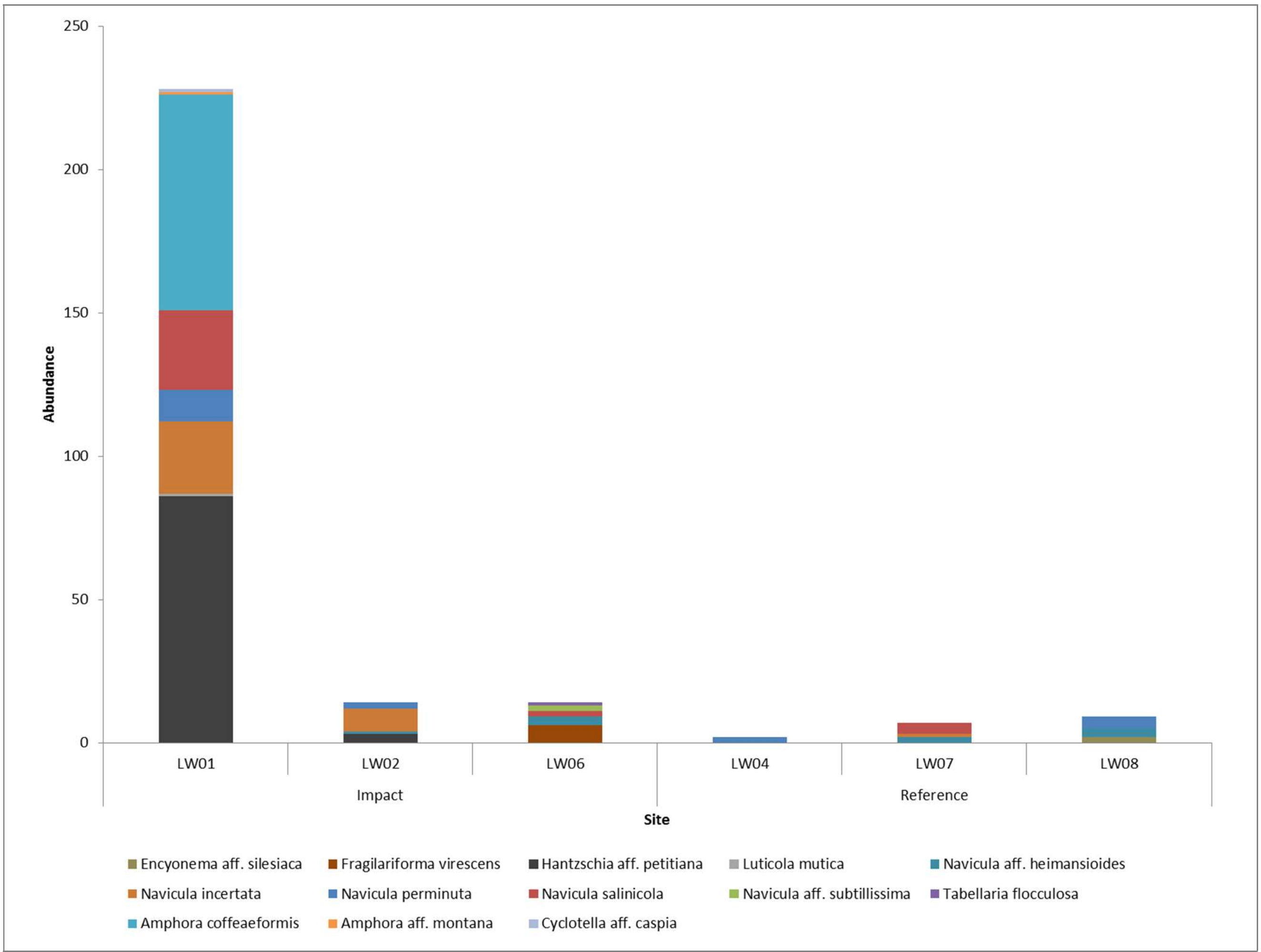


Figure 9 Composition and abundance of diatom assemblages

4.3.2 Patterns in Diatom Assemblages

Based on diatom assemblages, sites were not clearly separated in ordinated space (**Figure 10**). The lack of significant grouping was confirmed by ANOSIM (*R*-statistic= -0.13, significance = 60 %). Rather than reflecting similarity between diatom assemblages across sites, the ordination pattern shows considerable spatial heterogeneity, perhaps because of stochastic collection of species as a result of small sampling effort. As with analyses of patterns in metal concentrations and invertebrates (**Sections 4.1** and **4.2**), analysis of spatial patterns in diatom assemblages will be enhanced by the additional data collected in future rounds of monitoring.

It is currently unclear why such an abundant and diverse assemblage of diatoms was recorded at LW01 compared with other sites, including those associated with low-lying areas or tributaries (i.e. LW Pipe 2, LW06 and LW04). However, unlike any other site, the particle size distribution of sediments at LW01 was skewed towards fine particle grades, and this may influence diatom productivity. Diatom distribution is influenced by grain size and microtopography (Krecja and Lowe 1986), and at least one taxon (*Hantzschia*) recorded in high abundance at LW01 is commonly associated with eroded sediments (John 2000).

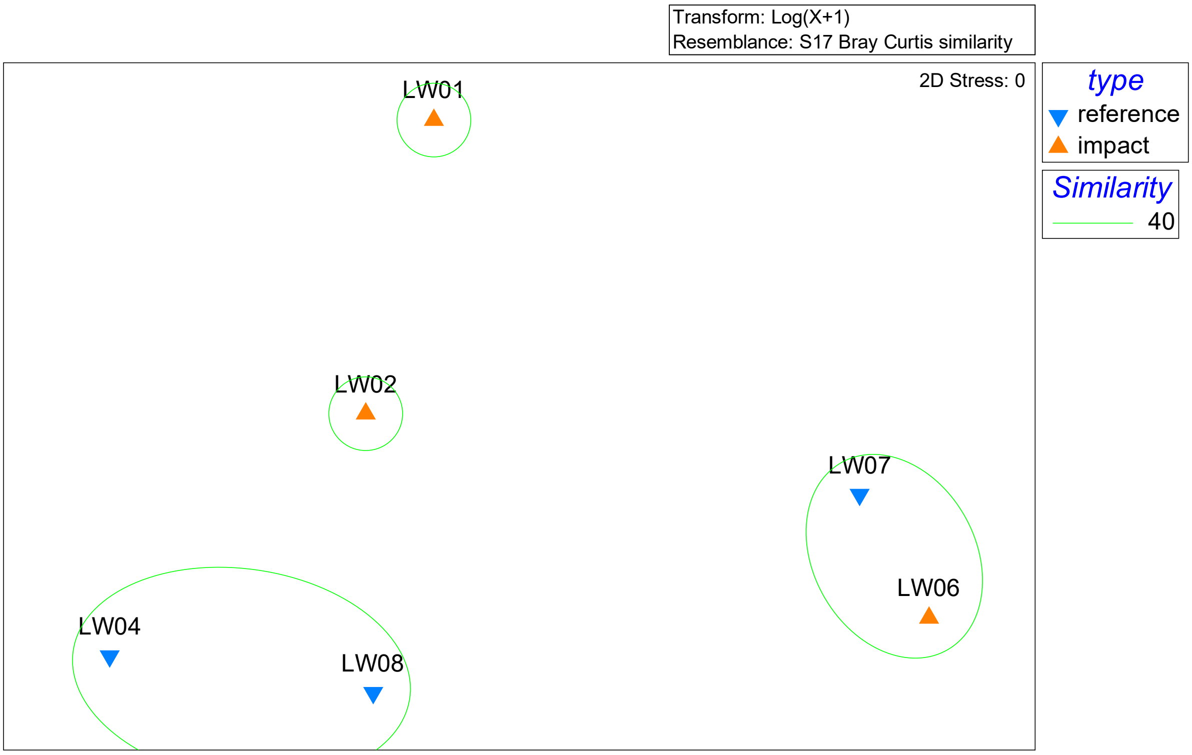


Figure 10 2D MDS ordination of monitoring sites based on diatom assemblages
Green lines show similarity of ≥40 % based on cluster analysis

4.4 VEGETATION

4.4.1 Vegetation Communities

The vegetation communities were mapped along each transect, with the distance along the transect at which communities transition noted. The dominant flora species for each visibly different vegetation type were recorded and communities were aligned with Outback Ecology (2007) and described to NVIS Level III. The results of the vegetation mapping along transects is summarised below in **Table 5** and with the 2-D linear vegetation maps presented in **Figure 11**.

All of the monitoring transects transition from playa/lake edge vegetation types into upland/dune vegetation types, besides one impact (LW Pipe 2) and one reference transect (LW04). It is expected that the quadrats that occur further from the lake edge would be less affected (if at all) by potential negative impacts on lake ecology that could result from discharge. Similarly, samphire (chenopod shrubland) vegetation occurring up to 300 m from the edge of playa vegetation would be expected to be less impacted, if at all. Therefore, based on their length, the vegetation monitoring transects are expected to appropriately detect any changes in vegetation composition and spatial and temporal changes over time. Additionally, the two transects that do not transition into dune vegetation types will be a comparable (additional) subset for statistical analyses following future monitoring events.

Table 5: Vegetation communities along monitoring transects

Transect	Reference/ Impact	Community start (m)	Community end (m)	NVIS Level III Description	Dominant species	Outback Ecology (2007) Community	Some affinity also for Outback Ecology (2007) Community
LW01	Impact	0	8	*Tecticornia* open chenopod shrubland	*Tecticornia laevigata, Tecticornia peltata, Eragrostris dielsii.*	Ac4	
	Impact	8	177	*Acacia* sparse shrubland	*Acacia caesaneura, Ptilotus obovatus, Aristida contorta.*	Ac3	Ac8
	Impact	177	300+	*Acacia* sparse shrubland	Occasional *Acacia caesaneura, Eremophila forrestii, Triodia melvillei, Monachather paradoxus.*	Ac3	Ac5, Ac4
LWPipe2	Impact	0	60	*Tecticornia* open chenopod shrubland	*Tecticornia halocnemoides, Tecticornia disarticulata, Lawrencia helmisii.*	Ha1	
	Impact	60	150	*Tecticornia* chenopod shrubland	*Tecticornia halocnemoides, Tecticornia disarticulata, Sclerolaena fimbriolata, Eragrostis dielsii.*	Ha1	
	Impact	150	300+	*Tecticornia* chenopod shrubland	*Tecticornia disarticulata, Tecticornia laevigata, Tecticornia ?halocnemoides, Frankenia cinerea, Maireana* sp.*, Eragrostic dielsii.*	Ha3	Ha1, Ha2, Te1
LW06	Impact	0	78	*Tecticornia* sparse chenopod shrubland	*Tecticornia halocnemoides, Tecticornia* sp. Dennys Crossing, *Zygophyllum compressum* Poaceae sp.	Ha1	
	Impact	78	159	*Tecticornia* sparse chenopod shrubland	*Tecticornia* sp. Dennys Crossing, *Zygophyllum aurantiacum* subsp. *aurantiacum, Zygophyllum compressum, Eragrostis dielsii.*	Ha1	
	Impact	159	300+	*Acacia* sparse shrubland	Occasional *Acacia caesaneura, Alyogyne pinoniana, Ptilotus obovatus.*	Ac4	Ac8
LW04	Reference	0	120	*Tecticornia* open chenopod shrubland	*Tecticornia s*p. Dennys Crossing, *Tecticornia laevigata, Tecticornia halocnemoides.*	Ha1	Ha3
	Reference	120	300+	*Tecticornia* open chenopod shrubland	*Tecticornia* sp., *Tecticornia laevigata*	Ha1	Ha3
LW07	Reference	0	28	*Tecticornia* sparse chenopod shrubland	*Tecticornia halocnemoides*	Ha1	
	Reference	28	240	*Tecticornia* open chenopod shrubland	*Tecticornia halocnemoides, Tecticornia s*p. Dennys Crossing, *Zygophyllum aurantiacum* subsp. *aurantiacum, Sclerolaena fimbriolata, Maireana pyramidata, Eragrostis dielsii.*	Ac8	
	Reference	240	300+	*Scleroleana* open chenopod shrubland	*Scleroleana bicornis, Enneapogon caerulescens, Eragroistis dielsii.*	Ac8	Ly1, Ac3
LW08	Reference	0	83	*Tecticornia* sparse chenopod shrubland	*Tecticornia* sp. Dennys Crossing, *Scaevola collaris, Tecticornia indica, Lawrencia helmsii, Eragrostis falcata.*	Ha1	La1
	Reference	83	170	*Acacia* sparse shrubland	*Acacia caesaneura, Scaevola spinescens, Ptilotus obovatus, Eragrostis eriopoda.*	Ac3	Ac7, Te2
	Reference	170	300+	*Acacia* sparse shrubland	*Acacia caesaneura, Ptilotus obovatus, Triodia melvillei.*	Ac3	Ac7, Ac4, Ac6

Figure 11 2D Linear Vegetation Map of Monitoring Transects

LW01-impact		
metres along transect	0 8	300
OE (2007) community	Ac4	Ac3 Ac3
NVIS III description	Tecticornia open chenopod shrubland	Acacia sparse shrubland

LWPipe2-impact		
metres along transect	0 150	300
OE (2007) community	Ha1 Ha1	Ha3 Ha3
NVIS III description	Tecticornia open chenopod shrubland	Tecticornia chenopod shrubland

LW06-impact		
metres along transect	0 159	300
OE (2007) community	Ha1 Ha1	Ac4 Ac4
NVIS III description	Tecticornia open chenopod shrubland	Acacia sparse shrubland

LW04-reference		
metres along transect	0	300
OE (2007) community	Ha1	Ha1
NVIS III description	Tecticornia open chenopod shrubland	Tecticornia open chenopod shrubland

LW07-reference		
metres along transect	0 28	300
OE (2007) community	Ha1 Ha1	Ac8 Ac8
NVIS III description	Tecticornia sparse chenopod shrubland	Tecticornia/Scleroleana open chenopod shrubland

LW08-reference		
metres along transect	0 83	300
OE (2007) community	Ha1 Ha1	Ac3 Ac3
NVIS III description	Tecticornia sparse chenopod shrubland	Acacia sparse shrubland

Future monitoring will also document or verify the change in vegetation types with a focus on dominant species, to detect any shift in boundaries that may result from impacts resulting from discharge. A focus on dominant species, as recorded during the baseline field assessment is recommended, as this methodology was found to detect more subtle changes in vegetation communities than the broader scale mapping of previous assessments (including Outback Ecology 2007) and mapping to NVIS Level III (**Table 5**).

As well as the impact and reference transect sets being represented by one transect each that encompasses only samphire vegetation (LW Pipe 2 (impact) and LW04 (reference)), each set is also represented by one transect each that traverses a short distance of samphire, followed by Acacia dunes (LW01 (impact) and LW07 (reference)) and one transect each that traverses approximately a third to half of the transect within samphire then Acacia dunes (LW08 (reference) and LW06 (impact), respectively). Therefore, these transects that correspond in pairs with regards to their spatial community composition will be able to be analysed in comparison to each other once consecutive years of monitoring data has been collected.

It is also recommended that during subsequent monitoring events, vegetation condition be mapped along the transects so that the overall condition of the vegetation (rather than only individual species) is recorded, and transition zones from one condition to the next are detectable at a finer scale than 20 m intervals.

4.4.2 Vegetation Monitoring Quadrats

The full set of data collected from quadrats along each transect is presented in **Appendix A,** photographic records of the start and end of each transect are presented in **Appendix B** and the list of vascular flora species recorded from each transect is presented in **Appendix C**.

4.4.2.1 Species Richness

The total number of species (species richness) recorded within quadrats along each transect is summarised in **Table 6**. Overall, the reference transects recorded a greater total species richness than the impact transects, with only one transect (LW07) recording fewer species than one of the impact transects. The mean total species richness across entire transects was recorded to be 56.9% greater for reference sites than at impact sites.

Table 6: Species richness for entire transects

Total Number of Species from Quadrats	Impact			Reference		
	LW01	LW Pipe 2	LW06	LW04	LW07	LW08
	18	16	12	30	17	25
Mean	15.3			24.0		

The results of the ANOVA, which compared individual quadrats between the transects, by testing for equal means, determined no significant differences among transects for species richness (p=0.08008), as shown below.

Test for equal means					
	Sum of sqrs	df	Mean square	F	p (same)
Between groups:	32.8889	5	6.57778	2.048	0.08008
Within groups:	269.733	84	3.21111		
Total:	302.622	89			

No significant differences were determined based on quadrat position (distance along the transect) for species richness (p=0.2585).

Test for equal means					
	Sum of sqrs	df	Mean square	F	p (same)
Between groups:	57.2889	14	4.09206	1.251	0.2585
Within groups:	245.333	75	3.27111		
Total:	302.622	89			

No significant differences were determined based on transect type (impact vs reference) for species richness (p=0.3633).

Test for equal means					
	Sum of sqrs	df	Mean square	F	p (same)
Between groups:	2.84444	1	2.84444	0.835	0.3633
Within groups:	299.778	88	3.40657		
Total:	302.622	89			

4.4.2.2 Plant Density

Plant density analyses were based on number of alive plants (stems). Number of dead stems can be comparatively analysed in future monitoring, allowing any observed increase in dead stem numbers to be correlated with alive stem numbers. This will subsequently inform conclusions about any decline in vegetation, allowing action to be taken.

Overall, a significant difference was identified for plant density (the number of alive stems/plants), between the transects (p=0.006767) with reference sites having a higher density than impact sites.

Test for equal means					
	Sum of sqrs	df	Mean square	F	p (same)
Between groups:	4057.2	5	811.44	3.465	0.006767
Within groups:	19670.4	84	234.171		
Total:	23727.6	89			

However, further analysis using (Tukey's) pairwise comparisons, demonstrates that transect LW07 (reference) is the only significantly different transect, found to record a significantly higher plant density than LW01 (impact), with p=0.005752, LW04 (reference) (p=0.04208) and LW6 (impact) (p=0.03947). Transect LW7 recorded some particularly high stem counts in the upper section (quadrats at 220 m to

280 m), whereas transects LW01, LW04 and LW06 recorded lower stem counts throughout the transect length.

Tukey's Q below the diagonal, p (same) above the diagonal.

	LW Pipe 2	LW1	LW4	LW6	LW7	LW8
LW Pipe 2		0.8556	0.9969	0.9961	0.1343	0.9407
LW1	1.637		0.9838	0.9862	0.005752	0.3099
LW4	0.6749	0.9618		1	0.04208	0.7294
LW6	0.7087	0.928	0.03375		0.03947	0.7151
LW7	3.543	5.18	4.218	4.252		0.6095
LW8	1.299	2.936	1.974	2.008	2.244	

This skewed result for plant density on transect LW07 was due to the dense area of *Sclerolaena bicornis* growing at the end of transect LW07 (**Plate 1**), in comparison to relatively open areas of dune sands or lake edge crust elsewhere along other transects, as is typical for the area.

Plate 1 Dense growth of *Scleroleana bicornis* at the end of transect LW07

There were no significant differences amongst quadrat position (distance along the transect, for plant density (number of alive stems (p=0.4737).

Test for equal means

	Sum of sqrs	df	Mean square	*F*	*p* (same)
Between groups:	3695.27	14	263.948	0.9882	0.4737
Within groups:	20032.3	75	267.098		
Total:	23727.6	89			

No significant distance was determined between different transect types (impact vs reference) for plant density (number of alive stems) (p=0.2209). The Kruskall-Wallis analysis was used instead of ANOVA for this dataset, as the Levene's test showed a significant difference, as shown below.

Levene´s test for homogeneity of variance, from means	***p* (same):**	1.681E-05
Levene´s test, from medians	***p* (same):**	0.002617

Kruskal-Wallis test for equal medians

***H* (*chi*^{2}):**	1.495
***H$_c$* (tie corrected):**	1.498
***p* (same):**	0.2209

There is no significant difference between sample medians

4.4.2.3 Foliage Cover

Foliage cover analyses were based on percentage alive foliage cover. Dead foliage can be comparatively analysed in future monitoring, to determine if any increase in dead cover is accompanied by a decrease in alive foliage cover, allowing subsequent conclusions to be made about any observed declining vegetation condition, allowing action to be taken.

There were no significant differences determined amongst transects for alive foliage cover (p=0.238).

Test for equal means

	Sum of sqrs	df	Mean square	*F*	*p* (same)
Between groups:	2027.97	5	405.595	1.386	0.238
Within groups:	24589.9	84	292.737		
Total:	26617.9	89			

No significant differences were determined amongst varying quadrat positions (distance along transect) for alive foliage cover (p=0.7539).

Test for equal means

	Sum of sqrs	df	Mean square	*F*	*p* (same)
Between groups:	3130.1	14	223.578	0.7139	0.7539
Within groups:	23487.8	75	313.17		
Total:	26617.9	89			

There were no significant differences determined between transect types (impact vs control) for alive foliage cover (p=0.08772).

Test for equal means

	Sum of sqrs	df	Mean square	*F*	*p* (same)
Between groups:	872.356	1	872.356	2.982	0.08772
Within groups:	25745.5	88	292.563		
Total:	26617.9	89			

4.4.2.4 Plant Health

Vegetation health can be observed, documented and compared in subsequent monitoring via vegetation condition "mapping" (scoring) along transects, alongside the 2D linear vegetation community mapping, as previously discussed. Overall vegetation health is also able to be monitored and analysed via scoring the health of individual species within each quadrat (average health across all plants present).

Results of mean plant health scores determined an overall significant difference between transects (p=0.0002681).

Test for equal means

	Sum of sqrs	df	Mean square	*F*	*p* (same)
Between groups:	14.175	5	2.83499	5.324	0.0002681
Within groups:	44.7327	84	0.532532		
Total:	58.9076	89			

Upon further investigation, Tukey's pairwise comparisons identified that LW08 (reference) is the only significantly different transect in terms of mean plant health scores, in comparison to LW Pipe 2 (impact) (p=0.0009029) and LW04 (reference) (p=0.002273). LW08 recorded consistently higher mean plant health scores than LW Pipe 2 and LW04, more-or-less along the entire transect length.

Tukey's Q below the diagonal, p (same) above the diagonal.

	LW Pipe 2	LW1	LW4	LW6	LW7	LW8
LW Pipe 2		0.1095	0.9998	0.7396	0.06151	0.0009029
LW1	3.672		0.2017	0.827	0.9999	0.5745
LW4	0.4052	3.267		0.8833	0.1217	0.002273
LW6	1.95	1.722	1.545		0.6917	0.05817
LW7	4.011	0.3392	3.606	2.062		0.7265
LW8	5.992	2.32	5.587	4.043	1.981	

There were no significant differences in mean plant health scores based on quadrat position (distance along transect) (p=0.482).

Test for equal means

	Sum of sqrs	df	Mean square	*F*	*p* (same)
Between groups:	9.10717	14	0.650512	0.9797	0.482
Within groups:	49.8005	75	0.664006		
Total:	58.9076	89			

A significant difference in mean plant health scores was determined between quadrats of differing transect type (impact vs control) (p=0.003387). The control transects were found to record a generally higher mean health score (3.077) than the impact transects (2.58), presumably largely due to the higher health scores at LW08, as discussed above.

Test for equal means

	Sum of sqrs	df	Mean square	*F*	*p* (same)
Between groups:	5.50565	1	5.50565	9.073	0.003387
Within groups:	53.402	88	0.606841		
Total:	58.9076	89			

During the field assessment conducted on 2-4 November, it was observed that many plants of a number of species and genera were in poor health, probably due to seasonal conditions. This resulted in difficulties in the accurate identification of some species.

It is recommended that subsequent monitoring events consider field assessment during the main flowering period for the region (typically optimal in March), following the majority of annual rainfall (from cyclonic activity in January and February), in order to record grasses and other annual or ephemeral species in better health and in more identifiable states.

5 CONCLUSIONS

5.1 SEDIMENTS

Concentrations of nickel in sediments at impact sites were found to be significantly higher than at reference sites, and although concentrations of other metals did not significantly differ, impact sites tended to have higher metal concentrations of most metal analytes. Arsenic concentrations exceeded the relevant ISQG-low trigger value at LW01, and the ISQG-high value at LW Pipe 2, the closest site to the historic dewatering discharge outlet. In accordance with contaminated site management principles, these exceedances may warrant further investigation (DEC 2010). Low to moderate concentrations of arsenic were recorded at all other sites (**Table 2**).

Concentrations of chromium exceeded the relevant trigger value at LW01 and LW06, while moderate concentrations of this analyte were recorded at all other sites. Concentrations of mercury exceeded the relevant trigger value at two reference sites (LW04 and LW08) and two impact sites (LW01 and LW06), with remaining sites having low to moderate concentrations of mercury (**Table 2**). All other metals were recorded at concentrations below ISQG trigger values, including levels of cadmium and thallium that were found to be below the respective limits of detection at several locations, predominantly reference sites.

Significant negative correlations between concentrations in sediments and distance from the discharge point were found for manganese, nickel, thallium and zinc, with high correlation coefficients pointing towards historic mine water discharge as the key contributing factor, although trigger values for these analytes were not exceeded.

Based on metal concentrations, monitoring sites were not separated in ordinated space and thus provide a useful baseline against which to monitor possible changes during and after future discharge. Metal and metalloid toxicants are known to be harmful to aquatic biota and concentrations in lake sediments of these pollutants, particularly arsenic, manganese, nickel, thallium and zinc, which were either in breach of trigger values or were significantly negatively correlated with distance from the historic discharge point, should continue to be monitored during future discharge activities.

Sediment particle size distribution did not markedly differ between reference and impact sites, although some variation between individual sites was apparent. Particle size distributions were skewed towards finer and coarser sediment grades at LW01 and LW04, respectively, and were relatively evenly distributed at other sites.

5.2 AQUATIC INVERTEBRATES

Hatching trials, used to assess assemblages of resting-stage aquatic invertebrates in the absence of surface water, yielded approximately 569 animals belonging to three species form three orders of typical salt-lake fauna.

A new species of seed shrimp belonging to an undescribed genus of Cyprididae was the most abundant recorded taxon (>500 individuals recorded across five sites; all excluding LW06) and was recorded at salinities approaching 30 mS cm^{-1}. This ostracod species is currently only known from Lake Way. A total of 56 specimens of the brine shrimp *Parartemia laticaudata* were recorded across three sites (LW01, LW Pipe 2 and LW04), but was probably present in low numbers at all sites as indeterminate specimens (Anostraca sp.) that failed to reach maturity. Samples in which brine shrimp matured had conductivities of 14–17 mS cm^{-1}. The rotifer Bdelloidea sp. 2:2 was only recorded in low-moderate abundance at a single site (LW Pipe 2) during low salinity trials (<3 mS cm^{-1}). Hatching trial results are considered likely to underestimate the complete Lake Way aquatic invertebrate fauna assemblage.

Based on assemblages recorded in hatching trials, there was no separation of reference and impact sites in ordinated space, however yields were dominated by sites on the western shoreline. This was partially reflected in MDS ordination, as well as by a reasonably high *R*-statistic following ANOSIM analysis, although the overall test result was insignificant. The spatial trend towards higher yields from western sites is probably driven by a combination of prevailing winds and drainage patterns, with western sites associated with tributary channels and/or embayments that probably hold water for longer periods following flooding than do flatter, more exposed sites elsewhere. Factors that explain poor yields at LW06, which is situated near a tributary, are unclear.

5.3 DIATOMS

A total of 274 diatom specimens representing 13 species from five orders and eight genera were recorded from monitoring sites at Lake Way. The impact site LW01 hosted the greatest abundance and richness, with 228 specimens from eight species recorded. Other sites where far less productive, with yields of two to14 specimens from one to five species. Low counts of diatoms are considered normal for inland saline lakes, where low productivity and cell dissolution often lead to low cell counts.

Assemblages of diatoms were found to be mostly typical of shallow salt lake flora, with the majority of specimens belonging to widespread halophilic, marine and estuarine taxa. However, a curious assemblage was present at LW06; four of the five species recorded at this site are typically considered to be freshwater species. Although previous estimates of salinity at LW06 from lake sediments have exceeded 20 mS cm^{-1}(Outback Ecology 2010), the site is situated near the mouth of a tributary on the northern shoreline and probably receives substantial freshwater inflow during flooding. This may lead to relatively low salinities, facilitating an anomalous assemblage of freshwater taxa.

Sites did not exhibit clear separation based on diatom assemblages, which may reflect either a high degree of spatial heterogeneity, a magnification of stochastic differences due to the small sample size, or a combination of both. Factors driving the highly productive assemblage of diatoms at LW01 are unclear but may include sediment properties, which are known to affect diatom distribution LW01 was dominated by fine particle grades). As with sediments and invertebrate assemblages, the power to analyse spatial and temporal change in diatom assemblages will increase with further sampling.

5.4 VEGETATION

5.4.1 Vegetation Communities

All of the transects encompass Chenopod shrublands at the lake edge, with two impact and two reference transects transitioning to Acacia dune vegetation along their length, but with one impact and one reference transect represented by samphire for their entire 300 m length. Future comparative analysis will benefit from the fact that the transects include comparable pairs of impact and reference transects comprising:

- all samphire vegetation
- very short sections of samphire (8-28 m) with mostly Acacia dunes
- approximately one third to half samphire and the remainder Acacia dunes.

5.4.2 Vegetation Monitoring Quadrats

The outcomes of the analysis of vegetation monitoring data, in which significant differences in mean values was investigated, are summarised in **Table 7**.

Table 7: Results of ANOVA, Testing for Significant Differences

Parameter Analysed	Between All Transects	Based on Quadrat Position (Distance Along the Transect)	Based on Transect Type (Impact vs Reference)
Species Richness	No significant difference (p=0.08008)	No significant difference (p=0.2585)	No significant difference (p=0.3633)
Alive Plant Density (no. stems)	Significant difference (p=0.006767)	No significant difference (p=0.4737)	No significant difference (p=0.2209)
Alive Foliage Cover (%)	No significant difference (p=0.238)	No significant difference (p=0.7539)	No significant difference (p=0.08772)
Plant Health Scores	Significant difference (p=0.0002681)	No significant difference (p=0.482)	Significant difference (p=0.003387)

The only parameters for which any significant differences in collected data were determined to exist were for:

- alive plant density, between all of the transects
- plant health, between all of the transects
- plant health, between impact and control transects.

Upon further interrogation of alive plant density, transect LW07 (reference) is the only transect, found to be significantly different to the impact transects LW01 and LW06 and the reference transect LW04. The significant difference is due to the high density of *Sclerolaena bicornis* growing at the end of the transect, which is not typical for most of the local vegetation, which tends to support larger plants in less dense numbers, surrounded by open areas of sand or lake edge crust.

Plant health between individual transects and between transect type (impact vs reference) were determined to be significantly different. Differences between transect types reveal greater plant health scores in reference transect LW08, which is the farthest from the historic discharge (approximately 15 km) and reference site LW04, which is approximately 17 km from the historic discharge location. Site LW04 is likely to have been adversely affected by exploration and related activity in the immediate vicinity which was apparent on site during the baseline field assessment in November 2016. Despite these potential impacts, LW04 is considered a suitable comparison site for impact site LW Pipe 2, as they both traverse only Chenopod (samphire) shrubland for the entire transect length, rather than encompassing Acacia shrublands in dunes as do all remaining impact and reference transects.

Overall, impact and reference transects were also found to be significantly different in terms of plant health scores, with vegetation of reference sites recording higher mean health than impact sites. This recorded difference is potentially due to residual and legacy impacts from historic discharge and is supported by the higher levels of metals recorded in the sediments during the current assessment in the north-eastern sections of Lake Way. Even low concentration of heavy metals may inhibit the physiological metabolism of health of plants. However, one reference site, LW08 recorded consistently higher mean plant health scores which were found to significantly different to two other transects; one impact (LW Pipe 2) and one reference (LW04). This significantly better health score has elevated the overall mean health of the reference transects across the study.

Subsequent monitoring data will provide further analysis opportunities where comparative analysis of the same results over time will become possible.

6 RECOMMENDATIONS

Following the baseline monitoring of sediment, aquatic invertebrates, diatoms and riparian vegetation, at Lake Way in 2016, the following recommendations are suggested:

- Monitoring of metal concentrations in lake sediments and/or surface water, especially those analytes that either exceed ISQG triggers or are negatively correlated with distance from the discharge point, should continue during and after dewatering discharge.
- An increase in the spatial intensity of monitoring should be considered, should metal concentrations breach guideline values.
- A separate study be considered that investigates the current concentrations of metals within and within close proximity of the historic discharge drain, and the degree to which existing build-up may drain into Lake Way following rainfall and flooding, to ascertain any existing or ongoing impacts from historic activities that would not be attributable to proposed new discharging of pit dewater.
- Surface water monitoring after the lake receives significant inflow, including comprehensive assessments of water quality, aquatic fauna and flora, should be implemented as a priority, ideally prior to dewatering discharge. This will allow a greater understanding of the Lake Way ecosystem and will provide more comprehensive baseline for periods of inundation following discharge.
- In the absence of flooding, monitoring as per the present study should continue on an annual basis to provide information on the spatial and temporal changes that may be occurring as a result of dewatering discharge.
- A focus on dominant species is recommended for monitoring the vegetation communities that occur along the transects, as was carried out during the baseline field assessment, as this methodology was found to detect more subtle changes in vegetation communities than more broad-scale mapping of previous assessments.
- It is recommended that during subsequent monitoring events, vegetation condition also be mapped along the transects to enable a finer-scale set of data relating to changes in condition to be used to detect changes.
- It is recommended that subsequent monitoring events consider field assessment during the main flowering period for the region, typically during March, following the majority of annual rainfall from cyclonic activity in January and February, in order to record grasses and other annual or ephemeral species in better health and in more identifiable states.

7 REFERENCES

Anderson, O. R. (1975) The ultrastructure and cytoshemistry of resting cell formation in *Amphora coffeaeformis* (Bacilariophyceae). *Journal of Phycology* **11**, 272-281.

Anderson, O. R. (1976) Respiration and photosynthesis during resting cell formation in *Amphora coffeaeformis* (Ag.) Kütz. *Limnology and Oceanography* **21**, 452-456.

Animal Plant Mineral (2015) Level One Biological Survey, Matilda Gold Project Murchison Western Australia. Unpublished report prepared for Blackham Resources Limited

ARMCANZ, A. (2000) Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council, Canberra.

Bastin, G. (2008) Taking the Pulse. Published on behalf of the ACRIS Management Committee by the National Land & Water Resources Audit, Canberra.

Bauld, J. (1981) Occurrence of benthic microbial mats in saline lakes. *Hydrobiologia*, **81**, 87-111.

Bauld, J. (1986) Benthic microbial communities in Australian saline lakes. In: P. De Deckker & W.D. Williams (Eds). *Limnology in Australia*. Dr. W. Junk Publishers, The Netherlands: 95-112.

Beladjal, L. and J. Mertens (2009) Diaspore dispersal of Anostraca by flying insects. *Journal of Crustacean Biology* **29**, 266-268.

Bennelongia (2012) Lake Raeside dewatering discharge compliance monitoring report 2012. Report 2012/176. Bennelongia Pty Ltd, Jolimont, 40 pp.

Boggs, D., E. I., et al. (2007) Salt lakes in the northern agricultural region, Western Australia. *Hydrobiologia*, **576**, 49 - 59.

Boulton, A.J., M.A. Brock (1999). *Australian Freshwater Ecology: processes and management*. Cooperative Research Centre for Freshwater Ecology, Adelaide, South Australia.

Boyle, T. P. and H. D. Fraleigh Jr. (2003) Natural and anthropogenic factor affecting the structure of the benthic macroinvertebrate community in an effluent-dominated reach of the Santa Cruz River, AZ. *Ecological Indicators* **3**, 93-117.

Bureau of Meteorology (2017) Climate Statistics for Australian locations. http://www.bom.gov.au/climate/averages/tables/cw_013012.shtml. Accessed 5 January 2017.

Cáceres, E. C. and M. S. Schwalbach (2001) How well do laboratory experiments explain field patterns of zooplankton emergence? *Freshwater Biology* **46**, 1179-1189.

Cook, S. E. K. (1976) Quest for an index of community structure sensitive to water pollution. *Environmental Pollution* **11**, 269-288.

Cowan, M., Graham, G., McKenzie, N. (2001) A Biodiversity Audit of Western Australia's 53 Biogeographical Subregion in 2002. Murchison 1 (MUR1 – East Murchison subregion). Collaboration between the Department of Conservation and Land Management and the Western Australian Museum.

Davy-Bowker, J., Murphy, J.F.; Rutt, G.P., Steel, J.E.C. and Furse, M.T., 2005. The development and testing of a macroinvertebrate biotic index for detecting the impact of acidity on streams. Arhiv für Hydrobiologie, **163**, 383-403.

DEC (2010) Assessment levels for soil, sediment and water. Contaminated sites management series. Version 4, revision 1. Department of Environment and Conservation, Perth, Western Australia.

Department of the Environment (2017) Interim Biogeographic Regionalisation for Australia. Version 7. http://www.environment.gov.au/land/nrs/science/ibra. Accessed 5 January 2017.

Flora, S. J. S., S. Bhadauria, S. C. Pant and R. K. Dhaked (2005) Arsenic induced blood and brain oxidative stress and its responses to some thiol chelators in rats. *Life Sciences* **77**, 2324–2337.

Focused Vision Consulting (2016) Ecological Monitoring Plan, Lake Way L5206/1987/10. Unpublished Report prepared for Blackham Resources Limited.

Gray, L.J., 1989. Emergence production and export of aquatic insects from a tallgrass prairie stream. Southwestern Naturalist, **34,** 313-318.

Green, A. J., M. I. Sanchez, F. Amat, J. Figuerola, F. Hontaria, O. Ruiz and F. Hortas (2005) Dispersal of invasive and native brine shrimps *Artemia* (Anostraca) via waterbirds. *Limnology and Oceanography* **50**, 737-742.

Gooderham J. and E. Tsyrlin (2002) The waterbug book, CSIRO Publishing, Collingwood, VIC.

Guiry, M. D. and Guiry, G. M. (2017) *AlgaeBase*. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org; searched on 16 January 2017.

Hargraves PE, French FW (1983) Diatom resting spores: significance and strategies. In: Fryxell GA (ed) Survival strategies of the algae. Cambridge University Press, Cambridge, p 49–68.

Hellawell, J. M. (1986) Biological indicators of freshwater pollution and environmental management. Elsevier Applied Science Publishing, London, UK.

John, J. (2000) A guide to diatoms as indicators of urban stream health. LWRRDC Occasional paper 14/99 (Urban Sub Program, Report no. 7). School of Environmental Biology, Curtin University of Technology, Bentley, WA.

Kuwata, A., T. Hama and M. Takahashi (1993) Ecophysiological characterization of two life forms, resting spores and resting cells, of a marine planktonic diatom, *Chaetoceros pseudocurvisetus*, formed under nutrient depletion. *Marine Ecololgy Progress Series* **102**, 245−255.

Li, L., B. Zheng and L. Liu (2010) Biomonitoring and bioindicators used for river ecosystems: definitions, approaches and trends. *Procedia Environmental Sciences* **2**, 1510-1524.

Montresor, M., C. Di Prisco, D. Sarno, F. Margiotta and A. Zingone (2013) Diversity and germination of diatom resting stages at a coastal Mediterranean site. *Marine Ecology Progress Series* **484**, 79-95.

Niche Environmental Services (2011) Assessment of the Flora and Vegetation at the Toro Energy Wiluna Uranium Project: Lake Way, Centipede and West Creek borefield. Unpublished report prepared for Toro Energy Limited

Outback Ecology Services (2007) Lake Way and Centipede Baseline Vegetation and Flora Survey. Unpublished report prepared for Toro Energy Limited

Outback Ecology Services (2010) Biological Assessment of Lake Way, 2009. Unpublished report prepared for Apex Gold Pty Ltd

Poulton, B. C., D. P. Monda, D. F. Woodward, M. L Windhaber and W. G. Brum,baugh (1995) Relations between benthic community structure and metals concentrations in aquatic macroinvertebrates: Clark Fork River, Montana. Journal of Freshwater Ecology 10, 277-293.

Radzikowski, J. (2013) Resistance of dormant stages of planktonic invertebrates to adverse environmental conditions. *Journal of Plankton Research* **0**, 1-17.

Rodman, S., J. Puglisi and F. Taukulis (2016) Using hatching trials to assess the aquatic biota in dry salt lakes and wetlands. MWH Global, Jolimont, Western Australia.

Sandin, L., J. Dahl and R. K. Johnson (2004) Assessing acid stress in Swedish boreal and alpine streams using benthic macroinvertebrates. In: Hering, D., P. F. M. Verdonschot, O. Moog and L. Sandin (Eds.) Integrated Assessment of Running Waters in Europe. Hydrobiology 516, 129-148.

Soininen, J. and K. Könönen (2004) Comparative study of monitoring South-Finnish rivers and streams using macroinvertebrate and benthic diatom community structure. *Aquatic Ecology* **38**, 63-75.

Sze, P. (1986) A biology of the Algae. Wm. C. Brown Communications, USA.

Taukulis, F. E. and J. John (2009) Development of a diatom-based transfer function for lakes and streams severely impacted by secondary salinity in the south-west region of Western Australia. *Hydrobiologia* **626**, 129-143.

Timms, B.V. (2012) An identification guide to the brine shrimps (Crustacea: Anostraca: Artemiina) of Australia. *Museum Victoria Science Reports* **16**, 1-36.

Velma, V., S. S. Vutukuru and P. B. Tchounwou (2009) Ecotoxicology of hexavalent chromium in freshwater fish: a critical review. *Reviews on Environmental Health* **24**, 129-145.

Ventura-Lima, J., M. R. Bogo and J. M. Monserrat (2011) Arsenic toxicity in mammals and aquatic animals: a comparative biochemical approach. *Ecotoxicology and Environmental Safety* **74**, 211-218.

Wallace, J. B. and J. R. Webster (1996) The role of invertebrates in stream ecosystem function. *Annual Review of Entomology* **41**, 115-139.

APPENDIX A VEGETATION QUADRAT DATA

LAKE WAY ECOLOGICAL MONITOING - VEGETATION QUADRAT DATA

Date	Site type	Transect	Quadrat (m)	Easting (mE)	Northing (mN)	Litter %	BG%	Species	No. A	No. D	% A cover	% D cover	Fruiting/ flowering	Health rating
3/11/2016	Impact	LW1	0	229021.85	7038470.18	3	80	*Aristida contorta*	-	12	-	10	-	0
			0	229021.85	7038470.18	3	80	*Tecticornia laevigata*	OH	-	4	1	-	4
			0	229021.85	7038470.18	3	80	*Tecticornia peltata*	1	-	12	1	Fl	5
			20	-	-	15	80	*Alyogyne pinoniana*	OH	-	1	-	Fr	3
			20	-	-	15	80	*Aristida contorta*	9	-	4	-	Fl	4
			20	-	-	15	80	*Euphorbia multifaria*	2	-	0.1	0.5	-	3
			20	-	-	15	80	*Podolepis capillaris*	2	-	0.5	-	-	3
			20	-	-	15	80	*Sclerolaena deserticola*	1	-	0.5	-	-	5
			40	-	-	35	30	*Alyogyne pinoniana*	1	-	10	-	Fr	3
			40	-	-	35	30	*Aristida contorta*	1	-	0.5	-	-	2
			40	-	-	35	30	*Austrostipa elegantissima*	5	-	25	-	-	3
			40	-	-	35	30	*Ptilotus obovatus*	OH	-	5	-	-	4
			60	-	-	50	40	*Alyogyne pinoniana*	2	-	15	2	Fr	3
			60	-	-	50	40	*Aristida contorta*	-	5	-	5	-	1
			60	-	-	50	40	*Austrostipa elegantissima*	OH	-	1	-	Fl	3
			60	-	-	50	40	*Ptilotus obovatus*	1	-	22	3	Fl	4
			60	-	-	50	40	*Sclerolaena deserticola*	4	2	15	10	Fr	5/1
			80	-	-	35	65	*Maireana georgei*	OH	-	0.5	-	-	5
			80	-	-	35	65	*Ptilotus obovatus*	2	-	20	-	Fl	4
			80	-	-	35	65	*Sclerolaena deserticola*	2	-	2	-	-	5
			80	-	-	35	65	*Sclerolaena fimbriolata*	2	-	5	-	-	5
			100	-	-	8	70	*Austrostipa elegantissima*	9	-	5	35	-	3
			100	-	-	8	70	*Eragrostis dielsii*	-	2	-	5	-	0
			100	-	-	8	70	*Sclerolaena deserticola*	-	1	-	5	-	0
			120	-	-	12	70	*Alyogyne pinoniana*	1	-	6	-	-	3
			120	-	-	12	70	*Austrostipa elegantissima*	3	-	18	-	-	3
			120	-	-	12	70	*Monachather paradoxus*	3	-	15	-	Fl	3
			140	-	-	3	85	*Eragrostis eriopoda*	1	-	10	5	-	3
			140	-	-	3	85	*Ptilotus obovatus*	1	-	25	1	Fl	4
			160	-	-	2	75	*Austrostipa elegantissima*	3	-	10	2	-	3
			160	-	-	2	75	*Triodia melvillei*	5	-	12	3	Fl	5
			180	-	-	25	65	*Eremophila forrestii*	OH	-	12	-	Fl	4
			180	-	-	25	65	*Monachather paradoxus*	4	-	4	15	-	2
			180	-	-	25	65	*Triodia melvillei*	1	-	10	-	Fl	5
			200	-	-	0	85	*Monachather paradoxus*	2	-	15	5	-	2
			200	-	-	0	85	*Triodia melvillei*	OH	-	8	-	-	5
			220	-	-	7	60	Poaceae sp.	-	1	-	0.5	-	0
			220	-	-	7	60	*Sclerolaena fimbriolata*	2	-	0.5	-	-	5
			220	-	-	7	60	*Triodia melvillei*	4	-	50	-	Fl	5
			240	-	-	2	75	*Acacia caesaneura*	-	1	-	15	-	0
			240	-	-	2	75	*Eragrostis eriopoda*	1	-	2	6	-	2
			240	-	-	2	75	*Monachather paradoxus*	3	-	3	5	-	2
			260	-	-	4	85	*Eremophila forrestii*	OH	-	3	-	Fl	4
			260	-	-	4	85	*Monachather paradoxus*	1	-	3	4	-	2
			260	-	-	4	85	Poaceae sp.	-	2	-	5	-	0
			260	-	-	4	85	*Triodia melvillei*	1	-	15	-	-	4
			280	-	-	40	50	*Eremophila forrestii*	1	-	18	-	Fl	4
			280	-	-	40	50	*Monachather paradoxus*	9	-	4	15	-	2
			280	-	-	40	50	*Ptilotus obovatus*	1	-	5	-	Fl	3
			280	-	-	40	50	*Sclerolaena deserticola*	-	1	-	3	-	0
			300	228990.20	7038768.14	-	-	-	-	-	-	-	-	-

LAKE WAY ECOLOGICAL MONITOING - VEGETATION QUADRAT DATA

Date	Site type	Transect	Quadrat (m)	Easting (mE)	Northing (mN)	Litter %	BG%	Species	No. A	No. D	% A cover	% D cover	Fruiting/ flowering	Health rating
3/11/2016	Impact	LW Pipe 2	0	228000.96	7041662.04	1	35	*Tecticornia* sp.	-	7	-	-	-	1
			20	-	-	0.5	85	Chenopodiaceae sp.	-	3	-	15	-	1
			20	-	-	0.5	85	*Scaevola collaris*	4	-	15	3	Fr	4
			20	-	-	0.5	85	*Tecticornia halocnemoides*	1	-	5	10	-	3
			40	-	-	0.5	85	*Scaevola collaris*	4	-	9	10	-	3
			40	-	-	0.5	85	*Sclerolaena fimbriolata*	2	-	5	10	-	3
			40	-	-	0.5	85	*Tecticornia disarticulata*	1	-	15	20	-	3
			40	-	-	0.5	85	*Tecticornia halocnemoides*	1	-	10	2	-	4
			60	-	-	15	75	*Eragrostis dielsii*	1	1	6	4	Fl	2/0
			60	-	-	15	75	*Muellerolimon salicorniaceum*	4	-	35	20	Fl	2
			60	-	-	15	75	*Tecticornia disarticulata*	1	-	8	10	-	2
			80	-	-	3	65	*Eragrostis dielsii*	7	-	3	20	-	3
			80	-	-	3	65	*Scaevola collaris*	-	1	-	2	-	0
			80	-	-	3	65	*Tecticornia disarticulata*	6	1	30	15	-	3
			100	-	-	30	55	*Scaevola collaris*	-	4	-	10	-	0
			100	-	-	30	55	*Sclerolaena fimbriolata*	1	-	0.5	-	-	5
			100	-	-	30	55	*Tecticornia disarticulata*	4	-	40	10	-	3
			100	-	-	30	55	*Tecticornia* sp.	-	3	-	20	-	1
			120	-	-	6	60	*Eragrostis dielsii*	1	-	1	3	-	3
			120	-	-	6	60	*Scaevola collaris*	4	-	8	-	Fr	4
			120	-	-	6	60	*Sclerolaena fimbriolata*	8	2	10	15	-	3/1
			120	-	-	6	60	*Tecticornia disarticulata*	5	-	25	10	-	3
			140	-	-	1	60	*Eragrostis dielsii*	-	6	-	15	-	1
			140	-	-	1	60	*Scaevola collaris*	-	2	-	1	-	0
			140	-	-	1	60	*Tecticornia laevigata*	2	-	40	3	Fr	4
			160	-	-	5	85	*Eragrostis dielsii*	-	16	-	20	-	0
			160	-	-	5	85	*Frankenia cinerea*	6	-	15	-	-	4
			160	-	-	5	85	*Maireana* sp.	2	-	5	-	-	5
			160	-	-	5	85	*Scaevola collaris*	1	4	0.5	10	-	0
			160	-	-	5	85	*Zygophyllum compressum*	-	1	-	5	-	1
			180	-	-	10	40	*Eragrostis dielsii*	7	6	20	20	Fl	3/0
			180	-	-	10	40	*Maireana* sp.	9	-	4	-	-	5
			180	-	-	10	40	*Tecticornia ?halocnemoides*	1	-	30	2	Fl	4
			180	-	-	10	40	*Tecticornia laevigata*	3	-	28	5	-	4
			180	-	-	10	40	*Zygophyllum compressum*	1	1	0.5	0.5	-	3/0
			200	-	-	10	75	*Eragrostis dielsii*	-	6	-	20	-	1
			200	-	-	10	75	*Maireana* sp.	22	-	8	-	-	5
			200	-	-	10	75	*Tecticornia ?halocnemoides*	OH	-	20	5	-	4
			200	-	-	10	75	*Tecticornia laevigata*	1	-	20	6	Fl	4
			200	-	-	10	75	*Zygophyllum compressum*	1	-	1	-	-	5
			220	-	-	20	60	*Angianthus tomentosus*	2	-	1	-	Fl	3
			220	-	-	20	60	*Eragrostis dielsii*	2	6	5	20	Fl	2/1
			220	-	-	20	60	*Lawrencia repens*	1	-	1	-	Fl	4
			220	-	-	20	60	*Lepidium platypetalum*	-	1	-	0.5	-	1
			220	-	-	20	60	*Maireana* sp.	36	-	15	-	-	5
			220	-	-	20	60	*Tecticornia ?halocnemoides*	1	-	15	18	-	3
			220	-	-	20	60	*Tecticornia sp.*	-	2	-	25	-	0
			220	-	-	20	60	*Zygophyllum compressum*	3	-	3	-	-	4
			240	-	-	10	70	*Angianthus tomentosus*	2	-	0.5	-	-	0
			240	-	-	10	70	*Eragrostis dielsii*	-	6	-	15	-	1
			240	-	-	10	70	*Lawrencia repens*	1	-	0.2	-	-	3
			240	-	-	10	70	*Maireana* sp.	16	-	4	-	-	5
			240	-	-	10	70	*Scaevola collaris*	-	2	-	1	-	0
			240	-	-	10	70	*Tecticornia laevigata*	1	-	20	3	Fl	4
			240	-	-	10	70	*Zygophyllum compressum*	1	-	0.5	-	-	0
			260	-	-	5	75	*Angianthus tomentosus*	-	5	-	1	-	1
			260	-	-	5	75	*Tecticornia ?halocnemoides*	1	-	20	4	-	4
			260	-	-	5	75	*Tecticornia* sp.	-	2	-	18	-	0
			280	-	-	2	90	*Eragrostis dielsii*	-	14	-	5	-	0
			280	-	-	2	90	*Frankenia cinerea*	1	-	1	-	-	4
			280	-	-	2	90	*Lawrencia repens*	1	-	0.5	0.5	-	3
			280	-	-	2	90	*Maireana sp.*	6	-	1	-	-	5
			280	-	-	2	90	*Tecticornia ?halocnemoides*	1	-	20	2	-	4
			280	-	-	2	90	*Zygophyllum compressum*	1	-	0.2	1	-	3
			300	228031.75	7041961.69	-	-	-	-	-	-	-	-	-

LAKE WAY ECOLOGICAL MONITOING - VEGETATION QUADRAT DATA

FOCUSED VISION consulting

Date	Site type	Transect	Quadrat (m)	Easting (mE)	Northing (mN)	Litter %	BG%	Species	No. A	No. D	% A cover	% D cover	Fruiting/ flowering	Health rating
3/11/2016	Control	LW4	0	238768.92	7028684.04	0	75	*Tecticornia halocnemoides*	5	2	30	5	-	3
			20	-	-	0	60	*Tecticornia halocnemoides*	3	-	12	2	-	3
			20	-	-	0	60	*Tecticornia laevigata*	4	-	27	5	-	3
			20	-	-	0	60	*Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)	10	1	25	10	-	2
			40	-	-	1	0	*Tecticornia laevigata*	8	-	23	7	Fr	3
			40	-	-	1	0	*Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)	2	1	3	4	-	2
			60	-	-	2	65	*Tecticornia laevigata*	9	-	45	15	Fr	3
			60	-	-	2	65	*Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)	2	-	6	6	-	2
			80	-	-	2	85	*Tecticornia laevigata*	3	-	20	5	-	3
			80	-	-	2	85	*Tecticornia* sp.	-	1	-	3	-	0
			100	-	-	0	80	*Tecticornia laevigata*	1	1	8	4	-	4/0
			100	-	-	0	80	*Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)	1	1	8	12	-	3/0
			120	-	-	4	70	*Tecticornia laevigata*	3	-	20	2	Fr	4
			120	-	-	4	70	*Tecticornia* sp.	4	-	25	6	Fr	3
			140	-	-	6	55	*Tecticornia laevigata*	OH	-	8	1	Fr	4
			140	-	-	6	55	*Tecticornia* sp.	10	1	45	10	-	3
			160	-	-	0	70	*Tecticornia laevigata*	1	-	12	1	-	4
			160	-	-	0	70	*Tecticornia* sp.	2	3	6	24	-	2
			180	-	-	15	55	*Tecticornia laevigata*	4	-	20	5	Fr	3
			180	-	-	15	55	*Tecticornia* sp.	7	4	15	30	-	2
			200	-	-	25	60	*Angianthus tomentosus*	1	-	1	-	-	2
			200	-	-	25	60	*Chenopodiaceae sp.*	-	1	-	1	-	0
			200	-	-	25	60	*Lawrencia repens*	10	1	4	0.5	-	1/3
			200	-	-	25	60	*Maireana* sp.	2	-	0.5	-	-	4
			200	-	-	25	60	*Tecticornia* sp.	5	-	20	2	-	4
			220	-	-	0	95	*Dysphania plantaginella*	-	1	-	0.2	-	1
			220	-	-	0	95	*Eragrostis dielsii*	-	OH	-	2	-	0
			220	-	-	0	95	*Lawrencia repens*	20	-	2	-	-	3
			220	-	-	0	95	*Salsola australis*	-	1	-	0.5	-	0
			220	-	-	0	95	*Tecticornia* sp.	1	-	3	4	-	2
			220	-	-	0	95	*Zygophyllum compressum*	4	-	1	-	-	4
			240	-	-	5	80	*Lawrencia repens*	-	9	-	1	-	1
			240	-	-	5	80	*Tecticornia* sp.	4	-	20	6	-	3
			240	-	-	5	80	*Zygophyllum compressum*	-	2	-	0.5	-	1
			260	-	-	1	60	*Dysphania plantaginella*	-	2	-	0.3	-	1
			260	-	-	1	60	*Lawrencia repens*	-	6	-	0.5	-	1
			260	-	-	1	60	*Tecticornia laevigata*	2	-	30	6	Fr	3
			260	-	-	1	60	*Tecticornia* sp.	2	1	15	10	-	2
			280	-	-	10	85	*Eragrostis dielsii*	-	12	-	25	-	1
			280	-	-	10	85	*Lawrencia repens*	10	5	2	1	-	1/2
			280	-	-	10	85	*Tecticornia laevigata*	1	-	15	2	-	4
			280	-	-	10	85	*Zygophyllum compressum*	7	-	3	-	-	3
			300	238470.71	7028653.83	-	-	-	-	-	-	-	-	-

LAKE WAY ECOLOGICAL MONITOING - VEGETATION QUADRAT DATA

Date	Site type	Transect	Quadrat (m)	Easting (mE)	Northing (mN)	Litter %	BG%	Species	No. A	No. D	% A cover	% D cover	Fruiting/ flowering	Health rating
2/11/2016	Impact	LW6	0	231704.59	7043390.67	1	85	*Tecticornia halocnemoides*	2	5	15	6	-	2/4
			20	-	-	20	70	*Eragrostis dielsii*	1	-	1	-	Fl	3
			20	-	-	20	70	Poaceae sp.	-	9	-	2	-	1
			20	-	-	20	70	*Sclerolaena bicornis*	1	1	0.5	0.5	-	3/2
			20	-	-	20	70	*Tecticornia disarticulata*	1	-	15	3	Fr	3
			20	-	-	20	70	*Tecticornia halocnemoides*	2	2	8	2	-	3
			20	-	-	20	70	*Tecticornia* sp.	-	1	-	20	-	1
			20	-	-	20	70	*Zygophyllum compressum*	-	2	-	0.5	-	2
			40	-	-	4	80	*Dysphania plantaginella*	-	2	-	0.3	-	2
			40	-	-	4	80	Poaceae sp.	-	7	-	15	-	1
			40	-	-	4	80	*Podolepis capillaris*	-	1	-	0.2	Fl	2
			40	-	-	4	80	*Salsola australis*	-	2	-	8	-	2
			40	-	-	4	80	*Scaevola collaris*	-	2	-	0.5	-	2
			40	-	-	4	80	*Tecticornia* sp.	-	2	-	30	-	1
			40	-	-	4	80	*Zygophyllum compressum*	-	21	-	10	-	2
			60	-	-	5	75	Poaceae sp.	-	11	-	4	-	1
			60	-	-	5	75	*Tecticornia disarticulata*	1	1	3	6	-	2/3
			60	-	-	5	75	*Tecticornia* sp.	-	3	-	10	-	1
			60	-	-	5	75	*Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)	1	-	25	1	-	4
			80	-	-	3	85	*Eragrostis dielsii*	3	35	3	25	-	1/3
			80	-	-	3	85	*Podolepis capillaris*	13	-	2	-	Fr	4
			80	-	-	3	85	*Sclerolaena deserticola*	1	-	2	-	Fr	4
			80	-	-	3	85	*Zygophyllum compressum*	12	-	8	-	Fr	2
			100	-	-	2	80	*Dysphania plantaginella*	-	1	-	0.2	-	2
			100	-	-	2	80	*Eragrostis dielsii*	5	15	10	10	Fl	1/3
			100	-	-	2	80	*Gnephosis macrocephala*	1	-	1	-	Fl	3
			100	-	-	2	80	*Maireana* sp.	5	1	3	1	-	2/4
			100	-	-	2	80	*Podolepis capillaris*	1	-	0.5	-	Fl	4
			100	-	-	2	80	*Zygophyllum compressum*	9	4	5	8	Fr	2/3
			120	-	-	5	85	*Dysphania plantaginella*	-	8	-	2	-	2/1
			120	-	-	5	85	*Eragrostis dielsii*	6	6	15	6	Fl	1/3
			120	-	-	5	85	*Gnephosis macrocephala*	-	1	-	1	-	2
			120	-	-	5	85	*Maireana* sp.	10	3	15	12	-	5/1
			120	-	-	5	85	*Podolepis capillaris*	2	-	1	-	Fl	2
			120	-	-	5	85	*Zygophyllum compressum*	5	6	10	10	-	4/2
			140	-	-	6	65	*Eragrostis dielsii*	-	5	-	2	-	1
			140	-	-	6	65	*Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)	1	-	35	2	-	4
			140	-	-	6	65	*Zygophyllum aurantiacum* subsp. *aurantiacum*	-	9	-	25	-	1
			160	-	-	35	65	*Acacia caesaneura*	1	-	30	-	-	7
			160	-	-	35	65	*Aristida contorta*	1	-	0.5	-	Fl	4
			160	-	-	35	65	*Eragrostis dielsii*	-	15	-	10	-	1
			160	-	-	35	65	*Sclerolaena deserticola*	20	-	3	-	Fr	5
			160	-	-	35	65	*Sclerolaena* sp.	-	OH	-	20	-	1
			160	-	-	35	65	*Sida* sp.	2	-	0.5	-	-	4
			180	-	-	15	85	*Abutilon ?fraseri*	13	-	4	-	Fr	4
			180	-	-	15	85	Poaceae sp.	-	26	-	10	-	2
			200	-	-	25	75	*Abutilon ?fraseri*	2	-	1	-	-	4
			200	-	-	25	75	*Alyogyne pinoniana*	2	-	30	2	Fl	3
			200	-	-	25	75	*Aristida contorta*	1	-	0.5	-	Fl	3
			200	-	-	25	75	*Eragrostis dielsii*	1	-	2	-	Fl	3
			200	-	-	25	75	Poaceae sp.	-	12	-	5	-	1
			220	-	-	5	65	*Alyogyne pinoniana*	3	-	20	4	-	3
			220	-	-	5	65	*Aristida contorta*	-	3	-	3	-	2
			220	-	-	5	65	*Triodia melvillei*	OH	-	6	-	Fl	5
			240	-	-	4	85	*Abutilon ?fraseri*	1	-	0.5	1	-	3
			240	-	-	4	85	*Austrostipa elegantissima*	12	-	20	15	Fl	1/5
			240	-	-	4	85	*Olearia subspicata*	OH	-	8	12	Fl	4
			240	-	-	4	85	*Salsola australis*	-	1	-	1	-	2
			240	-	-	4	85	*Sclerolaena deserticola*	1	-	0.2	-	-	4
			260	-	-	20	80	*Alyogyne pinoniana*	OH	-	10	5	-	3
			260	-	-	20	80	Poaceae sp.	-	10	-	4	-	2
			280	-	-	60	30	*Acacia caesaneura*	OH	-	35	-	Fr	4
			280	-	-	60	30	*Enchylaena tomentosa*	OH	-	6	1	-	4
			280	-	-	60	30	*Enneapogon caerulescens*	-	1	-	2	Fl	2
			280	-	-	60	30	*Euphorbia multifaria*	-	2	-	5	-	2
			280	-	-	60	30	Poaceae sp.	-	6	-	5	-	1
			280	-	-	60	30	*Ptilotus obovatus*	3	-	30	-	Fl	4
			280	-	-	60	30	*Solanum lasiophyllum*	OH	-	1	-	-	4
			300	231718.88	7043691.29	-	-	-	-	-	-	-	-	-

LAKE WAY ECOLOGICAL MONITOING - VEGETATION QUADRAT DATA

Date	Site type	Transect	Quadrat (m)	Easting (mE)	Northing (mN)	Litter %	BG%	Species	No. A	No. D	% A cover	% D cover	Fruiting/ flowering	Health rating
2/11/2016	Control	LW7	0	238194.40	7041239.82	5	85	*Tecticornia halocnemoides*	4	7	20	3	Fl	4
			20	-	-	2	75	*Tecticornia halocnemoides*	9	2	25	2	Fl	5
			40	-	-	2	80	*Eragrostis dielsii*	25	6	5	2	Fl	3
			40	-	-	2	80	*Salsola australis*	-	1	-	0.5	-	2
			40	-	-	2	80	*Sclerolaena fimbriolata*	15	9	10	4	-	3
			60	-	-	2	90	*Aristida contorta*	-	3	-	1	-	2
			60	-	-	2	90	*Eragrostis dielsii*	OH	-	0.5	-	-	2
			60	-	-	2	90	*Goodenia maideniana*	-	3	-	1.5	-	0
			60	-	-	2	90	*Salsola australis*	-	2	-	1	-	2
			60	-	-	2	90	*Sclerolaena fimbriolata*	1	-	0.2	-	-	3
			60	-	-	2	90	*Sclerolaena sp.*	3	-	1	0.2	-	3
			60	-	-	2	90	*Tecticornia sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)*	OH	-	2	-	-	4
			60	-	-	2	90	*Zygophyllum aurantiacum subsp. aurantiacum*	OH	-	1	3	Fr	3
			80	-	-	3	93	*Eragrostis dielsii*	25	2	12	1	Fl	3
			80	-	-	3	93	*Scaevola collaris*	1	-	0.5	-	-	0
			80	-	-	3	93	*Sclerolaena fimbriolata*	5	2	4	1	-	4
			80	-	-	3	93	*Tecticornia sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)*	1	-	1	3	-	3
			100	-	-	3	95	*Aristida contorta*	2	1	1	0.5	Fl	2/3
			100	-	-	3	95	*Eragrostis dielsii*	5	2	6	1	Fl	4
			100	-	-	3	95	*Maireana pyramidata*	OH	-	0.5	2	-	0
			100	-	-	3	95	*Sclerolaena fimbriolata*	5	3	8	1	-	4
			100	-	-	3	95	*Zygophyllum aurantiacum subsp. aurantiacum*	OH	-	0.5	0.5	-	0
			120	-	-	1	85	*Eragrostis dielsii*	22	2	15	1	Fl	4
			140	-	-	5	65	*Cratystylis subspinescens*	OH	-	6	10	-	3
			140	-	-	5	65	*Eragrostis dielsii*	-	20	-	5	-	2
			140	-	-	5	65	*Maireana pyramidata*	OH	-	8	12	-	4
			160	-	-	20	60	*Enneapogon caerulescens*	2	7	1	3	Fl	2/3
			160	-	-	20	60	*Sclerolaena bicornis*	3	-	5	2	Fr	3
			160	-	-	20	60	*Zygophyllum aurantiacum subsp. aurantiacum*	1	-	40	5	Fr	3
			180	-	-	0	97	*Euphorbia multifaria*	2	-	4	6	-	3
			200	-	-	20	55	*Enneapogon caerulescens*	1	9	0.5	6	Fl	2/3
			200	-	-	20	55	*Sclerolaena bicornis*	4	-	20	-	Fr	4
			200	-	-	20	55	*Solanum lasiophyllum*	1	-	10	4	-	3
			200	-	-	20	55	*Zygophyllum aurantiacum subsp. aurantiacum*	1	-	25	-	Fr	3
			220	-	-	20	70	*Aristida contorta*	-	1	-	0.5	-	2
			220	-	-	20	70	*Enneapogon caerulescens*	42	3	10	1	Fl	2/3
			220	-	-	20	70	*Salsola australis*	-	2	-	0.5	Fr	2
			220	-	-	20	70	*Sclerolaena bicornis*	32	-	30	2	Fr	4
			240	-	-	25	60	*Enneapogon caerulescens*	5	-	10	1	Fr	4
			240	-	-	25	60	*Salsola australis*	-	8	-	10	Fr	2
			240	-	-	25	60	*Sclerolaena bicornis*	85	-	40	5	Fr	3
			260	-	-	30	65	*Enneapogon caerulescens*	3	-	2	-	-	3
			260	-	-	30	65	*Eragrostis dielsii*	2	-	25	1	Fl	4
			260	-	-	30	65	*Salsola australis*	-	2	-	1	-	2
			260	-	-	30	65	*Sclerolaena bicornis*	28	7	30	10	Fr	2/3
			260	-	-	30	65	*Solanum lasiophyllum*	1	-	8	-	-	5
			280	-	-	15	50	*Atriplex bunburyana*	2	-	3	-	-	3
			280	-	-	15	50	*Sclerolaena bicornis*	60	-	40	20	Fr	3
			300	238478.75	7041331.89	-	-	-	-	-	-	-	-	-

LAKE WAY ECOLOGICAL MONITOING - VEGETATION QUADRAT DATA

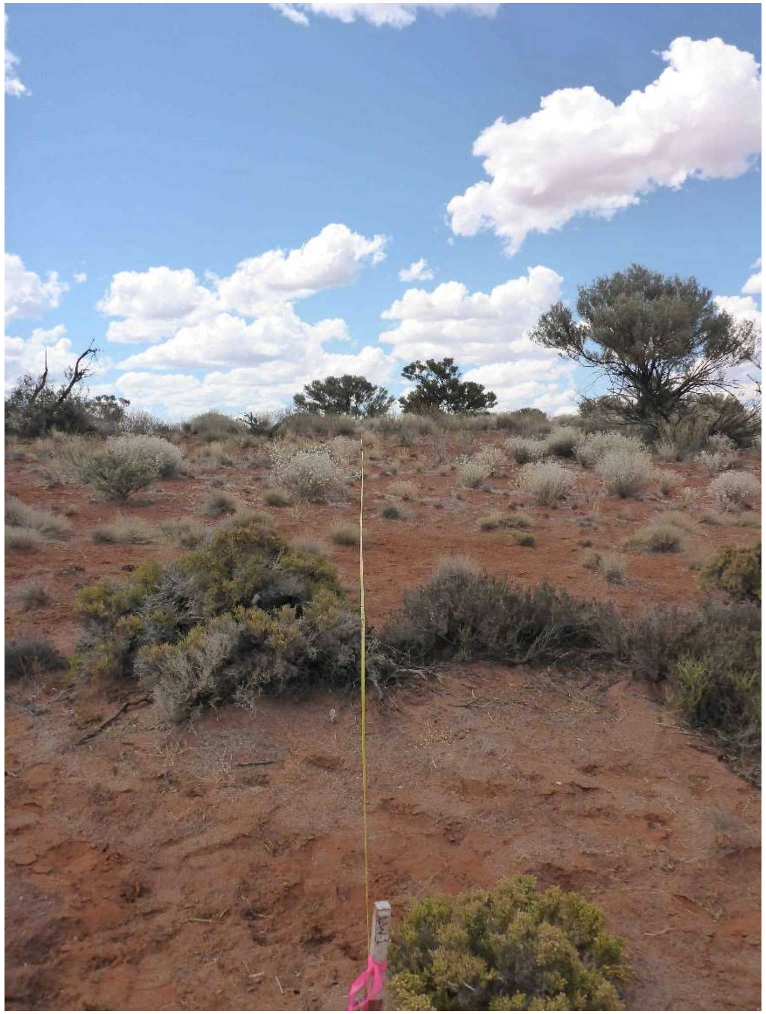
FOCUSED VISION consulting

Date	Site type	Transect	Quadrat (m)	Easting (mE)	Northing (mN)	Litter %	BG%	Species	No. A	No. D	% A cover	% D cover	Fruiting/ flowering	Health rating
2/11/2016	Control	LW8	0	241618.25	7035902.53	0	90	*Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)	1	-	15	-	-	4
			20	-	-	0.5	95	*Eragrostis falcata*	1	2	0.5	1	Fl	2
			20	-	-	0.5	95	*Scaevola collaris*	8	-	2	1	Fr	3
			20	-	-	0.5	95	*Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)	OH	-	1	-	-	3
			40	-	-	0	75	*Goodenia maideniana*	7	-	0.5	-	Fl & Fr	4
			40	-	-	0	75	*Scaevola collaris*	7	-	2.2	0.3	Fr	3
			40	-	-	0	75	*Sclerolaena fimbriolata*	1	-	0.2	0.3	-	4
			40	-	-	0	75	*Tecticornia indica*	2	-	25	2	Fr	4
			60	-	-	3	75	*Eragrostis falcata*	17	1	3	3	Fl	2
			60	-	-	3	75	*Frankenia cinerea*	1	-	1.5	0.2	Fl	4
			60	-	-	3	75	*Scaevola collaris*	9	-	3	2	Fr	3
			60	-	-	3	75	*Sclerolaena fimbriolata*	18	-	4	1	Fr	3
			60	-	-	3	75	*Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)	1	-	4	1	Fl	4
			60	-	-	3	75	*Zygophyllum aurantiacum subsp. aurantiacum*	OH	-	0.5	-	Fr	4
			80	-	-	1	90	*Eragrostis falcata*	15	2	1.5	0.5	Fl	3
			80	-	-	1	90	*Salsola australis*	-	3	-	0.3	Fr	2
			80	-	-	1	90	*Sclerolaena fimbriolata*	23	1	6	2	Fr	3
			80	-	-	1	90	*Zygophyllum aurantiacum* subsp. *aurantiacum*	1	1	0.3	0.2	Fr	3
			100	-	-	2	75	*Abutilon ?fraseri*	11	-	1.5	-	-	4
			100	-	-	2	75	*Aristida contorta*	31	-	4	0.5	Fl	4
			100	-	-	2	75	*Eragrostis eriopoda*	4	-	10	3	-	3
			100	-	-	2	75	*Lepidium platypetalum*	-	1	-	0.01	Fr	2
			100	-	-	2	75	*Sclerolaena fimbriolata*	4	2	3	4	Fr	3
			120	-	-	2	65	*Aristida contorta*	15	-	3	-	Fl	3
			120	-	-	2	65	*Eragrostis eriopoda*	2	3	2	2	Fl	2
			120	-	-	2	65	*Maireana carnosa*	8	-	2	2	Fr	3
			120	-	-	2	65	*Salsola australis*	-	3	-	1.5	-	2
			120	-	-	2	65	*Sclerolaena deserticola*	4	-	4	0.5	Fr	4
			120	-	-	2	65	*Sclerolaena fimbriolata*	4	3	2	2	Fr	2
			120	-	-	2	65	*Solanum lasiophyllum*	2	-	0.5	-	-	4
			140	-	-	6	65	*Aristida contorta*	4	-	4	-	Fl	5
			140	-	-	6	65	*Dysphania plantaginella*	-	8	-	1	Fr	2
			140	-	-	6	65	*Eragrostis eriopoda*	-	1	-	1.5	-	1
			140	-	-	6	65	*Euphorbia multifaria*	3	-	1	-	Fl	4
			140	-	-	6	65	*Goodenia maideniana*	3	-	1.5	0.1	Fr	3
			140	-	-	6	65	*Salsola australis*	-	2	-	0.5	Fr	2
			140	-	-	6	65	*Sclerolaena fimbriolata*	7	8	3	6	Fr	2/3
			140	-	-	6	65	*Swainsona* sp.	2	-	0.5	-	Fl	3
			140	-	-	6	65	*Zygophyllum aurantiacum* subsp. *aurantiacum*	4	-	3	0.2	Fr	4
			160	-	-	0.1	80	*Aristida contorta*	4	-	2	-	Fl	3
			160	-	-	0.1	80	*Enneapogon caerulescens*	1	-	0.2	-	Fl	4
			160	-	-	0.1	80	*Ptilotus obovatus*	5	-	5	2	Fl	3
			160	-	-	0.1	80	*Salsola australis*	-	2	-	1	-	2
			160	-	-	0.1	80	*Zygophyllum aurantiacum* subsp. *aurantiacum*	1	-	4	0.2	Fr	4
			180	-	-	15	80	*Acacia caesaneura*	OH	-	4	-	-	5
			180	-	-	15	80	*Triodia melvillei*	3	-	30	5	Fl	4
			200	-	-	4	75	*Eragrostis falcata*	6	-	20	10	-	3
			200	-	-	4	75	*Ptilotus obovatus*	1	-	10	-	Fl	4
			200	-	-	4	75	*Triodia melvillei*	OH	-	0.5	-	Fl	4
			220	-	-	0	70	*Aristida contorta*	6	-	0.5	0.2	-	3
			220	-	-	0	70	*Ptilotus obovatus*	1	-	0.5	-	-	5
			220	-	-	0	70	*Triodia melvillei*	2	-	30	-	-	4
			240	-	-	0	20	*Triodia basedowii*	1	-	60	10	Fl	4
			260	-	-	1	98	*Aristida contorta*	11	1	2	0.2	Fl	3/2
			280	-	-	2	85	*Aristida contorta*	2	-	0.5	-	Fl	4
			280	-	-	2	85	*Grevillea pterosperma*	1	-	15	-	-	5
			300	241925.19	7035895.10	-	-	-	-	-	-	-	-	-

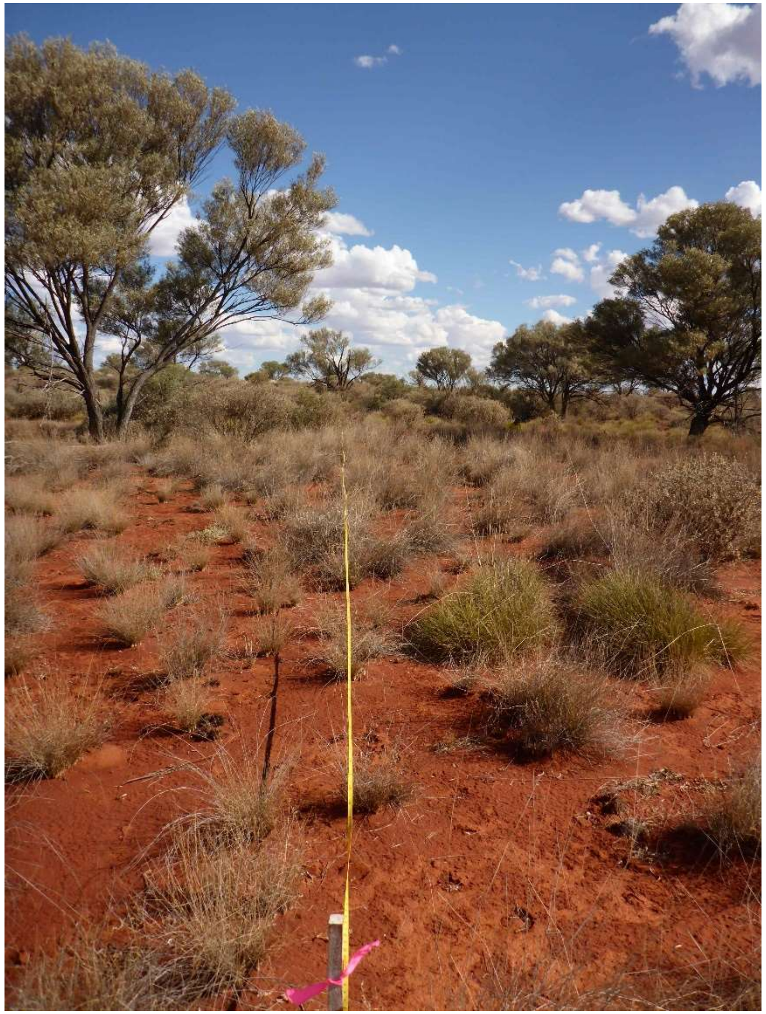
APPENDIX B PHOTOGRAPHIC RECORD OF TRANSECTS

Transect LW01 (Impact)

Start Location: 229021.85 mE, 7038470.18 mN



End Location: 228990.2 mE, 7038768.14 mN



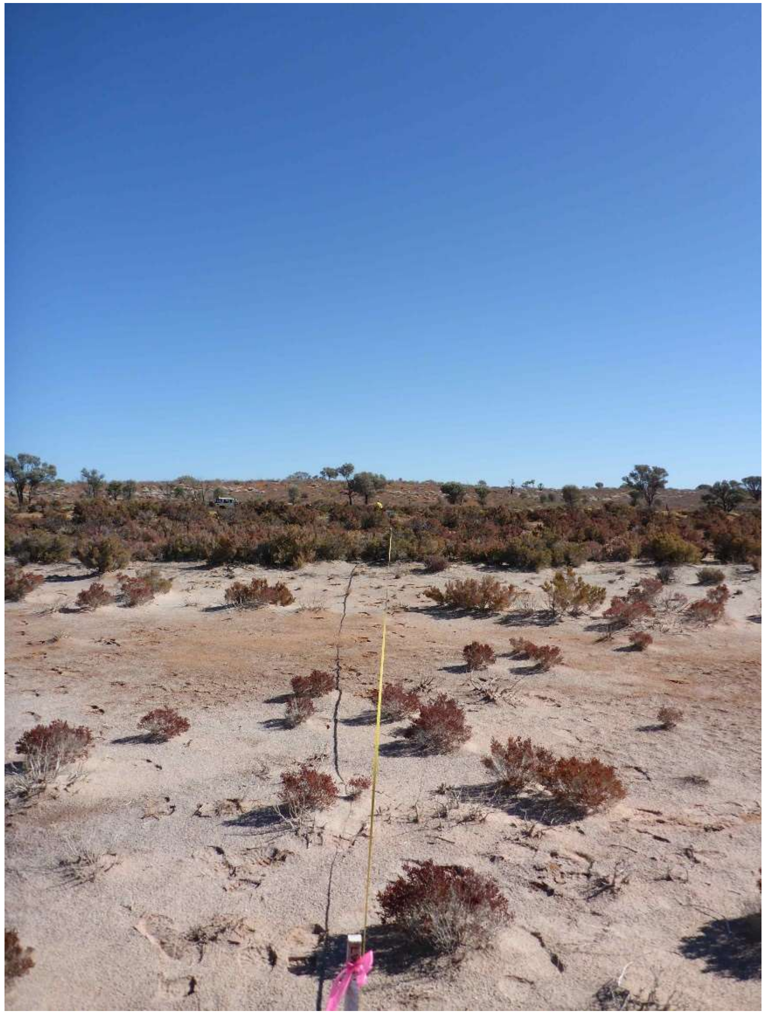
Transect LW Pipe 2 (Impact)

Start Location: 228000.96 mE, 7041662.04 mN

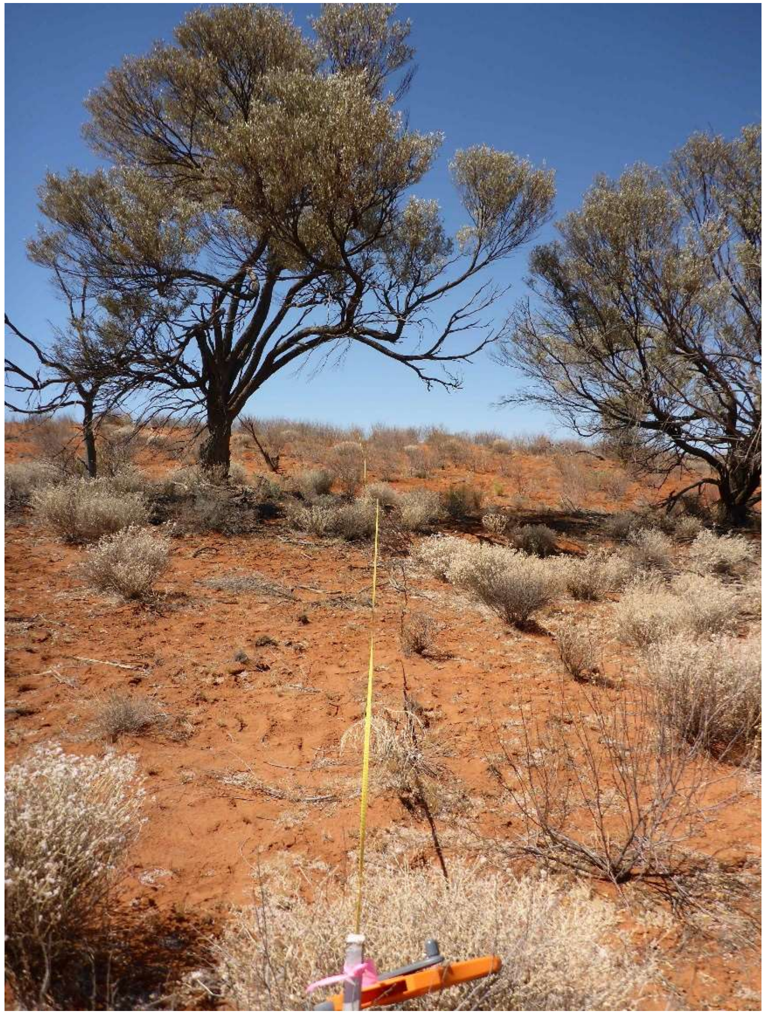
End Location: 228031.75 mE, 7041961.69 mN

Transect LW06 (Impact)

Start Location: 231704.59 mE, 7043390.67 mN

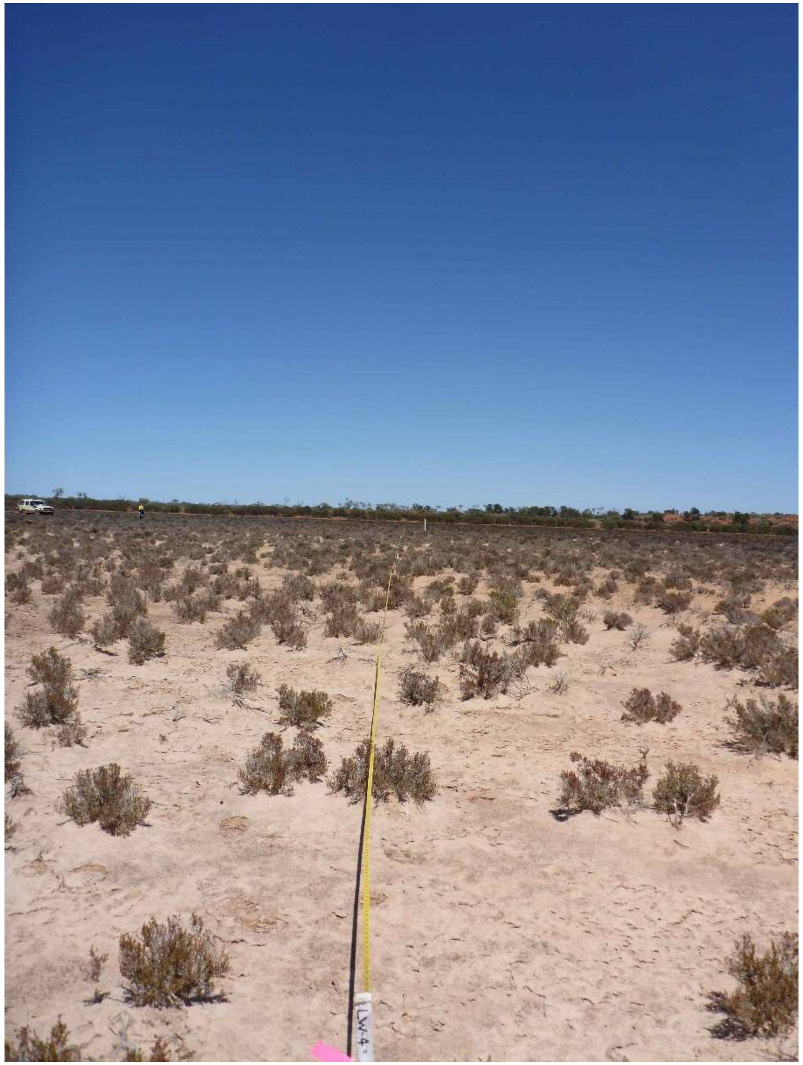


End Location: 231718.88 mE, 7043691.29 mN



Transect LW04 (Reference)

Start Location: 238768.92 mE, 7028684.04 mN



End Location: 238470.71 mE, 7028653.83 mN

Transect LW07 (Reference)

Start Location: 238194.40 mE, 7041239.82 mN

End Location: 238478.75 mE, 7041331.89 mN

Transect LW08 (Reference)

Start Location: 241618.25 mE, 7035902.53 mN

End Location: 241925.19 mE, 7035895.1 mN

APPENDIX C SPECIES RECORDED FOR EACH TRANSECT

Family	Species	Transect					
		Impact			Reference		
		LW1	LW Pipe 2	LW6	LW4	LW7	LW8
AMARANTHACEAE	*Ptilotus obovatus*	+		+			+
ASTERACEAE	*Angianthus tomentosus*		+		+		
	Cratystylis subspinescens					+	
	Gnephosis macrocephala			+			
	Olearia subspicata			+			
	Podolepis capillaris	+		+			
BRASSICACEAE	*Lepidium platypetalum*		+				+
CHENOPODIACEAE	*Atriplex bunburyana*					+	
	Dysphania plantaginella			+	+		+
	Enchylaena tomentosa			+			
	Maireana carnosa						+
	Maireana georgei	+					
	Maireana pyramidata					+	
	Maireana sp.		+	+	+		
	Salsola australis			+	+	+	+
	Sclerolaena bicornis			+		+	
	Sclerolaena deserticola	+		+			+
	Sclerolaena fimbriolata	+	+			+	+
	Sclerolaena sp.			+		+	
	Tecticornia ?halocnemoides		+				
	Tecticornia disarticulata		+	+			
	Tecticornia halocnemoides		+	+	+	+	
	Tecticornia indica						+
	Tecticornia laevigata	+	+		+		
	Tecticornia peltata	+					
	Tecticornia sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)			+	+	+	+
	Tecticornia sp.		+	+	+		
	Chenopodiaceae sp.		+		+		
EUPHORBIACEAE	*Euphorbia multifaria*	+		+		+	+
FABACEAE	*Acacia caesaneura*	+		+			+
	Swainsona sp.						+
FRANKENIACEAE	*Frankenia cinerea*		+				+

		Transect					
		Impact			Reference		
Family	Species	LW01	LW Pipe 2	LW06	LW04	LW07	LW08
GOODENIACEAE	*Goodenia maideniana*					+	+
	Scaevola collaris		+	+		+	+
MALVACEAE	*Abutilon ?fraseri*			+			+
	Alyogyne pinoniana	+		+			
	Lawrencia repens		+		+		
	Sida sp.			+			
PLUMBAGINACEAE	*Muellerolimon salicorniaceum*		+				
POACEAE	*Aristida contorta*	+		+		+	+
	Austrostipa elegantissima	+		+			
	Enneapogon caerulescens			+		+	+
	Eragrostis dielsii	+	+	+	+	+	
	Eragrostis eriopoda	+					+
	Eragrostis falcata						+
	Monachather paradoxus	+					
	Poaceae sp.	+		+			
	Triodia basedowii						+
	Triodia melvillei	+		+			+
PROTEACEAE	*Grevillea pterosperma*						+
SCROPHULARIACEAE	*Eremophila forrestii*	+					
SOLANACEAE	*Solanum lasiophyllum*			+		+	+
ZYGOPHYLLACEAE	*Zygophyllum aurantiacum* subsp. *aurantiacum*			+		+	+
	Zygophyllum compressum		+	+	+		